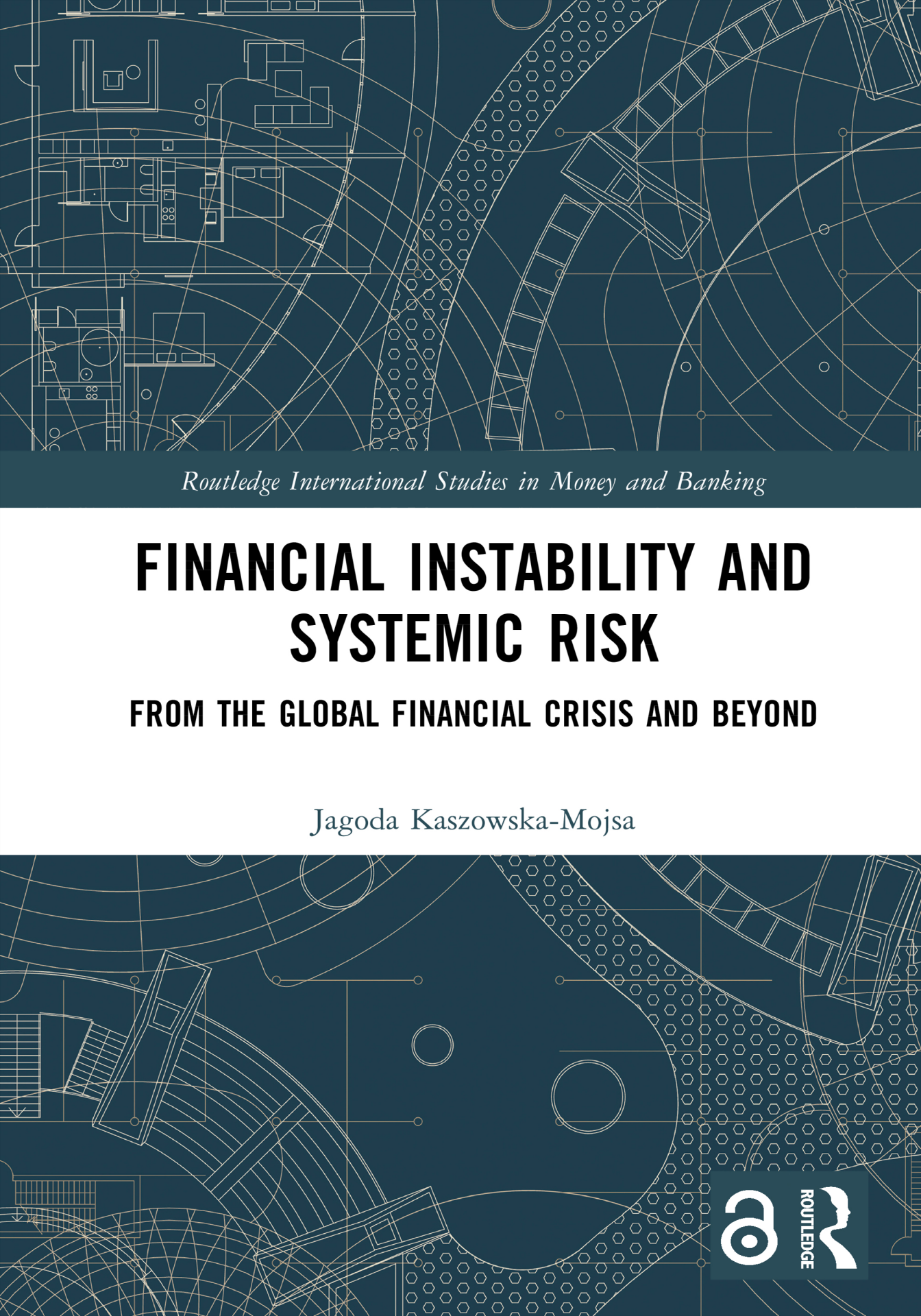




Routledge International Studies in Money and Banking

FINANCIAL INSTABILITY AND SYSTEMIC RISK

FROM THE GLOBAL FINANCIAL CRISIS AND BEYOND

Jagoda Kaszowska-Mojsa



Financial Instability and Systemic Risk

The Global Financial Crisis revealed that systemic fragility arises not only from identifiable risks but also from systemic uncertainty – the endogenous and often unpredictable dynamics that build up within financial systems and amplify across time and space. More than a decade later, this dual challenge remains pressing as the rising inequality and geopolitical insecurity have underscored the vulnerability of interconnected economies and societies.

This book illustrates how agent-based modelling (ABM) can enrich the study of crises, systemic risk and uncertainty, and the distributional effects of policies that are designed to contain them. Rather than treating crises as external shocks, the book highlights how fragility can emerge endogenously within economies that are understood as complex, evolving systems. Through clear explanations and targeted applications, it not only demonstrates how ABM can capture the effects of macroprudential regulation on the real economy and inequality and shed light on moments of financial instability but also provides a practical guide to building such data-driven models in the first place. At the same time, it situates these insights within a broader discussion of contagion, procyclicality and global financial regulation, thus connecting the modelling results with ongoing debates on how best to safeguard financial stability. Further, it offers a valuable synthesis of lessons learned from advanced economies, illustrating how institutional design and macroprudential policy can strengthen financial resilience while also generating significant redistributive effects across sectors and households.

The book is primarily aimed at an academic audience of scholars and advanced students in economics, finance and computational social science. It will also appeal to professionals in central banks, regulators and policymakers engaged in designing and evaluating macroprudential frameworks.

Jagoda Kaszowska-Mojša is a researcher and lecturer and holds positions at the Institute of Economics, Polish Academy of Sciences, the University of Oxford, the National Bank of Poland and Cracow University of Economics, Poland.

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Jagoda Kaszowska-Mojsa

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Preface

In 2013, at the 9th Congress of Economists, titled *Economics for the Future: Unveiling the Nature and Causes of Economic Phenomena*, the causes, course and effects of the global financial crisis (GFC) in the United States and European Union countries were discussed. The experts agreed that the causes of the financial crisis were diverse, but that gaps in the economic theories and errors in the macroeconomic policies and financial regulations played a crucial role in its development. This diagnosis led to proposals for changes in economic theory as well as in the strategies and institutional frameworks of central banks. Specifically, the challenges facing macroeconomics as a field of science were addressed. The ultimate goals of macroeconomics are to explain the theories behind certain phenomena and to assist in developing practical solutions for central bankers.

According to Spiegler and Milberg (2011), there were four possibilities for making changes in economic science after the financial crisis. The first group argued that modern economics did not require changes and that its paradigm was well-suited to explain both the crisis and the post-crisis reality. This group included the public statements of T. Sargent, E. Fama and J. Cochrane. “For this group, the dominant macroeconomic paradigm proved perfectly adequate for predicting and explaining the recent downturn. Contrary to the view that an unexpected financial collapse caused the current recession, these economists pointed to natural frictions in the economy and market distortions caused by public policy” (Spiegler and Milberg, 2011).

In the second group of views, the financial crisis “revealed inadequacies in existing methodology – most notably, the failure to incorporate the financial sector into our macroeconomic models” (Spiegler and Milberg, 2011). Spiegler and Milberg pointed out that within this group, we can distinguish both conventional and unconventional approaches to financial sector modelling. According to the conventional approach, more sophisticated financial frictions should be incorporated into the dynamic stochastic general equilibrium (DSGE) models. More radical approaches advocated for reforming the way in which we model finance and systemic risk. In the unconventional views, there is a need to go beyond the efficient market hypothesis and the hyper-rationality of agents. Akerlof and Shiller (2009) emphasised the role of irrationality and animal spirits in the financial market and in the development of the crisis. Even though Spiegler and Milberg (2011) explained that while other economists such as T. Lux and F. Westerhoff shared R. Shiller’s view, they emphasised at the same time that macroeconomics fails to adequately model systemic risks, and the solution is the adoption of methods from statistical physics. The advantage of this approach would be the ability to model economic reality by assuming plausible behavioural rules to replicate the stylised facts and regularities in the markets.

The third group of views encountered in the literature proposes changes concerning the methodology. Proponents of this approach, namely Caballero (2010) and Colander et al. (2009), highlight the inadequacy of the models to represent the complexity of the real world. Advocates of the complex systems theory argue that it is necessary to place a greater emphasis on institutions and the interconnectedness between economic agents, as well as to study complex behaviour at both the micro and macro levels.

The fourth group of views focuses on linking economics as a scientific discipline with economic reality while abandoning the deductive reasoning of mathematics, which was, in a sense, one of the causes of the crisis.

In reference to Spiegler and Milberg (2011), M. Belka, the former Governor of the National Bank of Poland, noted that despite the serious, sometimes fundamental issues raised by the authors of the third and fourth groups, the strongest and most influential position in the debate about the needed and desirable changes in macroeconomics seems to be that of the second group.¹

In opposition to this view, R. Caballero emphasised the need for new methods that would replace the DSGE models that are used in central banking over time. Caballero (2010) called for a new approach that would take into account the complexity of the system, while placing greater emphasis on modelling the financial system and its interaction with the real economy. More broadly, in the article *Macroeconomics after crisis*, the author struggled with the pretense-of-knowledge syndrome² in the contemporary paradigm of macroeconomic research. According to the author, the GFC has contributed significantly to the weakening of the reputation of macroeconomics. First of all, its ability to predict upcoming financial and economic crises was questioned. Our doubt, however, should not cause a lack of crisis-prediction ability but rather the choice of the dominant paradigm of macroeconomic research itself. The goal is obviously not to have endless methodological and philosophical disputes but rather to be aware of the dependence of models on the assumptions and research paradigms.

Regardless of whether we adhere to the second or third view, it is undeniable that both the theory and practice of central banking should place greater emphasis on the functioning of the financial system, its stability and the monitoring of systemic risk. Hence, in this book, we focus on the problem of systemic risk, specifically, on the concept of systemic risk, its endogenous nature, measurement and modelling techniques within both the mainstream and heterodox approaches as well as on its role in the causes, course and effects of the global financial crisis. In the final part of the book, we present a perspective on this crisis from the standpoint of the subsequent decades, highlighting the development of methods within complexity economics that gradually began to gain prominence after the global financial crisis.

The same dilemmas and debates that arose in the aftermath of the global financial crisis remain unresolved today. However, there has been a noticeable shift in focus towards alternative approaches, which is driven by the deepening crises linked to epidemics and climate change as well as the rapid advancement of modern technologies including fin-tech and artificial intelligence. In this context, the issue of systemic risk remains as relevant as ever. The need for a well-calibrated regulatory response alongside the adoption of appropriate analytical and modelling methods by central banks and supervisory institutions has never been more pressing.

Notes

1. “Mimo poważnych niekiedy fundamentalnych wątków podnoszonych przez autorów zaliczonych do grupy trzeciej i czwartej, najsilniejszą i najbardziej wpływową pozycję w dyskusji o potrzebnych i pożądanych zmianach w makroekonomii wydaje się zdobywać druga spośród powyżej wymienionych grup” [Own translation from Polish].
2. R. Caballero referred to the words of the Nobel Prize laureate F.A. Hayek: “The effects on policy of the more ambitious constructions have not been fortunate and I confess that I prefer true but imperfect knowledge, even if it leaves much indeterminate and unpredictable, to a pretense of exact knowledge that is likely to be false”.

Introduction

In 2007 the Chairman and the Chief Executive Officer of Citigroup Ch. Prince said, “When the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, you’ve got to get up and dance. We’re still dancing” (Nakamoto and Wighton, 2007). On September 15, 2008, the music was not silent, but it had changed its rhythm. Financial market events bring to mind the artistic metamorphosis of I. Stravinsky. His works were freed from the rigid framework dictated by neoclassical music and a certain *status quo* and they were transformed into serial forms¹ in a revolutionary manner. The serial forms used a series of values that changed the compositions that were already known and had been previously used in music. The sequence of these values apparently brought chaos to the music system due to changes in duration and dynamics. However, they were thought-out strategies that ensured achieving a harmonious whole – the *harmony in the chaos*. Serialism was criticised by music theorists “on the basis that the composition strategies employed are often incompatible with the way information is extracted by the human mind from a piece of music” (Ruwet, 1959). Ruwet’s methodology was in turn criticised by Pousseur (1959, 1970, 1997), who emphasised the need for the use of *wave theory* in the study of perception in compositions. Poussner believed that serialism could be analysed only by taking into account the *dynamic interactions* of the different phenomena components that create waves that interact in a sort of frequency modulation and that only such analysis would accurately reflect the *realities of perception*.

By analogy, the bankruptcy of Lehman Brothers was a symbolic change of the *status quo*² of many agents in the markets and the perception of a new reality in which they fell after the collapse of a key institution for the system. The results of the dynamic interactions of entities in the system were predetermined by the spatial structure and the degree of complexity in the system as well as the relations between the agents – their *interconnectedness*.³ However, these interactions unfold *over time*. Only by taking into account the spatial and *temporal dimensions* of the *endogenous interaction of agents within the systems* will we be able to understand the mechanisms beyond systemic risk *generation and amplification*.

Understanding that the spread of risk occurs *in space and time* allows us to associate the concept of systemic risk with the concepts of *contagion* and the *procyclicality* of agents’ behaviours and regulatory measures. By contagion, we understand “the spread of market disturbances” among the agents in a macro-financial system or from one country to another. It is a process “observed through co-movements in exchange rates, stock prices, sovereign spreads and capital flows” (Dornbusch et al., 2000; Claessens and Forbes, 2001). By procyclicality, we understand the financial sector’s tendency to exacerbate extreme phenomena in the business cycle (Borio and Drehmann, 2009a). From the methodological point of view, exploring the two dimensions of systemic risk and their connection to the problems of contagion and procyclicality also requires a focus on methods that permit spatial-temporal analysis. In this book, the focus is primarily on agent-based modelling, defined in Axtell and Farmer (2025) and discussed in Borsos et al. (2025), which permits spatial

and temporal analyses. However, the use of this method should be combined with the financial and business cycle identification procedures such as spectral analysis (Lenart, 2013; Lenart and Pipień, 2013, 2015, 2017, 2018). The cycle identification methods are based on techniques *de facto* derived from the same wave theory that was used by Pousseur in the study of the *perception* of a musical piece.

The subject of this book is, of course, not music. Nonetheless, the analogy helps to clarify why we need to approach what has happened in the financial markets since September 15, 2008, from a different perspective. Were we merely witnessing a sequence of inconsistent and mutually exclusive investor decisions? Or should the crisis be seen as a systemic reorganisation – apparently chaotic but ultimately structured? As it turns out, the analogy also led to reflections on the nature of systemic risk, which in turn determines the measurement and modelling techniques used by both the core and the periphery of economics (Caballero, 2010).⁴

Risk, Uncertainty and the Nature of Systemic Risk

To accurately define the concept of systemic risk, it is essential to first examine the distinction between risk and uncertainty. In the literature, these two aspects of randomness are clearly differentiated. F. Knight (1921) distinguished risk, which is measurable and can be evaluated economically, from uncertainty, which refers to the inherent unpredictability of certain phenomena and is difficult to quantify or hedge against. For many years, financial models largely ignored uncertainty, focusing instead on risk and developing methods for its valuation. However, this approach has been gradually shifting. Recent research increasingly addresses uncertainty alongside risk, thus reflecting a broader recognition of its significance in financial decision-making (Lewellen and Shanken, 2002; Rigotti and Shannon, 2005; Zhang, 2006; Epstein and Schneider, 2008).

*Measurability*⁵ of risk also extends to the definition of a specific type of random phenomenon, namely, systemic risk. In the broadest terms, we define systemic risk as “the probability of a systemic event occurring that could involve the collapse of one or more systemically important financial institutions or a malfunction of major financial market segments”, following the definition and approach to systemic risk proposed by De Brandt and Hartmann (2000). This definition is characteristic of the probabilistic approach that is prevalent in mainstream economics.

However, the set of systemic events cannot be limited to just these two cases. A “systemic event” refers to any event – whether an external shock to the system or an event arising within the system – that has a significant impact on the financial sector or the real economy. In practice, it is useful to distinguish between external shocks, factors that generate systemic risk within the system and amplification mechanisms (Kaszowska and Santos, 2014).

The Nature and Measurement of Systemic Risk

The distinction between external shocks and internal factors that generate crises is closely linked to how mainstream and alternative researchers perceive the *nature* of systemic risk, and it has significant implications for its measurement and modelling. The distinction between the *exogenous* and *endogenous nature of risk* became widespread following the publication of Danielsson and Shin (2003). The same authors stated that “endogenous risk refers to the risk from shocks that are generated and amplified within the system. It stands in contrast to exogenous risk, which refers to shocks that arrive from outside the system”. “Endogenous risk: risk that is created by and within the financial system itself rather than as a result of a devastating event outside of the system” (Danielsson and Shin, 2003). This idea was later further developed by researchers at the London School of Economics Systemic Risk Centre (LSE-SRC) in the context of systemic risk (Danielsson et al., 2013).

Despite the popularity of the economists from the LSE-SRC, the distinction made in their publication is not entirely new. Rather, it represents one of many interpretations and applications of systems theory within the social sciences. Systems theory is largely based on K. L. von Bertalanffy's publication *General System Theory: Foundations, Development, Applications* (1968). However, the origins of systems theory can be traced back to the work of mathematicians, physicists and biologists as early as the 1930s. In particular, the works of mathematicians such as N. Wiener, W. Ashby, J. von Neumann and S. Ulam on complex systems, cellular automata, self-organising systems and adaptive systems – as well as the contributions of A. Lyapunov and J. H. Poincaré to chaos theory – have been foundational. The theories and models developed by these scholars form the basis of modern complex systems theory, which encompasses concepts and techniques such as cellular automata, genetic algorithms, neural networks and artificial intelligence.

Both mainstream economics and some alternative approaches have adopted simplified versions of systems theory focusing on systems of interacting elements that, under certain conditions, may be subject to external shocks. Nevertheless, it should be noted that for the early proponents of systems theory, it was of fundamental importance to treat systems as *living organisms* and to engage in *reasoning in spatial and temporal terms*. Analysing the interactions among system components *in time* and *space* was considered to be essential. While mainstream models do not *per se* exclude the possibility of spatial-temporal analysis, they typically emphasise the effects of external shocks on the system. In contrast to mainstream models, heterodox models appear to align more closely with the philosophy of *true* systems theory.

In order to quantify and assess the role of systemic risk, economists have developed various methods of measurement and modelling. These methods relate to two key dimensions of systemic risk – its temporal and spatial aspects – as well as to its underlying nature. Viewing systemic risk as exogenous tends to lead to the measurement and modelling approaches that are commonly used within mainstream economic research. By contrast, proponents of the heterodox approaches favour methods of measurement and modelling that reflect an understanding of systemic risk as an endogenous phenomenon.

Following the publication of Olszak (2015), we begin by presenting her analysis, which focuses on the concept of procyclicality. We review and evaluate the methods that are used to measure systemic risk, applying three key criteria: their ability to anticipate crises, their capacity to account for the endogenous nature of systemic risk and their effectiveness in identifying feedback effects with the real economy. Building on this foundation, we introduce our own perspective on the *spatial* and *temporal* dimensions of systemic risk, as well as its role in the emergence, development and consequences of financial crises. In doing so, we also situate our research within both the Polish and international literature. We identify four main groups of measurement methods, drawing on Borio and Drehmann (2009b) and Galati and Moessner (2011a): indicators, early warning systems (EWS), econometric methods (focusing mainly on vector autoregressive (VAR), structural vector autoregressive (SVAR) and logit models) and macroeconomic stress tests.

Olszak (2015) emphasised that the first group – comprising the balance sheet and market indicators – includes aggregate risk measures based on financial statement data and aggregated financial information such as financial soundness indicators (Carson and Ingves, 2003; San Jose and Georgiou, 2009) as well as central bank indicators, credit ratings, market asset prices or spreads (Segoviano and Goodhart, 2009). The key advantages of such indicators lie in their forward-looking nature and their ability to capture all of the available market information at a given point in time. They may also potentially reflect the impact of interactions among financial intermediaries on the level of systemic risk. However, there is no available information for financial intermediaries whose shares and debt securities are not traded on regulated markets. As a result, systemic risk measures derived from data covering only a subset of financial intermediaries may not provide a complete picture of financial instability.

The second group of systemic risk measures comprises EWS, which are typically estimated using two fundamental models: the signal extraction model and the multivariate logit model. Both methods

rely on historical data with the key variable being one that identifies the occurrence of a financial or banking crisis. The greatest challenge in applying these methods lies in the accurate definition and identification of a banking crisis (Davis and Karim, 2008).

The signal extraction model was initially developed to identify inflection points in the business cycle and was later adapted by Kaminsky and Reinhart (1999) to assess the likelihood of a banking crisis. The core of this approach lies in analysing the behaviour of individual variables before and during crisis episodes. The underlying logic is that if the atypical behaviour of a given variable can be quantified, then a shift from relatively stable values to exceptionally unusual ones signals the onset of a crisis.

In a signalling model, each indicator is analysed individually, thus making it impossible to consider the information provided by all variables simultaneously. This issue becomes particularly problematic when one indicator signals a crisis while another does not. Further difficulties arise when the focus is solely on whether an indicator has exceeded the established threshold, as this approach overlooks valuable insights into the severity of the crisis. The solution to this kind of problem is the multivariable logit model, which was used by Demirgüç-Kunt and Detragiache (1998, 2005) to correlate the probability of a banking crisis with a vector of explanatory variables that could indicate crisis phenomena. EWS have been extensively studied and implemented by relevant institutions in recent years including the Basel Committee for Banking Supervision (Drehmann et al., 2010) and the European Central Bank (Behn et al., 2013), particularly in the context of calibrating countercyclical buffers.

Another group includes the VAR and SVAR models, which serve as highly flexible forecasting tools. They can also be employed to trace the transmission of shocks throughout the economy (Drehmann et al., 2007; Misina and Tessier, 2008; Borio and Drehmann, 2009b). However, their main drawback is that they provide only a simplified representation of the financial sector dynamics and their effects on the real economy (Galati and Moessner, 2011a). A key limitation of these models is the assumption that relationships between variables are linear or log-linear. In practice, however, banks often exhibit non-linear responses to even minor disruptions.

The final group comprises stress tests, which, despite their variety, share four common components as was outlined by Olszak (2015). The first is a defined set of risk exposures that are subject to stress testing. The second is a scenario that specifies an external shock. The third component is a model that integrates the shock with its projected impact and traces its transmission through the banking system. The fourth and final element is a measure of the outcome. Although the primary objective of macroeconomic stress tests is to assess the stability of a selected group of financial intermediaries, it is important to highlight the two specific goals that these tests can serve. Depending on whether the tests are conducted during a recovery or slowdown phase, they can help identify vulnerabilities and provide valuable information for taking preventive action. However, a key limitation is that most of the models that are used in macro stress tests were designed under the assumption that the relationships between variables in the real world are linear or log-linear. This oversimplification fails to capture the complex, non-linear dynamics that often characterise economic systems, thus limiting the accuracy of the predictions. In reality, however, these relationships are non-linear, meaning that even a small change in one parameter can lead to disproportionate changes in another (see discussions in Drehmann et al. (2010) and Misina and Tessier (2008)). These tests should not be viewed as early warning tools. Their primary purpose has always been different – to assess the resilience of institutions or specific segments of financial markets.

Conventional stress tests represent the real and financial sectors in a stylised manner. Furthermore, they assume that economic disturbances stem from external shocks. A key limitation is their portrayal of the financial sector as incapable of triggering global disruptions – an assumption that conflicts with Minsky's concept of financial instability and the theory of endogenous business cycles. It is worth noting, however, that modern stress testing has advanced significantly, mainly due to the incorporation of simulation techniques and ideas derived from complexity economics (Farmer et al., 2022), which will be discussed later in this book.

Spreading Through Space and Time: Procyclicality and Contagion

Although we have thus far focused on the issue of procyclicality following Olszak's approach (2015), it is also crucial to examine the spatial dimension of systemic risk. Measuring systemic risk in this spatial context allows us to assess the impact of factors such as the size of financial institutions, their interconnectedness and the availability of substitute financial services. Since changes in systemic risk over time are often linked to spatial shifts in risk across different phases of the business cycle, the measurement of systemic risk must be addressed in both the spatial and temporal dimensions. Therefore, in the following section, we will explore examples of the measures of spatial shifts in risk. Although Olszak (2015) and Karkowska (2015), among others, have already examined the main methods for analysing the spatial dimension of systemic risk, our contribution, as outlined below, will be to present alternative approaches for addressing the spatial-temporal dimensions of systemic risk in this book.

As Olszak (2015) noted, a significant development in the analytical framework for this area was the introduction of CoVaR – the value at risk of the financial sector, which depends on the distress of other institutions (Adrian and Brunnermeier, 2008). Adrian and Brunnermeier define the contribution of individual financial institutions to systemic risk as the difference between CoVaR and the VaR calculated for the entire financial system. Their study permits the assessment of how factors such as the size of an institution, its leverage and maturity mismatches influence the level of systemic risk. However, CoVaR analysis has been criticised for the non-additive nature of individual institutions' contributions to systemic risk, meaning that the aggregated systemic risk cannot be easily determined (Tarashev et al., 2010).

The literature on the interconnectedness of financial institutions also includes studies that model the financial system as a *network* or a *complex system* of interacting agents. These models are often closely linked to behavioural economics and behavioural finance (Hommes and Wagener, 2009; LeBaron and Tesfatsion, 2008). They typically assume the existence of complex, interconnected systems that are characterised by nonlinear relationships, a significant heterogeneity and bounded rationality among agents. The learning processes of agents and their decision-making under uncertainty influence the dynamics of the entire system. In some models, rational agents form complex, dynamic networks through which shocks and behaviours are transmitted across the financial system.

In recent years, one more spatial method of measuring systemic risk has emerged. It was proposed in Tarashev et al. (2010) to determine the systemic risk of the entire financial system defined as a portfolio of financial institutions. The aggregated systemic risk measures such as Value at Risk (VaR) and expected shortfall (ES) is compiled in such a way as to determine the risk level of individual entities, taking into account their impact on systemic risk. This methodology is based on Shapley value and is derived from game theory. According to the proposal presented in Tarashev et al. (2010), Shapley's value is a measure of the systemic significance of each institution included in the analysed system. Information on the level of risk of individual institutions can be used in the development of instruments aimed at preventing the occurrence of systemic events.

Business and Financial Fluctuations

The phenomenon of fluctuations in economic aggregates, especially aggregate production, is called a business cycle.⁶ There is no one commonly used definition of a business cycle. The classic approach to this phenomenon was proposed by Burns and Mitchell (1946) and later also adopted by Olszak (2015): "Business cycles are a type of fluctuation found in the aggregate economic activity of nations (...); a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions and revivals, which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration, business cycles vary from more than one year to ten years; they are not divisible into shorter cycles of

similar characteristics with amplitudes approximating their own”. Business fluctuations should be distinguished from fluctuations in the financial sector – financial cycles, e.g. fluctuations in asset prices or banks’ lending.

One of the main problems of modern economics is the lack of synchronisation between cycles and the need to identify both the business cycle and the financial cycle based on economic and financial variables. Variables that change in the same direction as GDP are called procyclical. Meanwhile, these variables whose values change in the opposite direction to GDP changes are considered anti-cyclical or countercyclical.⁷

The subject of research is primarily the phenomenon of excessive procyclicality, i.e. one that leads to high systemic risk, which is inadequate to the behaviour of economic agents and the needs of the real sector. The experts in Bank for International Settlements (2008) define procyclicality as “mutually reinforcing (“positive feedback”) mechanisms through which the financial system can amplify business fluctuations and possibly cause or exacerbate financial instability”.

Business cycles can be explained by both exogenous and endogenous theories of economic fluctuations. Exogenous theories emphasise that the economy tends to remain in a state of long-run equilibrium. Deviations from this long-term path arise as a result of external shocks to the system. Among the main exogenous theories of business cycles are political business cycle theory, monetarism and real business cycle theory. By contrast, endogenous theories stress that the system evolves dynamically, driven by internal mechanisms, with cycles being an inherent feature of the economy. The most prominent endogenous theories of the business cycle include Keynesian theory, Kalecki’s theory and Minsky’s financial instability hypothesis.

The procyclicality of financial variables is best explained through the lens of endogenous business cycle theories, particularly the financial instability hypothesis. In explaining the phenomenon of excessive procyclicality, key factors include changes in risk perception and risk-taking behaviour by agents – particularly financial intermediaries – over the course of the business and financial cycles as well as risk measurement errors and shortcomings in financial regulation including both microprudential and macroprudential policy failures.

Theories that Explain the Excessive Procyclicality

Theories that explain procyclicality and excessive risk-taking over time primarily stem from classical economics and behavioural finance. The key distinction between the theories in these two groups lies in their treatment of agent rationality. In the first approach, when receiving new information, a rational agent updates their beliefs and expectations according to Bayes’ theorem. In the second approach, a rational agent makes choices that are deemed acceptable based on subjective expected utility functions, taking into account their beliefs (see: Savage (1954) [in:] Karni (2005), Savage (1961) and Olszak (2015)).

Most mainstream theories link market inefficiency to failures of the market mechanism, mainly moral hazard, information asymmetry and the phenomenon of imitation. Market distortions that result in excessive risk-taking and procyclicality by banks can be classified into three groups: motivational distortions, disruptions in the flow of information and coordination problems.

According to Olszak (2015), motivational distortions, agency problems⁸ and information asymmetry issues can often be associated with inappropriate financial regulation (for example, regulations concerning institutions deemed too-big-to-fail or too-interconnected-to-fail). By contrast, the phenomenon of imitation appears to be an inherent feature of the system with no clear consensus on whether such behaviours are rational or irrational. Rational imitation occurs in cases of information cascades where investors ignore their own knowledge believing that other investors possess superior information. Imitation may also stem from a rational fear of reputational damage or from payoff externalities where an agent’s payoff increases when others take the same action. Irrational imitation by investors is explained through cognitive psychology, which is much more closely associated with

behavioural finance than with mainstream economics. In behavioural economics and finance, the explanation of risk-taking, procyclicality and economic dynamics relates to agent irrationality. In practice, irrational agents either violate the Bayesian rule or make choices that are inconsistent with subjective expected utility functions.

From a risk management perspective, behavioural finance provides explanations for the limitations of financial arbitrage, the psychological foundations of expectation formation and the determination of preferences. Equally important are studies on the effects of representativeness and availability heuristics on banks' capital allocation as well as research on the institutional memory hypothesis and the impact of bounded rationality on subjective credit losses.

According to the efficient market hypothesis, asset price volatility reflects changes in the fundamental value of companies. In reality, however, market efficiency does not always hold. Competition among well-informed investors does not necessarily eliminate excess profits and arbitrage strategies are not always effective or feasible. There are at least two risks associated with the errors and irrationality of investors: fundamental risk, which results from the inability to find substitutes for mispriced assets and the risk arising from irrational investor behaviour (Barberis and Thaler, 2003; Olszak, 2015). Additionally, investors are exposed to the costs of implementing arbitrage strategies. Empirical evidence regarding the limits of arbitrage strategies was provided by Froot and Dabora (1999) in their study of Royal Dutch and Shell Transport stock prices and by Wurgler and Zhuravskaya (2002) in their research on overvalued firms newly included in stock indices. Furthermore, Lamont and Thaler (2003) tested an arbitrage strategy in the case of Palm Inc. Hu et al. (2013) examined deviations from fundamental values based on the US Treasury yield curve between 1987 and 2009.

Olszak (2015) noted that a limitation of arbitrage theory lies in the assumption that rational investors are unable to correct the price deviations that are caused by irrational investors. Nonetheless, it should be remembered that irrational investors make mistakes for a variety of reasons. One explanation is provided by behavioural finance where such errors are attributed to heuristics (representativeness, availability and anchoring) (Tversky and Kahneman, 1974). Heuristics are simplified decision-making rules. Representativeness involves classifying situations based on superficial similarities with known cases. Examples of heuristic-driven distortions in systemic risk and procyclicality include ignoring the likelihood of well-known events (such as underestimating default risk during booms or assuming that securitisation eliminates all risk as was the case during the subprime crisis). The availability heuristic refers to the tendency to overestimate the likelihood of events that are easily recalled or emotionally charged. This heuristic is linked to cognitive errors such as irretrievability bias (for example, investors failing to recognise similarities between crises by assuming each one is entirely different) or imaginability bias (for instance, underestimating the risk posed by large firms just before a crisis). Anchoring involves placing excessive weight on initial information such as maintaining favourable credit terms for long-standing corporate clients despite changing conditions.

In addition to heuristics and related cognitive errors, other behavioural biases such as overconfidence, excessive optimism, wishful thinking and conservatism also play a significant role. Two particularly influential theories explain deviations from the predictions of subjective expected utility theory: prospect theory, which explains perceptual errors and the theory of bounded rationality. According to prospect theory, decision-making involves two stages: the editing phase and the evaluation phase. The editing phase can give rise to anomalies such as reference point dependence. The value function concept in prospect theory sheds light not only on portfolio allocation decisions but also on income smoothing behaviours. According to bounded rationality theory (Simon, 1955, 1978), irrational agents do not seek to maximise utility but instead pursue satisfactory outcomes, primarily due to cognitive limitations when making decisions under uncertainty.

Procyclicality in banking is most closely linked to the effects of the representativeness and availability heuristics. Bank managers often perceive crises as highly improbable events. The availability heuristic manifests itself in managers reacting strongly to risk only once a crisis has already materialised. The longer the period since the last crisis, the weaker the institutional memory – another

variant of the availability heuristic, often referred to as the institutional memory hypothesis (Berger and Udell, 2004). Also, the longer the time since a bank last experienced a severe deterioration in loan portfolio quality, the weaker its ability to distinguish between high- and low-quality borrowers.

Neglect of very low-probability risks is also linked to the availability heuristic. Bank staff often assess the likelihood of a crisis based on the length of time since the previous one. The longer the period without a crisis, the lower the perceived risk of another. This decrease in subjective crisis probability leads banks to reduce the amount of capital they set aside. The prolonged economic expansion prior to 2007 caused many managers and economists to believe that the probability of a crisis was negligible.

Systemic Risk: The Missing Piece of the Global Financial Crisis Puzzle?

Although procyclicality and contagion are widely recognised as key challenges for central banks and policymakers, this book adopts a broader perspective. The central question explored here is the relative role of systemic risk in shaping the origins, development and consequences of the financial crisis within the European Union (EU).

To fully grasp this issue, we begin by clearly distinguishing between risk and uncertainty and by examining the roles each played during the crisis. The analysis seeks to determine whether systemic risk played a more significant role in explaining the underlying causes of the crisis or in shaping its course and consequences.

There is no doubt that this is an inherently complex question. The causes of the crisis varied significantly – not only between the United States and the EU – but also among different groups of EU countries and even within these groups. In other words, both cross-country and within-country heterogeneity are central to understanding the crisis. Furthermore, the transmission mechanisms were either genuinely different or were perceived as such across various countries and contexts.

Assessing the effects of the crisis is equally challenging. The crisis produced both direct and indirect consequences for financial systems and real economies, not only within the affected countries but also beyond their borders, through contagion and spillover channels. In addition, there were important distributional effects associated with the crisis itself as well as with systemic risk and efforts to mitigate it – effects that are often overlooked or neglected in the existing literature.

To address these complexities, this book adopts a dual approach: we aim not only to describe these phenomena but also to quantify them wherever possible including the quantification of systemic risk. This required careful selection of appropriate measurement and modelling techniques. In this sense, the research challenge extended beyond the analysis itself; it also involved a critical assessment of methodological choices and the recognition that these choices are inherently linked to broader theoretical paradigms.

In the sections that follow, we present the key motivations, research objectives and hypotheses underpinning this study followed by a description of its structure.

Motivation

There are many compelling reasons for undertaking this research. First, despite the growing body of work on systemic risk – and on the influence of regulation and prudential policies on the financial system and the broader economy – many fundamental questions remain unresolved. Key uncertainties persist regarding the nature of systemic risk, the most effective methods for measuring and modelling it and its precise role in the financial crisis.

The topic explored in this book remains relatively under-researched, particularly within the Polish academic literature. In particular, the challenges of modelling systemic risk and assessing the effects of macroprudential policies in a heterogeneous economy are still poorly understood. Developing a coherent methodological framework for the study of systemic risk – and applying this framework to

evaluate regulatory and prudential policies – appears essential not only to fill in the gaps in academic theory but also to address the practical shortcomings in financial policymaking.

Secondly, there is a growing interest globally in the measurement and modelling of the financial sector and systemic risk. This interest is closely linked to rapid advances in mathematical, econometric and simulation-based methods. Yet, no comprehensive agent-based model has been developed in Poland that would allow for the analysis of how risks spread across agents, institutions and sectors of the economy or for assessing the effects of macroprudential policies in a heterogeneous economic environment. Questions surrounding the welfare implications of changes in macroprudential policies also remain unanswered.

The agent-based modelling approach is evolving rapidly worldwide. This is evident in the increasing number of academic publications, international conferences on complex systems modelling and research initiatives led by central banks and other public and private institutions. However, despite this global interest, knowledge of agent-based approaches within Poland remains limited. A notable exception is the National Bank of Poland, which has incorporated agent-based modelling into its broader research agenda on quantitative methods.

Thirdly, the outbreak and progression of the financial crisis exposed the limitations of traditional microprudential approaches to financial regulation and policymaking. This experience has underscored the urgent need for mechanisms specifically designed to safeguard the stability of the financial system as a whole.

Moreover, the deepening integration of financial markets has increased systemic risk globally and Poland is not immune to these developments. Analysing the experiences of EU member states is particularly relevant for Poland, not only in light of ongoing financial integration but also with regard to the potential implications of eurozone membership.

Research Objectives

The main research objective of this study was to identify the role of systemic risk in the causes, the course and the effects of the financial crisis in the EU countries. In parallel, the aim was to assess the effectiveness and optimality of the regulatory and prudential measures that have been introduced within the EU to mitigate systemic risk. Both of these issues remain central to the ongoing debate concerning the stability of the financial system in Europe.

In order to address the main research goal, several complementary objectives are pursued throughout the book. The first objective was to systematise the theoretical foundations of systemic risk with particular focus on its spatial and temporal dimensions. This required distinguishing between the factors that generate systemic risk from within the financial system itself and the factors that amplify the effects of external shocks. Additionally, the analysis included a comparison of systemic risk measurement and modelling techniques, contrasting approaches within the mainstream and heterodox economic frameworks.

Subsequent parts of the book examine the role of specific systemic risk factors in explaining the causes, development and consequences of the financial crisis in the United States and in selected EU Member States. In this context, the focus was not only on identifying the underlying factors but also on the role of external shocks and amplification mechanisms that contributed to shaping the dynamics of the crisis across countries with different institutional and financial structures.

Further analysis is devoted to the regulatory and macroprudential responses to systemic risk in the EU. The book investigates the effects of the regulatory frameworks and macroprudential measures that were adopted in response to the crisis, evaluating their effectiveness in selected countries. Alongside this, particular emphasis is placed on the theoretical justification for the use of macroprudential policies and on assessing their optimality within the broader context of financial stability.

The final part of the research shifted towards the methodological aspects of systemic risk analysis. Here, an agent-based model was developed that was designed to capture the impact of macroprudential

policies in economies that are characterised by the heterogeneity of agents. This approach made it possible to conduct research on the optimal macroprudential stance beyond the limitations of traditional models based on the social planner assumption.

The research presented in this book is guided by a central hypothesis according to which the relative role of systemic risk in the EU countries was greater during the course and aftermath of the crisis than in its initial phases. This is primarily explained by the presence of feedback effects and amplification mechanisms that altered the functioning of the financial system during the crisis.

In addition to the main hypothesis, several auxiliary hypotheses were formulated to account for the heterogeneity of EU Member States. It was assumed that systemic risk should be regarded as an endogenous phenomenon and that its perception – together with its spatial and temporal dimensions – had a fundamental influence on the choice of systemic risk measurement and modelling methods, both in the mainstream and heterodox economic approaches.

The analysis also rested on the hypothesis that the financial crisis in the United States was driven by deregulation processes, affordable housing policies and global current account imbalances. At the same time, it was posited that the differentiated perceptions of risk and uncertainty, both before and during the crisis, amplified the effects of shocks in the EU Member States.

The book further hypothesises that the crisis in the EU periphery countries was predominantly driven by internal vulnerabilities – such as excessive exposure to the real estate sector, fragile banking systems, high levels of indebtedness and heightened uncertainty, which intensified cross-border contagion – while the older EU Member States, despite being significantly exposed to the U.S. financial crisis, demonstrated a greater resilience to external shocks.

Another important hypothesis assumed that the crisis and systemic risk contributed to rising inequality in both the United States and the EU. Furthermore, the book argues that the introduction of certain prudential regulations in the EU countries may have increased systemic risk and financial instability, contrary to their intended purpose.

From a methodological perspective, the book challenges the suitability of dynamic stochastic general equilibrium (DSGE) models for systemic risk analysis, arguing that data-driven agent-based models (ABMs) offer superior capabilities in this regard due to their ability to capture the endogenous nature of systemic risk and the non-linear dynamics that are inherent to financial systems. It is also hypothesised that incorporating heterogeneity into the models significantly alters the conclusions regarding the optimality of macroprudential policies, thereby implying that research on macroprudential stances should rely on agent-based approaches rather than the DSGE models, which are based on the social planner framework.

Finally, in the latter part of the book, the focus turns to the optimal calibration of macroprudential policy within the agent-based framework. It is hypothesised that a well-calibrated macroprudential stance stabilises the economy and reduces inequality, whereas a miscalibrated stance may lead to heightened financial instability and increased inequality. In addition, the research explored the hypothesis that erroneous perceptions of risk and uncertainty increase the systemic importance of highly interconnected institutions, in some cases even exceeding the systemic relevance of institutions deemed “too big to fail”.

These research objectives and hypotheses collectively provide a coherent analytical framework, guiding the book’s investigation of systemic risk, crisis dynamics and macroprudential policy in the context of heterogeneous financial systems.

Structure

The book is divided into five chapters. The first chapter is primarily theoretical. It introduces the key concepts and situates them within the broader context of economic theory. While the discussion focuses on mainstream economics, it also considers the most important alternative approaches.

The second and third chapters examine the causes, progression and consequences of two major crises: the global financial crisis (2008–2009), with a focus on the United States and the EU and

the sovereign debt crisis (2009–2014) in the euro area. These chapters analyse the crises from two complementary perspectives. Firstly, they explore the crisis mechanisms and the associated policy and regulatory responses supported by empirical data where available and relevant. Secondly, they revisit the theoretical concepts discussed in the first chapter, offering additional context and interpretation.

The fourth chapter examines the issue of systemic risk mitigation. It discusses the main regulatory changes after the global financial crisis. The final chapter presents the agent-based simulations and their results. The agent-based approach occupies a unique position between traditional theoretical modelling and empirical analysis. While the simulations use empirical data to calibrate variable distributions and set initial system conditions, the model dynamics are driven by behavioural rules. These rules reflect the best available theoretical, empirical and expert knowledge about the behaviour of agents, market functioning and the broader economy. This simulation framework enables counterfactual analysis – so-called what-if scenarios – allowing us to explore how the economy might evolve under different conditions.

Chapter 1: Defining Systemic Risk and Uncertainty – Nature, Measurement and Modelling

In the first chapter, we define the key concepts and distinguish between systemic risk and systemic uncertainty. We also examine the nature of systemic risk with particular attention being paid to its spatial and temporal dimensions. Next, we highlight the relationship between these concepts and dimensions of systemic risk and the issues of procyclicality and contagion in the financial system. Finally, we present various methods for measuring systemic risk, alongside both the mainstream and heterodox approaches to systemic risk modelling.

This chapter begins with Knight's distinction between risk and uncertainty. Firstly, we present the key ideas from Knight's *Risk, Uncertainty and Profit* (1921). We then review the various reinterpretations of Knight's ideas that are found in the literature focusing in particular on the concept of information uncertainty in financial markets. Understanding information uncertainty is essential for analysing the U.S. financial crisis of 2008–2009.

Next, we explore the main insights from Bewley's *Knightian decision theory* (1986). Bewley developed a foundation for decision-making under risk and uncertainty that has been applied in the mathematical formulations of models with microfoundations such as DSGE models with uncertainty as well as in the behavioural rules of heterodox models including agent-based models. In Bewley's framework, the completeness assumption from the Anscombe-Aumann formulation of Savage's theory is removed.

From the perspective of studying crisis mechanisms and the generation and amplification of systemic risk, the most important element of Bewley's theory is the inertia assumption. In this framework, agents define a *status quo* and only accept an alternative if it is strongly preferred over the *status quo*. Without the completeness assumption from Savage's theory, it is no longer possible to compare lotteries purely in terms of winning or losing; instead, agents face a set of *subjective* probability distributions.

Understanding Bewley's approach is particularly useful for explaining the financial crisis. As Bewley (1986) explained: "if an investor found a new investment opportunity uncertain and hard to evaluate, he would be unlikely to undertake it; he would do it only if it had positive expected value for each of a large set of probability distributions. This is a form of aversion to uncertainty which is distinct from the usual risk aversion".

In the final subsection, drawing on the works of Radner (1982) and Guth (1994), we examine the treatment of risk and uncertainty within the Arrow-Debreu general equilibrium framework. The Arrow-Debreu models represent some of the most significant contributions to economic theory and continue to form the foundation of many of the models that are widely used in central banking today, particularly the DSGE models. It is therefore essential to understand how different authors have addressed the concepts of risk and uncertainty and how misunderstandings in this area affected the economic analyses and forecasts prior to the crisis.

In the context of the financial crisis, it is difficult to overlook the role that was played not only by measurable risks but also by the ways in which the market participants perceived uncertainty. For this reason, it seems reasonable to distinguish clearly between these two distinct forms of randomness. We then move on to defining and analysing the nature of systemic risk and we indirectly address the question of how the failure to distinguish between risk and uncertainty in many models has shaped economic forecasting and crisis analysis.

A crucial starting point for the study of systemic risk – often overlooked in pre-crisis literature – is its endogenous nature. De Brandt and Hartmann (2000) noted that debates surrounding the definition of systemic risk are closely linked to differing views on its underlying nature. The first approach assumes that systemic risk is fundamentally exogenous: it arises from external shocks affecting markets and institutions including financial intermediaries. By contrast, the second approach emphasises the endogenous character of systemic risk, which is generated within the financial system itself, independent of external shocks. According to this perspective, systemic risk spreads through internal market dynamics and feedback loops between the financial system and the real economy.

Systemic risk can also be analysed from either a horizontal or vertical perspective as was noted by De Brandt and Hartmann (2000). The horizontal approach focuses on the stability of the financial sector in isolation without considering its links to the real economy. In contrast, the vertical approach explicitly incorporates interactions between the financial sector and the broader economy. Many theoretical and empirical studies published before and during the global financial crisis adopted the horizontal perspective often overlooking the importance of feedback effects. While this perspective simplifies the modelling of systemic risk, it does so at the cost of ignoring key aspects of financial instability. As a result, such models may lead to misleading conclusions regarding the design of prudential policies and regulatory frameworks.

However, feedback effects are not the only source of complexity in systemic risk analysis. According to De Brandt and Hartmann (2000), the term “systemic risk” encompasses both idiosyncratic and systematic risks, which may originate from either exogenous or endogenous factors and may have sequential or simultaneous effects.⁹ Furthermore, within this conceptual framework, it is useful to distinguish between factors that generate systemic risk internally and those that amplify external shocks through transmission channels that affect financial stability. Both sets of factors played different roles in the causes, progression and consequences of the financial crisis. Their identification and quantification are particularly important for economic theory, regulatory practice and the development of effective macroprudential policies.

In this chapter, we also analyse how perceptions of the nature of systemic risk influence its measurement and modelling within both the mainstream and heterodox economic approaches. Firstly, we present the main methods that are used to measure systemic risk, discussing their respective strengths and limitations. We then examine various approaches to modelling the spread of risk in both space and time. Here, the link between the assumed nature of systemic risk and the chosen modelling approach becomes especially evident.

In most mainstream modelling techniques, systemic risk is treated as exogenous with external shocks assumed to threaten the stability of the system. By contrast, heterodox approaches more frequently view systemic risk as endogenous, generated and propagated within the financial system itself. In this sense, these alternative models often align more closely with Minsky’s financial instability hypothesis than with the neoclassical frameworks typically adopted in mainstream economics.

The financial crisis has drawn economists’ attention back to the issue of financial system stability and has highlighted the need to develop new methods for measuring and modelling systemic risk. This has sparked not only debate about integrating the financial sector into general equilibrium models but also wider discussions about the potential need for a shift in the prevailing economic paradigm; see, for example, Wojtyna (2008, 2014) and Caballero (2010). Against this backdrop, this chapter examines various measurement methods and modelling strategies in relation to both the mainstream and heterodox approaches.

Chapter 2: Systemic Risk and the 2008–2009 U.S. Financial Crisis: Causes, Course and Consequences

In the second chapter, we examine both the triggers and vulnerabilities that shaped the financial crisis in the United States. Here, we make a clear distinction between these two concepts emphasising not only their differing roles but also the importance of perceptions – often described as prospects – and the dynamic developments within the financial system’s spatial-temporal structure. While this distinction is introduced here for clarity, key aspects of it are also revisited in [Chapter 2](#) itself to aid the reader’s understanding.

The distinction between triggers and vulnerabilities was brought to wider public attention by B. Bernanke, Chairman of the Federal Reserve, in his testimony before the Financial Crisis Inquiry Commission on 2 September 2010 in Washington, DC. His remarks attracted considerable interest from both researchers and the media. According to Bernanke, “*the triggers* of the crisis were the particular events of factors that touched off the events of 2007–2009 – the proximate causes –”, whereas “*the vulnerabilities* were the structural and more fundamental weaknesses in the financial system and in regulation and supervision that served to propagate and amplify the initial shocks”. This distinction remains highly relevant in understanding both the immediate causes of the crisis and its deeper, systemic origins.

In his testimony, B. Bernanke stated that the most significant trigger was “*the prospect* of significant losses on residential mortgage loans to subprime borrowers, which became apparent shortly after house prices began to decrease”. However, excessive leverage, liquidity and maturity mismatches, deficiencies in regulation and risk management within major institutions, market concentration and the speculative use of derivatives were among the key examples of vulnerabilities.

The subtle distinction between triggers and vulnerabilities was largely symbolic – if not »strategic« – in the context of the testimony before the Commission. In the view expressed by the Chairman of the Federal Reserve, years of regulatory negligence had made the system more susceptible to shocks – more vulnerable. Nonetheless, this was not regarded as a direct cause of the crisis; it was not a trigger of the crisis.

Nonetheless, the official rhetoric surrounding the subprime crisis has shifted over the years. In 2010, during his testimony, B. Bernanke emphasised that “[the trigger was] the *prospect* of significant losses on residential mortgage loans to subprime borrowers”. However, in 2012, when referring to his earlier testimony, Bernanke replaced the phrase *the prospect of significant losses* with *developments in the market for subprime mortgages*. Although this change may appear minor – since in both cases he referred to the core issue of subprime lending – it is, in fact, crucial. It subtly redefines how we understand the crisis, the nature of systemic risk and the evolving dynamics of the financial system.

In his 2010 testimony, B. Bernanke observed: “with more than \$1 trillion in subprime mortgages outstanding, the potential for losses on these loans was large in absolute terms; however, judged in relation to the size of global financial markets, prospective subprime losses were clearly not large enough on their own to account for the magnitude of the crisis”. He went on to note that “indeed, daily movements in global equity markets not infrequently impose aggregate gains or losses equal to or greater than all the subprime mortgage losses incurred thus far”. The emergence of the crisis was not the result of an external shock in the sense of the mainstream economics. In the broader sense of the role of the systemic risk in explaining the financial crisis, it is also a good illustration of a problem that can arise when the nature of systemic risk is perceived to be exogenous. Nonetheless, whenever the mainstream explanation seems to be incomplete, the behavioural approaches appear as a viable alternative. “\$1 trillion in subprime mortgages” was not the shock *per se* that caused the crisis. It was “the prospect” – *the perception of the loss* – that really mattered.

The combination of this type of crisis trigger with the interactions among systemic vulnerabilities brings us closer to the issue of the endogenous nature of systemic risk, as explored in the works of Danielsson and Shin (2003) and Danielsson et al. (2013). The phrase “developments in the market for subprime mortgages were a prominent example of a trigger of the crisis” shifts our focus away from a single, isolated shock and instead towards an ongoing process – towards changes within the spatial-

temporal structure of the financial system. This interpretation aligns more closely with the heterodox approaches, which emphasise the endogenous nature of systemic risk. However, when systemic risk is viewed as fundamentally endogenous, the distinction between triggers and vulnerabilities becomes increasingly blurred. All elements interact, shaping the behaviour of the system over time and across space. It is in this spirit that we analyse the causes of the crisis throughout this book.

We begin by examining the potential causes of the crisis, many of which have been linked to domestic political decisions and regulatory policies in the United States over the years. In this context, we focus on the processes of deregulation within the United States, the impact of the Glass–Steagall Act on the financial system and the country’s affordable housing policies. We critically assess the argument that deregulation was the primary cause of the crisis in the United States. Following this, we also consider external factors in the global economy – such as current account imbalances and expansionary monetary policy – which are frequently cited in the literature as additional potential causes of the crisis. Finally, we assess the degree of systemic risk in the United States prior to the onset of the crisis.

To provide a better understanding of crisis management and the regulatory responses within the EU, we first present the details of the financial crisis in the United States. We assess the evolution of systemic risk during the crisis and examine the key aspects of the policy and regulatory responses implemented in the United States.

We analyse the impact of the crisis on the U.S. financial system followed by its effects on the U.S. real economy and, subsequently, on the EU economy. Within this section, we place particular emphasis on two areas of research that remain significantly under-explored: the distributional effects of the crisis and the cross-country contagion and spillover effects.

Chapter 3: The Role of Systemic Risk and Uncertainty in the Development of the EU Crisis

In the third chapter, we assess the role of systemic risk and uncertainty in the emergence and development of the crisis within the EU. The causes and progression of the 2007–2009 financial crisis followed by the sovereign debt crisis were far from uniform across the EU Member States. We explain the key differences between the various groups of countries within the EU.

In the first part of the chapter, we examine the so-called periphery countries of the EU. We demonstrate that, although these economies were indeed affected by the U.S. subprime crisis, this was not the primary cause of the economic and financial turmoil they experienced between 2009 and 2014. Nor did the transmission of risk and uncertainty within their financial systems follow the same patterns as those seen in the United States. In the case of the PIIGS (Portugal, Italy, Ireland, Greece, Spain) countries, it was the perception of risk and uncertainty that played a critical role in amplifying existing imbalances.

We then turn to the Scandinavian, Baltic and Central and Eastern European (CEE) countries. In the following section, we analyse the core EU Member States – the older members of the Union. Paradoxically, this group was among those most directly affected by the U.S. financial crisis, yet it also proved to be the most resilient to external shocks. In the final subsection, we focus on the particular case of the United Kingdom.

Chapter 4: Mitigating Systemic Risk Through Regulation and Macroprudential Policies

In [Chapter 4](#), we examine the issue of systemic risk mitigation. The chapter is divided into two main thematic sections. In the first section, we review the regulatory and institutional changes that were introduced following the crisis. In the second section, we focus on macroprudential policies which were specifically aimed at limiting systemic risk and safeguarding the stability of the financial system.

As part of the first section, we begin by analysing the regulatory and institutional changes that followed the G20 summits along with those proposed in the de Larosi re Report of 2009. This

overview also provides a useful basis for a comparison between the measures that were subsequently adopted within the EU and the provisions of the Dodd-Frank Act that was introduced in the United States.

We then examine the legal and regulatory reforms that have been implemented since the publication of the de Larosière Report. Particular emphasis is placed on the analysis of the new institutional framework with a specific focus on the role of the European Systemic Risk Board in safeguarding the stability of the EU financial system.

In the second section, we examine the experiences of EU Member States in mitigating systemic risk drawing on both the pre-crisis and post-crisis periods. Particular attention is paid to the impact of the implementation of the CRR/CRD IV and V frameworks within the EU. We also analyse the theoretical foundations and rationale behind the use of macroprudential policies.

In the final part of the chapter, we present a review of the literature on the effectiveness of macroprudential policies worldwide and discuss the limitations that constrain empirical research in this area.

Our research on macroprudential policies continues in [Chapter 5](#), where we explore the optimal design of macroprudential policy stances under various counterfactual scenarios.

Chapter 5: Analysing the Effects of Macroprudential Policies Through Agent-Based Model with Heterogeneous Agents

Before the financial crisis, economic analysis in most central banks relied heavily on Dynamic Stochastic General Equilibrium (DSGE) models. These models were primarily designed to assess the effects of exogenous shocks on an economy. However, DSGE models proved inadequate in explaining the mechanisms of systemic risk generation and were not well-suited for evaluating the potential consequences of defaults or crashes within the financial sector. This was mainly due to the marginal role assigned to the financial system in such models.

Most DSGE models are built on several restrictive assumptions, including the existence of equilibrium, perfect market competition and the hyper-rationality of agents. Shocks are assumed to either temporarily displace the economy from its equilibrium state or result in a permanent shift to a new equilibrium. In both cases, limited attention is paid to the adjustment processes or nonlinear dynamics.

The shortcomings of this approach – especially its inability to capture the interactions between the financial and real sectors – have prompted the search for alternative modelling frameworks. Among these alternatives, non-equilibrium theories that are rooted in physics offer promising insights. One such theory is linked to the concept of self-organised criticality (Bak et al., 1987), which suggests that large, complex systems naturally evolve into critical states where even small disturbances can trigger large-scale systemic changes. In macro-finance, this idea translates into the potential for collapses within the financial sector, which is driven by the system's internal dynamics.

Given the complex nature of a financial system, we adopt an agent-based modelling (ABM) approach derived from non-equilibrium theory. This enables us to study the propagation of systemic risk and the impact of macroprudential policies on the broader economy. Our model contributes to the ABM literature by offering a detailed and broad exploration of agent heterogeneity. We also compare our findings with the DSGE model incorporating the layers of default (“3D model”) developed by Clerc et al. (2015a,b), which has been used by researchers at the European Systemic Risk Board (ESRB) and the European Central Bank (ECB).

Using the agent-based model, we simulate the Minsky moment and demonstrate the stabilising effects of macroprudential policies. Unlike in DSGE models – which rely on a social planner framework – optimal macroprudential policy in our model is defined by its ability to stabilise an economy while maintaining an acceptable level of social inequality. This optimality is understood in a local rather than global sense. We also compute various measures of inequality and analyse shifts in distributions under different counterfactual scenarios. Using this approach, we can also explore

the role of risk and uncertainty in generating and amplifying systemic risk. This analysis highlights how financial institutions' risk perceptions – as well as their beliefs about how they are perceived by others – shape systemic outcomes. Both the core simulations and the additional extensions are linked to reinterpretations of Minsky's financial instability hypothesis. From a Keynesian perspective, the Minsky moment reflects capital accumulation dynamics, whereas from a Knightian viewpoint, it reflects the challenges of allocating resources under conditions of risk and uncertainty.

Final remarks

This monograph has sought to provide a comprehensive and interdisciplinary examination of systemic risk and uncertainty – both as theoretical constructs and as empirical realities that can manifest into financial crises. The structure of the book reflects the layered nature of the subject: from foundational debates in economic theory, through historical case studies, to regulatory developments and computational modelling.

Across the chapters, a central theme emerges – that the failure to distinguish clearly between risk and uncertainty, between exogenous shocks and endogenous dynamics and between formal modelling assumptions and behavioural responses, has had profound implications – not only for academic theory but also for policy formulation and institutional design. While the financial crisis of 2008–2009 initially appeared to be triggered by developments in the subprime mortgage market, a closer analysis reveals that it was the interaction of perceived vulnerabilities and structural fragilities that ultimately shaped its scope and severity. A similar logic applies to the euro zone sovereign debt crisis, where the spatial-temporal diffusion of uncertainty played a critical role in amplifying national asymmetries.

In response to these crises, regulatory and institutional reforms were introduced. However, the extent to which these reforms have addressed the root causes of systemic instability remains an open question. As the analysis in [Chapters 4 and 5](#) suggests, the design and implementation of macroprudential policies require not only better data or more refined tools but also a deeper theoretical reorientation – one that recognises the endogenous, nonlinear and often unpredictable nature of systemic interactions.

It is in this spirit that the agent-based simulations presented in the final chapter should be understood. Rather than offering prescriptive answers, they open up a space for a counterfactual analysis – what-if scenarios that allow us to explore the dynamic consequences of regulatory choices, shifts in risk perception or changes in institutional framework. These models, grounded in empirical calibration yet freed from the constraints of equilibrium assumptions, highlight the importance of complexity, heterogeneity and bounded rationality in shaping macro-financial outcomes.

To summarise, the aim of this monograph is to contribute to the ongoing debate about the nature of systemic risk, the limitations of prevailing economic paradigms and the possibilities for more robust and reflective analytical frameworks. Whether in the classroom, the research seminar or the policy arena, it is hoped that the ideas presented here may serve as both a reference point and a provocation for further discussion.

Notes

1. In 1954, Igor Stravinsky changed the way he composed his works. The period between 1954 and 1971 in his life is well-known as serialism. The change in musical forms is largely related to the influence of Arnold Schoenberg's 12-tone compositions on his work as well as to the changes that occurred in his life in that period: in 1945 he came to the United States as a Russian war refugee and in 1954 became a naturalised US citizen. In 1962 'The Flood: A Musical Play' was premiered on the CBS Television Network in New York and in the same year, the play was performed on stage for the first time in Santa Fe, New Mexico. Both the theme of the play and its release might be considered symbolic. The Russian war refugee created a play about a Noah's Ark that would save the mankind

from extermination. The play was shown to the public for the first time in Santa Fe, near Los Alamos, the place where a decade ago E. Teller and S. Ulam developed a first hydrogen bomb; and in 1962, just a few months after the detonation of the biggest Russian hydrogen bomb, Tsar Bomba. But Santa Fe has another symbolic dimension to the argument too. In the 1960s in the same place, Santa Fe – Los Alamos, the group of researchers under the supervision of J. Von Neumann and S. Ulam carried out the first study on the theory and applications of complex systems and cellular automata. And it is the cellular automata that laid the foundations for non-equilibrium models of financial systems and the economy, including agent-based models, that allow us to analyse the dynamic interactions of many entities in time and space. At present, the Santa Fe Institute is still the world-leading research centre on complex systems in the world.

2. Throughout the book, we play with the term *status quo*. We begin with its role in the inertia assumption of Bewley's decision theory under uncertainty. Later, we use "change in status quo" to refer to shifts in dynamical systems, including those exhibiting self-organised criticality.
3. The interconnectedness, the degree of complexity and concentration in the markets characterise in fact what we denominate the spatial dimension of the systemic risk.
4. Throughout this book, the terms periphery economics and heterodox economics are used interchangeably.
5. That is, the existence of a probabilistic measure.
6. In the book, we do not analyse the theories of business and financial fluctuations in details and we do not use econometric methods to identify the cycles. Nonetheless, it is crucial to understand that the problem of procyclicality and spatial-temporal dimensions of contagion, the cycles shall be studied and identified. We based this section on research of Olszak (2015) and Olszak et al. (2014). For further research on procedures of identification of financial cycles, i.a. see: Lenart (2013); Lenart and PipieŃ (2013, 2015, 2017, 2018).
7. Anticyclicality should not be confused with acyclicity that is the lack of periodicity, lack of constant repeatability of the chosen feature of processes (Olszak, 2015). The relationships between change in financial variables and changes in GDP can be correlated or regressive, positive or negative. We can talk about procyclicality when the relation is positive and anticyclicality when the relation is negative.
8. The agency problem should be analysed from an intra-bank perspective, from the perspective of creditors and within the broader context of public interest.
9. The terms idiosyncratic risk and residual risk are often used interchangeably.



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Part I

Systemic Risk and the Global Financial Crisis (GFC)



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1 Defining Systemic Risk and Uncertainty – Nature, Measurement and Modelling

The aim of this chapter is to present the principal concepts articulated by F. Knight in Chapter VII of his work *Risk, Uncertainty and Profit* (1921), without introducing subsequent developments or reinterpretations – whether intentional or inadvertent – found in the literature. Thereafter, we examine selected interpretations and reformulations of Knight’s ideas within the academic discourse, with particular attention to their influence on the modelling of systemic risk.

1.1 Risk and Uncertainty

In the opening part of the study, we focus on issues related to the subtle distinctions of random phenomena and their possible inclusion in macroeconomic modelling. In his 1921 monograph *Risk, Uncertainty and Profit*, F. Knight pointed out the existence of two categories of randomness that economic agents face when operating in the financial markets.

F. Knight (1921) referred to these two aspects of randomness as *risk* and *uncertainty*, respectively, highlighting the important distinction between the measurable element, which is subject to economic valuation – termed *risk* – and the intrinsic feature of the “observed world”, which is difficult to measure or to hedge against the negative effects of its existence – termed *uncertainty*. The world of financial mathematics models mostly abstracts from the existence of uncertainty focusing only on the aspects of risk and proposing methods for its valuation. The observed fluctuations in exchange markets and losses on the financial markets may result from an erroneous perception of risk driven by conclusions derived from models with simple and stylised assumptions such as the homogeneity of agents or may be justified by the existence of an irreducible aspect of randomness, namely uncertainty. Some suggestions for modelling risk and uncertainty separately were contained in the paper by Rigotti and Shannon (2005) (see also Pipień, 2013). The authors acknowledged that, since the work of F. Knight, significant progress has been made in the modelling of risk and in the methods of its measurement. However, the issues of uncertainty and its formal inclusion in models of economic phenomena have been largely understudied. Therefore, the main questions of the first part of the book are: what do we mean by systemic risk and how can we distinguish systemic risk from systemic uncertainty? The goals of this section are to define the concept of systemic risk and to present its measurement and modelling techniques.

1.1.1 *Knight's Risk and Uncertainty*

Knight (1921) distinguished between two types of random phenomena – *risk* and *uncertainty*. Risk is measurable and subject to economic valuation, while uncertainty is an immanent feature of observable phenomena, which is difficult to measure or to safeguard against the negative effects of its existence.

According to Knight (1921, pp. 19–20) “uncertainty must be taken in a sense that is radically distinct from the familiar notion of Risk from which it has never been properly separated.(...) The essential fact is that “risk” means, in some cases, a quantity susceptible of measurement, while at other times, it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomena depending on which of the two is really present and operating.(...)”. It will appear that a measurable uncertainty or “risk” proper, as we shall use the term, is so different from an unmeasurable one that it is not in effect an uncertainty at all. We shall restrict the term “uncertainty” to cases of the “non-quantitative type”. It is somewhat puzzling that, since Knight’s publication, so many doubts have arisen regarding the meaning of the measurability of risk.

Knight (1921, pp. 198–232) analysed risk and uncertainty in the context of actual *deviations* from the premises of a perfectly competitive market, which, for him, are related to the existence of imperfect information. In a perfectly competitive setting, “the businessman could not know in advance the results of individual ventures, [but] he could operate and base his competitive offers upon accurate foreknowledge of the future if quantitative knowledge of the probability of every possible outcome can be had. For by figuring on the basis of a large number of ventures (...), the losses could be converted into fixed costs”. In practice, however, the probability of every possible outcome is rarely known. As Knight stated, “the essence of the situation is action according to opinion, of greater or less foundation and value, neither entire ignorance nor complete and perfect information but partial knowledge” (Knight, 1921, p. 199).

In the presence of imperfect knowledge, agents “*perceive* the world before [they] react to it and [they] react not to what [they] perceive but always to what [they] *infer*” (Knight, 1921, p. 201). Although the agents try to infer what the future might have been without their interference, their evaluations are often subject to perception and inference errors. In the author’s opinion, the working assumption of practical inference¹ about the world should be a number of properties or *modes of resemblance* between them and not a number of kinds of things. Inference should be used in order to determine that *X* is associated with *Y* or at least to ascertain that there is “the numerical proportion of the cases in which *X* is associated with *Y*, which yields the familiar probability judgment” (Knight, 1921, p. 213). In practice, we sometimes are able to *estimate* only the probability that *Y* will follow from *X* if present in the degree assumed.

Indeed, Knight distinguished between “two fundamentally different ways of arriving at the probability judgment of the form that a given numerical proportion of *Xs* are also *Ys*”, and the third procedure – *estimation of proportion* – which is not *probability* at all (Knight, 1921, p. 214).

The first way is by *a priori* computation, e.g. the probability that is obtained by throwing a perfect die. The second one is more common in real life. It consists of statistical grouping that is then used in the computation of the probability of event in the given group, e.g. the probability of fire of houses in a given neighbourhood.² In the first case, it is a “real” probability; in the second case, it is an empirical generalisation with reference to a group.³ “The practical difference between *a priori* and statistical probability seems to depend upon the accuracy of classification of the instances grouped together”⁴ (Knight, 1921, p. 217).

The science of inference should, without any doubt, rest upon probability judgement whether *a priori* or statistical. However, as Knight pointed out, “we act upon estimates rather than inferences, upon “judgement” or “intuition”, not reasoning, for the most part” (Knight, 1921, p. 223). An estimate or intuitive judgement is somewhat akin to a probability judgement but at the same time, it differs significantly from the two types of probability previously described. In the case of estimates, there is “*no valid basis of any kind* for classifying instances” and, as a result, for making possible a quantitative determination of true probability (Knight, 1921, p. 224). Moreover, according to Knight,

in contrast to Fisher's view that there is only one subjective feeling of probability itself, both the formation of an estimate and the evaluation of its value should be studied. Errors in the formation of an estimate and in the estimation procedure can affect the estimated *proportion*, which in the end may differ substantially from the true *probability*.

This "somewhat like a probability judgement" was referred to in the book as "the third type of probability" or "uncertainty", though the author emphasised that the former term can be misleading. "The confusion arises from the fact that we do estimate the value or validity or dependability of our opinions and estimates and such an estimate has the same *form* as a probability judgement; it is a ratio expressed by a proper fraction. But in fact, it appears to be meaningless and fatally misleading to speak of the probability, in an objective sense, that a judgement is correct" (Knight, 1921, p. 231).

Knight employed the terms "objective" and "subjective" probability to refer to "risk" and "uncertainty". In the first case, "the distribution of the outcome in a group of instances is known (either through calculation *a priori* or from statistics of past experiences), while in the case of uncertainty, this is not true; the reason being in general that it is impossible to form a group of instances because the situation being dealt with is in a high degree unique" (Knight, 1921, p. 233). In principle, if the distribution of outcomes is known, we can avoid uncertainty by grouping instances. However, the real challenge lies in being able to analyse or model cases where such grouping is not possible.

1.1.2 Perceptions and Reinterpretations of Knight's Ideas

Knightian risk and uncertainty have been interpreted in a variety of ways in the literature. In particular, with the development of new methodologies, considerable controversy has arisen regarding both concepts. Rudne (1998) attempted to systematise and explain Knight's ideas. The author of *Clarifying Frank Knight's Discussion of the Meaning of Risk and Uncertainty* focused on "situations of risk" and "situations of uncertainty". In his view, "situations in which the decision-maker assigns probabilities to events on the basis of "known chances" (where chances are defined as numerical proportions of otherwise (in some sense and to some degree) homogeneous *x*s that are also *y*s" are examples of the first group of situations. The second group includes "situations in which the decision-maker is unable to assign probabilities to events because it is not possible to calculate chances (where there are insufficient *x*s that are homogeneous enough to form classes within which the proportions of *x*s that are also *y*s can be determined)".

J. Rudne (1998) distinguished between *a priori* probability, statistical probability and estimates exactly as Knight did in *Risk, Uncertainty and Profit*. In addition, the author emphasised that Knight thought "in terms of a *continuum* of probability situations depending on the degree of the homogeneity of the "instances" in question". Instances that are homogeneous enough to be grouped correspond to *a priori* probability; less homogeneous instances correspond to statistical probability, while instances that are not sufficiently homogeneous are treated as estimates. However, the distinction between the three cases is not a matter of gradation but rather one of logical difference. J. Runde noted that in the case of *a priori* probability, the values are derived from principles, whereas in the second case, "statistical probabilities are determined *a posteriori* by empirical methods" (Rudne, 1998, p. 542).

J. Runde interpreted the Knightian "instances" as trials in a real or imaginary experiment along with their outcomes. As a result, he emphasised that the assumption of "the perfect homogeneity of trials is not a sufficient condition for calculating *a priori* probabilities even when the other necessary conditions are met" (Rudne, 1998, p. 542). This remark, however, appears to be a creative interpretation of Knight's idea. There is no reason to think that Knight confounded trials and outcomes. As Runde pointed out, Knight associated "perfectly homogeneous trials with fair games of chance in which each of the outcomes that might follow a single trial *are* equally probable". And indeed, the perfect homogeneity of successive trials does not imply the equiprobability of the outcomes associated with each individual trial.

Regardless of the reason why Knight used the example of fair games of chance, Runde's reformulation (1998, p. 543) may prove useful in further studies on systemic risk and uncertainty, and it should be stated:

- 1 Classical or *a priori* probability – “the ideal case in which numerical probabilities can be computed on general principles, namely where they are assigned to equally probable and mutually exclusive possible outcomes”;
- 2 Statistical probability – “situations in which frequencies may be derived on the basis of an empirical classification of outcomes obtained in classes of more or less homogeneous trials”;⁵
- 3 Estimates – “situations in which it is not possible to calculate *a priori* probabilities or where there are insufficient trials “like” enough to form a class of even more or less homogeneous trials on the basis of which frequencies can be determined”.

These insights highlight that Knightian uncertainty is closely linked to situations in which agents cannot reliably infer future outcomes due to insufficient or ambiguous information. This distinction has gained particular significance in contemporary financial analysis where crises often reveal the limits of probabilistic risk assessment. Therefore, before analysing systemic risk in depth, it is necessary to address the problem of information uncertainty in financial markets.

1.1.2.1 Information Uncertainty in Financial Markets

In order to fully understand risk and systemic uncertainty, particularly their role in explaining the 2008–2009 global financial crisis, it is worth first considering the notions of *idiosyncratic* and *systematic* risk and uncertainty. Knight's idea was analysed and reinterpreted by Chen (2017) in the context of *systematic* and *systemic* risk in financial markets. In his reflections on the interpretation of Knight's idea, he referred first to Der Kiureghian and Ditlevsen (2009), who distinguished between epistemic probability and aleatory uncertainty. “Epistemic probability describes risks that could be known in principle but have not been measured in practice. Aleatory uncertainty, by contrast, describes imprecision in the measurement of risk that cannot be reduced through either theory or observation” (Chen, 2017, p. 209). Chen then explained that the distinction between risk – as a situation in which probabilities are known – and uncertainty, when they are unknown, is, in essence, quite “naïve”. Referring to the formulation of the CAPM model under Knightian uncertainty, Epstein and Wang (1994) emphasised that Knight's distinction between risk and uncertainty should be interpreted as situations in which we “either have probabilities according to which we can make decisions or the information available to us is too vague and in this case, we are talking about uncertainty”. Such an interpretation is closely related to the main paradigm of economics and in particular to the theory of market failures. Here, uncertainty is specified as *information uncertainty*. In fact, the mechanisms of the financial crisis and the demand for safe assets during the Greek crisis in 2012 can be explained in terms of information uncertainty. As an example, in Greece, uncertainty related to political changes led to an increase in precautionary savings among households (Chen, 2017).

As Chen (2017) explained, information uncertainty “applies with particular force to the distinct streams of information conveyed by the cash flow and discount-rate components of beta [in the CAPM model]”. In financial markets (or capital markets), information uncertainty is related to ambiguity regarding the implications of new information for a company's value. It is associated with the volatility of fundamental value and the presence of poor or incomplete information in the market (Zhang, 2006).

The analysis of capital markets by Campbell et al. (2001) demonstrated that, since the 1960s, financial market volatility in the United States has increased. According to this study, this higher volatility was not related to new market practices including the use of derivative instruments but rather to the deteriorating quality of earnings information. As a consequence, investors only *estimate*⁶ earnings. This “estimation uncertainty may lead to higher volatility and depress investors' estimates

of the true value of stock. Uncertainty thus decouples volatility from asset returns and prices” (Chen, 2017). Chen’s interpretation of uncertainty and volatility referred to Zhang (2006), who emphasised that financial market volatility is the sum of the variation in fundamental value – reflecting future cash flows and dividends – and a noise term, which reflects the quality of information.

Another approach to uncertainty treats it as “changes in the conditional variance of economic fundamentals”, which explain, at least partially, the equity premium puzzle. Uncertainty is also often compared, in the sense of heteroskedasticity in economic fundamentals, with changes in risk aversion. This explanation is closely related to the theory of habit formation and consumption smoothing across different phases of the business cycle (Campbell and Cochrane, 1999; Chen, 2017)

Chen (2017) presented an unusual approach to Knight’s legacy. In the case of capital market analyses, we should not focus on separating risk from information uncertainty at all costs. While it is likely that most investors only have incomplete data and rely on empirical proxies to make decisions in financial markets, Chen (2017) noted that “as a matter of semantics and theory, some quanta designated as “uncertainty” may indeed be “risk” in Knight’s original epistemic sense of that word”. Such an approach is, of course, often criticised by mathematicians and quantitative finance researchers, who argue that risk can be precisely quantified – by obtaining probability distributions – whereas uncertainty refers to estimating the values of indicators that are inherently imprecise. Nonetheless, Chen’s point is that, in practice, the distinction between risk and uncertainty is blurred and tends to “track the difference between ‘known unknowns’ and ‘unknown unknowns’” (Rumsfeld, 2002). As a matter of expedience, however, little practical significance hinges on distinctions between fundamental volatility and the quality or reliability of information because both effects contribute to uncertainty and because it is hard to empirically disentangle one from the other (Hirschleifer, 2001; Zhang, 2006; Chen, 2017).

When analysing investors’ behaviour prior to and in the aftermath of a crisis, what really matters is the *reaction to uncertainty*. During a crisis, under conditions of heightened uncertainty, investors demand an increasingly higher premium to hold the market portfolio.

Anderson et al. (2009) formulated uncertainty in the asset pricing setting as follows:

$$\mathbb{E}_t(r_{e,t+1}) = b + \gamma V_t + \theta M_t \quad (1.1)$$

r_e is the excess return of the market over a risk-free asset, V is the conditional volatility of the market, M measures the amount of uncertainty in the economy, t indexes all of the foregoing variables on a temporal scale and γ and θ indicate aversion to risk and uncertainty, respectively (Chen, 2017) and b is a constant term. Both risk and uncertainty carry a positive premium in this model. When there is no uncertainty, that is, when $M_t = 0$ or when agents are not averse to uncertainty, meaning $\theta = 0$, the equation reduces to a regression of expected returns over a risk-free baseline.

Chen (2017) noted that investors seek to predict mean returns, for example, based on the volatility of certain fundamental measures, which are conditional on a time-varying measure of subjective aversion. The author then observed that all of these approaches to uncertainty are consistent with the variance risk premium measure where the variance risk premium refers to the difference between the realised variance and the variance swap rate – that is, the value of the corresponding portfolio of options.

In his view, information uncertainty should also have been incorporated into financial regulations after 2008 as the development of the crisis was related to a “reduced rate at which trading and other business activity transmit information about economic conditions” (Chen, 2017). From this perspective, the mechanisms of the crisis were predominantly driven by information uncertainty. During a crisis, the quality of information is difficult to assess (Epstein and Schneider, 2008). Consequently, information ambiguity and aversion to ambiguity are key elements for understanding a crisis. Without doubt, this is not the only explanation of the crisis. In the next section, we present an alternative explanation of the mechanisms underlying the financial crisis, based on Bewley’s decision-making theory and the concept of the *status quo*. While information uncertainty theory is primarily applied in reinterpretations of portfolio theory models, Bewley’s theory has influenced the

general equilibrium models with uncertainty – particularly the more sophisticated DSGE models employed in central banking and recently also new heterodox models.

Chen explained in his book *Econophysics and Capital Asset Pricing. Splitting the Atom of Systematic Risk* that “as informational ambiguity amplifies uncertainty over the probability of default, the magnitude of default outcomes at the left tail, the premium commanded by the risk of default and the dead weight cost of bankruptcy, all premiums associated with bearing risk rise sharply. (...) [and] an ambiguity-averse agent behaves as if he maximises the expected utility under a worst-case belief that is chosen from a set of conditional probabilities”.

This is consistent with A. Roy’s safety-first criterion, according to which an investor seeks to minimise the probability that actual returns (R_a) will fall below the minimum acceptable level (R_b), that is, $P(R_a < R_b)$. Ambiguity aversion is closely related to the Ellsberg paradox, which shows that people tend to prefer known risks – situations in which probabilities can be determined – over situations involving a “completely ambiguous set of odds, even where some odds include the prospect of a pure win”.

In reference to Epstein and Schneider’s *Learning under ambiguity*, Chen (2017) considered aversion towards ambiguity in terms of *information, learning and resolution over time*. Assuming that θ is a parameter that agents aimed to learn and s is a signal related to this parameter, the following holds:

$$s = \theta + \varepsilon, \varepsilon \sim \mathcal{N}(0, \sigma^2), \sigma^2 \in [\underline{\sigma}_s^2, \bar{\sigma}_s^2] \quad (1.2)$$

The signal that affects an investor’s decision is noisy. In effect, uncertainty may lead to “equilibria that are indeterminate in the sense that a given set of economic fundamentals may permit a continuum of equilibria rather than a precise point”.

We can assume, for a moment, that agents believe that “the excess return on the market is normally distributed with some unknown mean μ and known standard deviation σ , that is, $r_e \sim \mathcal{N}(\mu, \sigma^2)$ ”, as in Anderson et al. (2009). In such a case, σ^2 is known and can be treated as market risk but *investors* make decisions based solely on their *beliefs* about the variance of μ . In this context, “uncertainty is a measure of the confidence of an agent in their beliefs about μ and can be approximated by the mean square error of their beliefs, $\mathbb{E}(\mu - \hat{\mu})^2$, where $\hat{\mu}$ is the best estimate of μ ”.

Ambiguous information has at least two effects. Firstly, agents react asymmetrically when they receive such information; they tend to believe bad news, while they often reject good news as unverified. Secondly, in anticipation of new information, the potential depreciation of agents’ expectations may become relevant. This informational explanation of the crisis represents one possible perspective. Investors lack confidence when confronted with ambiguous information, which affects how they value assets and how they perceive and assess the overall condition of the economy. Under conditions of increasing uncertainty, abnormal returns unrelated to fundamental value tend to attract investors.

In Chen’s view, this mechanism explains the stock market fluctuations following the WTC terrorist attack in 2001 and the financial crisis of 2007–2009 in the United States. However, an important aspect in interpreting the ambiguity aversion model (or approach) is that, depending on the degree of aversion, investors assign different weights to information. In this respect, investors are heterogeneous. Their perception of signals differs from that predicted by the rational expectations model. Ambiguous signals lead to asymmetric investor behaviour, regardless of the phase of the business or financial cycle. This approach aligns with the behavioural perspective and with psychological studies on investor underreaction and overreaction. It is also consistent in the sense that it explicitly contrasts with the rational expectations hypothesis, which assumes the existence of an objective probability law that describes the state process and the presence of agents who possess knowledge of this probability. The existence of uncertainty makes rationally predictable business cycles difficult to expect (Illut and Schneider, 2014).

In his analysis, Chen goes even further, assuming that information uncertainty leads to financial instability. It is worth noting, in anticipation of the next section, that while in Chen’s approach

uncertainty leads to instability through the information transmission channel, in Bewley's framework instability may arise from changes in the *status quo* in the market that are driven by investors' decision-making processes that do not necessarily involve the spread of information within the system. However, Chen does not relate his analysis to Minsky's financial instability hypothesis but rather to the use of Bayesian priors, which represent "each agent's beliefs about the likelihoods of future states of the world" (Chen, 2017).

The approaches presented here demonstrate that, although research often begins with an analysis of mainstream theories – focusing on the role of information in explaining the behaviour of agents and the system – a full understanding of the problem is only possible when the insights of behavioural economics and alternative approaches are also considered. These perspectives go far beyond the traditional view that investors are guided solely by fundamental values, markets are efficient and agents are rational. Nonetheless, behavioural economics is not a remedy for all problems. An investor who is faced with valuation parameter uncertainty may *rationaly* price stocks in a manner that appears to produce deviations from market efficiency (Chen, 2017). Ultimately, there is no clear or definitive answer as to which of these models most accurately reflects the behaviour of agents and markets. The most appropriate approach is to draw upon the insights of both mainstream economics and alternative perspectives.

Chen (2017) drew attention to another important issue – the uncertainty of the parameter that determines uncertainty itself. On the one hand, there is the distribution as perceived by the investor; on the other hand, there is the distribution estimated from empirical data. As long as there is uncertainty about changes in the payoff structure of investments, investors tend to underestimate the role of information (the signal) and they continue to do so until the level of uncertainty falls significantly, by which point returns are also much lower. Nonetheless, investors are also capable of rational learning. In practice, however, the distinction between rational learning and the irrational behaviours and anomalies that have been identified in behavioural economics can be very difficult to detect, particularly when market conditions change dynamically over time.

As Vriend (1996) noted, "perceived opportunities evolve over time within the economic process; these changes will not only be due to changes in the perception of the underlying circumstances, i.e. learning but also to changes in these circumstances themselves as a result of the interactions between many agents". Nonetheless, as Tversky and Kahneman (1986, 1992) emphasised that although human choices are "not always rational in the traditional sense", they are not "chaotic and intractable" but rather "orderly". It is precisely this inherent order that must be explained in order to better understand economic and financial processes.

1.1.2.2 Bewley's Knightian Decision Theory

Another study that refers to Knight's idea is Bewley's (1986) *Knightian decision theory*. Bewley outlines the foundations of decision theory under risk and uncertainty, which form the basis of both standard models with microfoundations such as DSGE models and alternative approaches including agent-based modelling. In 1986, Bewley presented a theory of choice under uncertainty. In his formulation, the completeness assumption from the Anscombe–Aumann extension of Savage's theory was removed (*see* Savage, 1954; Anscombe and Aumann, 1963). However, from the point of view of our research on systemic risk and financial crises, the introduction of the *inertia assumption* is absolutely crucial. Under this assumption, there is the *status quo* and an alternative is accepted only if it is preferred to this *status quo*. This idea is, of course, not the first reference to Knight's theory since 1921; Bewley (1986) discusses the main conclusions of earlier works in Section 7 of his work. However, from the perspective of systemic risk and crisis research, it is particularly important to adopt the inertia assumption as it governs decisions regarding changes to the *status quo*. For this reason, we discuss this theory in relation to earlier contributions by Savage (1951); Smith (1961); Aumann (1962, 1964); Kannai (1963) and P. Walley (as presented in Hand, 1993).

Bewley removed the assumption of completeness from the reformulation of Savage's theory as presented by Anscombe and Aumann (1963). The completeness assumption states that we can compare lotteries in such a way that either one is preferred to the other or that they are considered equivalent. When this assumption is removed, we obtain a *set* of subjective probability distributions rather than a single distribution. One lottery is preferred over another only if its expected value is higher for all of the subjective probability distributions. Under the inertia assumption, an agent will not accept a lottery unless they strictly prefer acceptance – according to at least one probability distribution – over rejection. Thus, we assume the presence of a *status quo*, a state in which the agent remains until they prefer an alternative, which then becomes the new *status quo*.

Indeed, Knight's intuition and Bewley's *perception of uncertainty* appear to align with the behaviour of investors prior to and during the financial crisis. As Bewley (1986) pointed out, "if an investor found a new investment opportunity uncertain and hard to evaluate, he would be unlikely to undertake it, for he would do so only if it had a positive expected value for each of a large set of probability distributions. This is a form of aversion to uncertainty which is distinct from the usual risk aversion".

According to Bewley, the key issue for understanding Knight's decision-making theory is that we cannot predict decisions solely on the basis of knowledge of preferences. "The theory can say only which decisions would be undominated by others and would be preferred to the *status quo*" (Bewley, 1986, p. 3). The assumption of inertia rules out intransitive choices.

While analysing Knight's ideas, (Bewley, 1986) stated, "it is not entirely clear what he had in mind and there is an attractive alternative class of preferences which display uncertainty aversion. These are complete preferences represented by a utility function of the form $u(x) = \min_{\pi \in \Delta} E_{\pi}x$, where x is a random variable, Δ is a set of probability distributions and E_{π} is the expectation with respect to π ". However, although in Section 5 of his theory, he returned to this idea, in the main part of the theory, the assumption of completeness was removed.

Moreover, in economics, there has always been a certain degree of tension between mainstream economics, which assumes the rationality of agents and behavioural economics, which largely assumes the bounded rationality or even irrationality of agents. In line with this "division", Knight's ideas have often been interpreted within the framework of either hyper-rationality or irrationality of agents. Bewley's theory, however, differs substantially from both approaches as it reinterprets the mainstream concept of rationality – typically associated with expected utility theory and the preferences of Gilboa and Schmeidler – without rejecting rationality itself.

Bewley (1986) argued that Knight's theory also assumes the rationality of agents. In this respect, Bewley's theory differs from other approaches that are derived from behavioural economics and finance. However, rationality in his theory is understood differently. A rational agent makes decisions "using reason" and based on the available information to achieve a specific goal. In this sense, the agent is rational. However, the agent is not necessarily rational in the sense of maximising preferences. There is a subtle but important difference between these two views: "The first says that when preferences exist, behaviour serves them. The second says that all behaviour is generated by preferences. The second sense seems very unlikely to be true except by definition".

A different perspective on incomplete preferences is associated with each of the two concepts of rationality. Under the first approach to rationality, it is assumed that preference ordering forms part of the model that explains certain aspects of agents' behaviour. While behaviour cannot contradict preference ordering, not all choices are necessarily explained solely by preferences. The model remains consistent even if an agent has a strong preference for a particular alternative but considers it incomparable with other alternatives within the model. As was noted, "such behaviour does not make the individual irrational since the intransitive choices are not assumed to be in pursuit of some goal" (Bewley, 1986).

According to the second approach, an agent may conclude that two alternatives are not comparable. However, the observed choice behaviour cannot distinguish between indifference and incomparability.

Bewley, however, argued that “incomparability is an empty category”. Theoretically, any individual would be willing to accept a financial advantage to choose y instead of x even if they initially preferred x to y . For this reason, Bewley asserted that incompleteness, in this context, effectively amounts to “intransitivity of indifference”. In this approach, all agents are considered rational by definition. Nonetheless, such a strong model is contradicted by reality. As a result, Bewley favoured the first definition.

The central goals of Bewley’s article were to define the inertia assumption and to defend the thesis that, even under this assumption, the rationality of agents is preserved. The intuition behind this idea is that when new alternatives arise – those that were previously unavailable – the agent will select such an alternative only if it is preferred *over all previous possibilities*. According to this theory, the decision-maker selects the “undominated programme for the entire lifetime decision tree” and defines the *status quo*, that is, the initial position in the decision tree. The main concern, which Bewley addressed, relates to the possibility of choosing a programme that is incomparable with the initial position. In this context, Bewley argued that inertia is not a consequence of rationality. While it does not contradict rationality in the first sense of the term, it is not itself a necessary consequence of rationality in the strict sense.

The article presents three possible interpretations of inertia. Under the first interpretation, inertia applies to alternatives that did not exist previously – those assigned a probability of zero. According to the second interpretation, inertia refers to the programme chosen at the beginning of an agent’s lifetime. In this case, it is assumed that some choices may appear to be new even if they were known and anticipated from the outset. Here, the assumption of independence applies, thus ensuring that choices among the new alternatives do not interact with other choices. Bewley explained that “the inertia assumption is that the chosen programme makes use of new alternatives only if any programme not doing so would be dominated”. Bewley also proved the existence of an undominated programme that satisfies the inertia assumption. The third interpretation of inertia is linked to the assumption of bounded rationality. In this approach, Bewley assumed that decision-makers form only approximate plans. These plans are revised or rejected only if it is believed that the situation could be improved by abandoning the original plan. All three interpretations of inertia are significant from the perspective of research into investor behaviour during financial crises. To clarify our reasoning, we present Bewley’s formulation in the [Appendix A](#).

Firstly, theorems concerning incomplete preferences over gambles are presented.⁷ The von Neumann–Morgenstern theory remains unchanged assuming that probabilities are known objectively. Incompleteness arises only in the context of lotteries in which the probabilities are unknown, that is, in “gambles with unknown probabilities”. Bewley follows the Anscombe–Aumann (1963) formulation of choice under uncertainty but also draws on the work of Myerson (1979, 1986). In the latter case, all assumptions remain unchanged – except for completeness – on the grounds that they have normative justification even though some of them may not adequately describe actual behaviour. However, if lotteries are repeated many times and probabilities are known, the expected value serves as a good approximation of the outcome, thus leaving no reason to reject these assumptions. By contrast, when probabilities are unknown, there is no normative justification for assuming completeness.

The formal theorems presented in Bewley’s work (see [Appendix A](#) for the notation and theorems extracted from Bewley, 1986) provide a rigorous foundation for the inertia assumption by showing that agents’ preferences can be represented through a closed convex set of probability distributions rather than a single distribution. In particular, the “fatness” of this set, as defined in the structural assumptions, captures the degree of Knightian uncertainty surrounding future states of the world. This mathematical representation is crucial for understanding systemic risk during the 2008 global financial crisis: the unprecedented uncertainty about the valuation of complex mortgage-backed securities and the solvency of financial institutions meant that no single probability distribution could adequately represent investor beliefs. Instead, a wide set of plausible distributions existed, within which no new investment programme could dominate the *status quo* with certainty. As a result, the

inertia assumption helps to explain the widespread investor paralysis and liquidity hoarding observed during the crisis, as agents rationally refrained from reallocating capital in the face of profound ambiguity.

1.1.3 Risk and Uncertainty in General Equilibrium Framework

While Bewley's framework highlights how incompleteness of preferences and the inertia assumption capture decision-making under Knightian uncertainty, the general equilibrium tradition has initially taken a different path. Within this approach, uncertainty is treated through the introduction of contingent claims in complete markets, as pioneered by Arrow. In contrast to Bewley, who emphasised hesitation and incomparability in the face of unknown probabilities, Arrow's model assumes that markets can span all possible states of nature, enabling a direct link between competitive equilibria and Pareto optimality. This theoretical move laid the foundation for the formal treatment of uncertainty in welfare economics and subsequently influenced the development of dynamic stochastic general equilibrium models and related mainstream models.

Guth (1994) began his reflections on within the general equilibrium framework by stating that the two main theories of welfare economics do not account for uncertainty at all. "The first states that assuming no externalities or non-convexities in production or consumption, then every competitive equilibrium is a Pareto optimum. The second theorem holds that given an appropriate distribution of resources, then, roughly speaking, every Pareto optimal allocation can be achieved as a competitive equilibrium" (Guth, 1994). The author explained that it was Arrow's contingent claims model that made it possible to study the relationship between competitive equilibrium and Pareto optimality in an economy in which *uncertainty occurs*. Arrow introduced a new variable – the "state of nature" – into the standard pure-exchange economy.

In the model, I agents, C commodities and S states of nature are assumed. Agents buy and sell contingent claims X_{sc} before the state of nature is revealed. If state s occurs, the agent holding the corresponding contingent claim receives the pay-off, subject to the feasibility constraint,

$$\sum_{i=1}^I X_{isc} = \bar{X}, \forall s, c \quad (1.3)$$

Arrow demonstrated that if there is a complete set of contingent claims, the competitive economy with uncertainty is isomorphic to a pure exchange economy (with a few exceptions as was explained by Guth, 1994).

The number of trading instruments increases once contingent claims are taken into account. We no longer have $S \times C$ instruments in the model. Instead of maximising the utility of consumption of C commodities, each agent now maximises expected utility, which is equal to the product of utility from the consumption of goods and the subjective probability ρ_{is} . The utility function is then given by:

$$V_i(X_{i11}, \dots, X_{isc}) \equiv \sum_s \rho_{is} U_i(X_{is1}, \dots, X_{isc}) \quad (1.4)$$

where U_i is a non-decreasing, concave function. This assumption implies that V_i is non-decreasing and quasi-concave.

In the model, agents trade X_{sc} contingent claims. Trading concludes when an equilibrium state is reached. Subsequently, the state s is revealed and agents holding the contingent claim s^* receive the corresponding pay-off.

Assuming quasi-concavity of V_i and given a set of weights $(\omega_1, \dots, \omega_I)$, the central planner should maximise

$$\sum_i \omega_i V_i \quad (1.5)$$

subject to $\sum_{i=1}^I X_{isc} = \bar{X}, \forall s, c$.

In this way, we obtain the optimal allocation X_{isc}^* .

For any given set of incomes Y_i of agent i and for a fixed price $\bar{P}_{sc}$ for a claim to one unit of commodity c in state s , the chosen quantity X_{isc} maximises V_i subject to $\sum_s \sum_c \bar{P}_{sc} X_{isc} = Y_i$. The chosen quantity X_{isc} is thus the optimal allocation X_{isc}^* . The competitive equilibrium in the contingent claims market achieves a Pareto-optimal allocation, cf. the first Arrow's theorem (1954), see also in Mas-Colell et al. (1995).

In the second part of the article, Arrow presented a new version of the contingent claims model. Each security s pays 1 dollar if the state s occurs and 0 otherwise. Arrow assumed that there are exactly S securities whose S -dimensional payoff vectors are linearly independent.

Agents buy securities before the state is revealed. Once the state is revealed, payments due on the contingent claims are made and the agents buy in the spot market. If the markets are complete, agents must have access to $S + C$ markets in order to achieve a Pareto-optimal competitive equilibrium.

To prove the equivalence between the contingent claims and securities market allocations, we follow the procedure described by Nagatani (1975). Firstly, we present the feasibility constraints in the model.

Let q_s be the price of security s , let P_{sc} be the price of good x on spot market in state s , let X_{isc} be the quantity of good c bought by the agent i in state s . Then, the feasibility requires:

$$\sum_s q_s Y_{is} = Y_i \quad (1.6)$$

$$\sum_s \sum_c P_{sc} X_{isc} = Y_i \quad (1.7)$$

The basic question is how prices q_s and P_{sc} are determined within this framework. In Arrow's model, q_s and P_{sc} are determined according to the following procedure:

The price is chosen to ensure that $q_s P_{sc} = \bar{P}_{sc}$. The values $\bar{P}_{sc}$ correspond to the contingent claims prices from the first part of Arrow's model. Each agent acquires security s according to: $Y_{is}^* = \sum_c P_{sc} X_{isc}^*$.

Y_{is}^* must satisfy both $\sum_s q_s Y_{is} = Y_i$ and $\sum_s \sum_c P_{sc} X_{isc} = Y_i$. The total income in the economy must equal the sum of individual incomes, that is $Y \equiv \sum_i Y_{is}$ for all s . If we substitute this into the equation $\sum_s \sum_c P_{sc} X_{isc} = Y_i$ summing across all agents and taking into account that $q_s P_{sc} = \bar{P}_{sc}$, the prices of

securities can be expressed as: $q_s = \frac{\sum_i \sum_c \bar{P}_{sc} X_{isc}^*}{Y}$. In this way, we define q_s and P_{sc} .

Radner (1970, 1982) pointed out that if $\bar{P}_{sc}$ were known to agents in the Arrow–Debreu economy, then there would exist a set of prices (q_s, P_{sc}) such that sequential trading in securities followed by purchases on spot markets would lead to the same allocation X_{isc}^* . This is the content of Arrow's second theorem (Arrow, 1951; Debreu, 1951; Mas-Colell et al., 1995).

Although Arrow's contingent claims model provides an elegant framework for integrating uncertainty into general equilibrium, the events of the 2008 global financial crisis underscored the limits of this approach. In practice, financial markets were far from complete: complex instruments such as mortgage-backed securities were not fully understood and many states of nature that materialised were not covered by tradable claims. The failure of markets to approximate Arrow–Debreu completeness revealed why the inertia and incompleteness emphasised by Bewley may be more realistic tools for analysing systemic risk and uncertainty. Thus, a full understanding of risk and uncertainty in modern economies requires moving beyond Arrow's idealised vision of complete contingent markets and incorporating Bewley's acknowledgement of Knightian ambiguity and status-quo behaviour. This, in turn, may also require moving away from traditional general equilibrium models towards alternative modelling approaches, as we will see in the following chapters of this monograph.

1.2 The Concept and the Nature of Systemic Risk

The distinction between risk and uncertainty is not only a matter of individual decision-making but also has systemic implications. Whereas risk can often be treated as the measurable exposure to identifiable shocks, uncertainty captures the unquantifiable fragilities that emerge from the complexity of financial and economic systems. This tension becomes crucial when considering phenomena that threaten the stability of the system as a whole. Systemic risk can therefore be seen, to some extent, as the macroeconomic analogue of Knightian uncertainty: it is not merely the aggregation of individual risks but the result of feedback loops, interdependencies and amplification mechanisms that unfold across institutions, markets and time. In what follows, we examine the concept and nature of systemic risk paying particular attention to its endogenous and exogenous sources and to its spatial and temporal dimensions. These features provide the conceptual bridge between the theoretical foundations of risk and uncertainty and the practical challenge of measuring and modelling systemic fragility.

There is currently no universally accepted definition of systemic risk, though the attempts to conceptualise it have been numerous (De Brandt and Hartmann, 2000; Szczepańska, 2008; Smaga, 2014; Szpunar, 2012). According to the Systemic Risk Centre (LSE, 2014), systemic risk refers to the risk of a breakdown of an entire system rather than the failure of individual components. In a financial context, this is understood as the risk of cascading failures within the financial sector driven by strong interlinkages among institutions that ultimately lead to a severe economic downturn. By contrast, an idiosyncratic shock – affecting only a single institution or asset – does not propagate to the wider system and therefore remains a contained event.

The diversity of approaches to defining systemic risk is well illustrated by the survey that was conducted by Bisias et al. (2012), who reviewed not only systemic risk analytics but also the range of competing definitions. Harun and Gunadi (2022) defined systemic risk “as any set of circumstances that threatens the stability of or public confidence in, the financial system”. Similarly, the European Central Bank (2009) emphasises its macroeconomic impact, describing systemic risk as a risk of financial instability that is “so widespread that it impairs the functioning of the financial system to the point where economic growth and welfare suffer materially”.

Other contributions to the systemic-risk literature have taken a more granular view of the mechanisms through which such risk emerges. Caballero (2010) argued that the roots of the global financial crisis lay in a structural imbalance, namely, the global shortage of safe assets, which placed unsustainable pressure on the U.S. financial system and amplified the consequences of the collapse of securitised instruments. Acharya et al. (2017) approached the problem from the perspective of correlated exposures, introducing the concept of a systemic expected shortfall to capture how institutions that appear solvent in isolation may become undercapitalised precisely when the system as a whole is in distress.

Other scholars have emphasised the role of liquidity spirals and balance-sheet linkages. Kapadia et al. (2013) showed how distress in one part of a system can propagate as funding dries up, fire sales occur and liquidity is hoarded, thereby destabilising even healthy institutions. Mishkin (2007), by contrast, highlighted information disruptions, noting how opacity and complexity undermine price discovery and aggravate uncertainty during periods of stress. The contagion dynamics of financial networks were analysed in depth by Moussa (2011), who demonstrated how shocks can spread across interdependent institutions in ways that magnify systemic breakdowns. Finally, both academic and policy literature, including the Financial Stability Board as discussed in Bisias et al. (2012), stress the importance of negative externalities – behaviours that are individually rational such as selling assets in response to falling prices can collectively destabilise markets and disrupt financial intermediation.

Many additional contributions in the literature dig beneath the surface to specify how systemic risk emerges through structural and behavioural channels. A growing body of work examines overlapping institutional portfolios, where correlated holdings create the potential for common-shock propagation. Poledna et al. (2021) offered a pioneering framework for quantifying this effect on a national scale.

Relatedly, research on network architecture – notably by Acemoglu et al. (2015) – revealed “phase-transition” dynamics, in which interconnectedness initially aids stability but then sharply increases fragility once critical thresholds are surpassed. Credit-derivative markets, particularly CDS-based networks, have been shown to act as potent contagion channels as was illustrated in models by Paddrik et al. (2016); related network contagion mechanisms were also explored by Nier et al. (2007). Dynamic contagion frameworks such as the PD model of Petrone and Latora (2018) further extend this analysis by combining default risk with evolving network exposures to simulate systemic losses and trace the contributions of institutions. More recently, Zhu et al. (2023) demonstrated that the degree of network clustering plays a critical role in systemic stability: reductions in clustering weaken contagion channels. Finally, theoretical advances in liquidity dynamics (liquidity spirals) illustrate how market funding shifts and spillovers intensify systemic stress – especially during episodes of uncertainty (Wiersema et al., 2023).

From the perspective of our earlier discussion on risk and uncertainty, however, it is striking that most of these definitions remain silent on whether systemic risk should be understood as a problem of measurable risk (with assignable probabilities, as in Arrow’s framework) or of fundamental uncertainty (as was emphasised by Knight and Bewley). The dominant strand of the literature treats systemic risk as an institutional, technical or regulatory phenomenon rather than as an expression of deeper epistemic limits in modelling probabilities. This creates a tension: systemic risk is often described as if it were a quantifiable “risk”, yet the 2008 global financial crisis revealed it to be rooted in profound uncertainty about complex financial instruments and market interconnections. In this sense, while the definitions reviewed above provide important operational clarity, they leave open the question of how systemic risk should be situated in the broader debate between risk and uncertainty – a theme that will recur in the following chapters.

1.2.1 Understanding the Endogenous and Exogenous Nature of Systemic Risk

De Brandt and Hartmann (2000) observed that disputes over how to define systemic risk are closely tied to whether its origins are viewed as primarily exogenous or endogenous. Broadly, two approaches dominate. The first interprets systemic risk as the consequence of external shocks striking the financial system and triggering instability. The second regards systemic risk as something that can arise endogenously, generated “from within” the financial system or the broader economy. In practice, both types of drivers often operate in combination, sometimes sequentially, sometimes simultaneously.

A further distinction can be drawn between the horizontal and vertical perspectives. The horizontal approach considers systemic risk only within the financial sector, while the vertical approach explicitly incorporates feedback loops between the financial system and the real economy. Before the global financial crisis, most theoretical and empirical work adopted the horizontal view. This simplification aided modelling but came at a cost – by ignoring the feedback and amplification mechanisms, analyses were often incomplete or misleading and policy recommendations rested on weak foundations.

Within the endogenous perspective, it is useful to distinguish between two categories. Firstly, endogenous systemic risk generators – factors that originate inside the financial system and initiate non-equilibrium dynamics. Examples include leverage and liquidity mismatches (Brunnermeier et al., 2014) or high interconnectedness (Drehmann and Tarashev, 2011). Secondly, amplification mechanisms – the channels through which the adverse effects of shocks are propagated and magnified even if external in origin. These mechanisms often reflect market failures (Korinek, 2011) or shifts in agents’ expectations. Both categories played critical yet distinct roles in the build-up and unfolding of the 2008 crisis and disentangling their relative importance is crucial for both theory and regulation.

The divide between the internal generators of crisis and external shocks is thus central to how mainstream and alternative schools of thought understand the nature of systemic risk, which have far-reaching implications for its measurement and modelling. As was already noted in the introduction, this distinction gained particular prominence in the literature following the contributions of Danielsson and Shin (2003) and Danielsson et al. (2013) at the LSE Systemic Risk Centre. They

describe endogenous risk as “the risk from shocks that are generated and amplified within the system”, in contrast to exogenous risk, which stems from shocks arriving from outside (Danielsson and Shin, 2003). In the words of the LSE (2014), endogenous risk is created by and within the financial system itself rather than by catastrophic events that originated elsewhere. While these formulations have been highly influential, the underlying idea is not new; it can be traced back to general systems theory developed by von Bertalanffy (1968) and earlier work by mathematicians, physicists and biologists since the 1930s as previously discussed in the introduction.

After the recent crisis, the shortcomings of mainstream methodologies prompted heterodox economists to call for a paradigm shift. Concepts from physics, biology and complex systems began to enter the economics discourse and even mainstream and behavioural economists started to adopt them. As a result, the once sharp divide between behavioural approaches and econophysics has become increasingly less dogmatic. Yet, in many strands of mainstream economics, the acceptance of the endogenous perspective owes less to this scientific legacy and more to the popularity the concept gained in the aftermath of poorly understood financial instability. Too often, the approach remains oversimplified; it rejects the idea of analysing a system’s evolution in spatial and temporal terms while still relying on the same measurement and modelling techniques that proved to be inadequate before the crisis.

1.2.2 The Spatial and Temporal Dimensions of Systemic Risk

In the literature, systemic risk is often examined along two principal dimensions: cross-sectional (or structural) and temporal. Following the Bank for International Settlements (2010), Smaga (2014) defined the cross-sectional dimension as the distribution of systemic risk within a financial system at a given point in time. It captures the vulnerabilities arising from the instability of particular institutions, the concentration of exposures or funding sources, the size and structure of the financial system and the direct and indirect linkages between financial institutions. The temporal dimension, by contrast, reflects the build-up of systemic risk over time. It is concerned less with the condition of any individual institution and more with collective behaviour that amplifies volatility, for example, through leverage cycles, procyclicality in lending or the underestimation of risk during booms followed by its abrupt overestimation during downturns.

Although Smaga used the terms “cross-sectional” and “structural” interchangeably and likewise treated “temporal”, “cyclical”, “time-varying” and “time-series” as synonyms, these concepts are not in fact equivalent. The labels “cross-sectional” and “time-series” are most naturally associated with econometric methods; panel data techniques lend themselves to the former, while time-series analysis is used for the latter. By contrast, “structural” and “cyclical” are more closely tied to the substantive dynamics of the financial system itself; structural changes may arise, for instance, from contagion that reshapes the network of interbank connections while cyclical movements reflect the boom-bust tendencies of the credit and asset markets.

A further distinction, which is not made explicit in Smaga’s analysis, is between the spatial and the temporal nature of systemic risk. This perspective is particularly useful for modelling rather than measurement. Whereas cross-sectional and time-series analyses seek to produce numerical estimates of systemic risk, spatial and temporal approaches are more concerned with how risk emerges, spreads and evolves within a system. In this view, the emphasis shifts towards understanding how agents interact in space and over time, how their behaviour influences that of others and how local shocks propagate through a network of connections. Such a framework highlights systemic risk as a dynamic and evolving process rather than a static parameter and is therefore especially valuable when analysing crises that involve rapid feedback effects and cascading failures.

1.2.3 Understanding Procyclicality and Contagion in Financial Systems

As was highlighted in the introduction, procyclicality and contagion are two central mechanisms through which systemic risk unfolds. They also map directly onto the spatial and temporal dimensions that were discussed in the previous section; procyclicality reflects the temporal build-up and amplification of systemic risk while contagion represents its spatial diffusion across institutions, markets and borders.

Drawing on Olszak (2015), we noted the theoretical underpinnings of excessive procyclicality earlier. In the Polish literature, research has often focused on contagion in the context of the interbank market and liquidity channels (Hałaj, 2007). In the international debate, however, the scope has been broader with contagion analysed not only between banks but also across markets, industries, countries and even among individual agents. Both theoretical and empirical contributions have shown how systemic risk materialises through these channels – insights that have proved to be highly relevant for understanding the origins, transmission and consequences of the global financial crisis.

The failure of a single financial institution might trigger the default of others as interbank exposures transmit distress through the system. Yet contagion is not confined to banking; it also propagates across industries, sectors and international markets. The macro-financial agent-based model therefore have to incorporate both the cross-sectoral transmission channels and the cyclical dynamics of economic processes. Cross-border contagion was particularly visible during the 2008 crisis when shocks that had originated in the United States spread rapidly to European economies – an aspect that will be revisited later in the book.

The causes and mechanisms of contagion are diverse. Dornbusch et al. (2000) define contagion as the transmission of shocks across markets through excess co-movements or spillover channels. Allen and Gale (2007) demonstrated that the structure of financial interconnections can propagate local shocks into systemic crises, even when individual institutions appear stable. In contrast, other scholars emphasise informational contagion, where crises spread through news, shifts in sentiment or changes in collective expectations rather than through direct balance-sheet exposures (e.g. Kaminsky and Reinhart, 2000). In this view, contagion is amplified by factors that directly shape the perceptions of risk and uncertainty, thus making market sentiment an active transmission channel. This underscores the role of belief dynamics in systemic crises – a link between opinion formation and financial fragility that is central to our analysis.

1.3 The Measurement and Modelling of Systemic Risk

Having defined the concept and nature of systemic risk and examined its key dimensions, we now turn to the challenge of measurement and modelling. As was emphasised in the introduction, the experience of the 2008 crisis demonstrated that understanding systemic fragility requires more than theoretical clarity; it also demands tools that are capable of capturing both the spread of risk within the financial system and its spillovers into the real economy. This task has drawn on methodologies from mainstream economics as well as from heterodox approaches, which, as was discussed earlier, often emphasise complexity, non-linearity and feedback effects.

1.3.1 Contrasting Mainstream and Heterodox Approaches

The distinction between mainstream and heterodox economics is not always clear-cut, yet it remains useful. Mainstream or “core”, economics has traditionally been associated with general equilibrium theory and the neoclassical growth models. Heterodox or “periphery” approaches are more eclectic, encompassing alternative modelling strategies and drawing on complex systems theory. While many assumptions are shared across the two traditions, heterodox approaches place greater emphasis on

non-equilibrium dynamics and admit the possibility of self-organised criticality (Bak et al., 1987). In this sense, they offer a broader framework for understanding systemic phenomena.

The long-standing tension between the two traditions reflects differences in style as much as in substance. Mainstream economics has prided itself on its rigour and econometric precision, whereas heterodox economics has often been criticised as a patchwork of less formal, sometimes untested, hypotheses. Yet the crisis of 2008 undermined confidence in mainstream theories and tools, which forced economists to re-examine alternative methodologies (Wojtyna, 2008, 2014; Caballero, 2010). In practice, mainstream and heterodox approaches are not mutually exclusive; they are complementary and can be integrated within what we term an econophysical time–space continuum.

Econophysics exemplifies this integrative spirit. Emerging in the mid-1990s, it applies concepts from physics to social and economic systems. Such theories have proved to be particularly useful in contexts where mainstream economics struggles, for instance in modelling decision-making under uncertainty or in capturing non-linear dynamics. The cross-fertilisation between physics and economics is not new; Bernoulli’s work on probability and utility and von Neumann’s contributions to equilibrium theory illustrate how deeply intertwined these fields have long been. In recent decades, econophysics has expanded into diverse domains – from the microstructure of financial markets and order-book modelling to macroeconomic dynamics, wealth distribution and the analysis of bubbles and crashes (Chakraborti et al., 2011).

From the perspective of this study, three areas of analysis are particularly relevant: the microstructure of financial markets with links to consumer and investor finance, the macrostructure of wealth distribution and the dynamics of systemic change including the formation and bursting of bubbles. Crucially, these should not be understood as separate levels of analysis but as interconnected dimensions within a spatial–temporal continuum. The spatial dimension captures the structure of financial and economic systems at a given point in time, while the temporal dimension focuses on their evolution and dynamic adjustments. Framing systemic risk within this continuum, as econophysical models often do, highlights its multidimensional character and helps explain why seemingly small shocks can cascade into crises.

1.3.2 *Measurement Techniques in the Analysis of Systemic Risk*

In the preceding sections, we distinguished systemic risk from uncertainty beginning with Knight’s original insights (Knight, 1921), then reviewing reinterpretations for individual decision-making (Bewley, 1986) and investment under constrained information (Chen, 2017). We also outlined how risk and uncertainty can be embedded in a general equilibrium framework and analysed the concept and nature of systemic risk with particular attention being paid to its spatial and temporal dimensions. While that discussion was primarily theoretical, the global financial crisis highlighted the need for a complementary empirical agenda, i.e. one that identifies the mechanisms of risk generation and amplification in practice.

To analyse the relative role of systemic risk in the causes, evolution and consequences of the crisis in the United States and the EU, one must first confront the difficulties of measurement and modelling. At the onset of the crisis, a genuinely *systemic* perspective had not yet been adopted; most analyses focused on the contribution of *individual* institutions to overall risk. The immediate strategy was pragmatic: extend familiar tools into a new domain. Accordingly, researchers began with adaptations of Value at Risk (VaR)⁸ and Expected Shortfall (ES).

VaR is defined as the maximum loss over a given horizon at confidence level, while ES is the conditional loss beyond VaR (*see*: Acharya et al., 2017). It naturally leads to the Marginal Expected Shortfall (MES), which asks how a group’s return r_i contributes to a firm’s total return ($R = \sum_i r_i$) and, by extension, to tail losses (Acharya et al., 2017). Systemic Expected Shortfall (SES) should be treated as the MES-based contribution to system-wide tail risk. In practice, SES requires estimating ex ante conditional losses – using variables that are informative about crises (e.g. equity

returns) – computing MES on “bad” market days and employing extreme value methods to link those episodes to tail behaviour. SES thus quantifies an institution’s *propensity* to be undercapitalised when the system is undercapitalised; it increases with leverage and with expected tail losses and can be used to calibrate the corrective “taxes” that are aimed at internalising externalities.

A key merit of this programme is its *ex ante* orientation. Acharya et al. (2017) benchmarked *ex ante* risk measures against *ex post* realisations – capital shortfalls in the 2009 regulatory stress tests, equity value decreases during the crisis and CDS-implied credit risk – showing informative cross-sectional relationships between pre-crisis MES and realised systemic stress.⁹

The broader literature on systemic risk measurement can be organised into two families.¹⁰ The first employs a contingent-claims (structural) analysis of institutions’ asset values (e.g. Lehar, 2005; Gray et al., 2006). The second uses reduced-form approaches to characterise the tail behaviour of asset returns and joint distress (e.g. Hartmann et al., 2005; Adrian and Brunnermeier, 2008; Segoviano and Goodhart, 2009; Huang et al., 2009a; De Jonghe, 2010). SES was designed to bridge these strands while remaining closely aligned with reduced-form estimation.

Beyond SES and CoVaR, surveys of practice – particularly Bisias et al. (2012) – cover a wide spectrum of analytics ranging from *ex ante* early-warning indicators, counterfactual stress testing and scenario-based simulations through contemporaneous fragility and crisis monitoring to *ex post* forensic analysis and orderly resolution frameworks. In the Polish literature, systemic risk analytics were developed by, *inter alia*, Karkowska (2015) and Czerwińska and Jajuga (2016). Taken together, these approaches reflect the dual imperative outlined earlier: to measure systemic risk both *across space* (structure, interconnectedness and exposure concentrations) and *over time* (build-ups, procyclical dynamics and amplification), thereby linking the empirical techniques to the theoretical distinctions that are drawn in this chapter.

1.3.3 The Modelling of Systemic Risk

Before the crisis, most public organisations relied on dynamic stochastic general equilibrium (DSGE) models. Despite deficiencies in representing the complexity of the financial sector and the heterogeneity of agents and sectors, a broad consensus on their use for forecasting and policy analysis persisted. Crucially, these “core” models were not designed to capture the endogenous generation of systemic risk, amplification mechanisms or the potential effects of credit crunches. In response, a wide array of alternative approaches has since emerged, which offer complementary insights to the DSGE tradition (Caballero, 2010).

Behavioural and complexity economics relax the assumptions of full rationality and equilibrium by emphasising bounded rationality, feedback effects and “endogenous instability” (Akerlof and Shiller, 2009; Battiston et al., 2016). Network-based models focus on interconnectedness and systemic externalities, showing how local shocks can propagate through financial linkages (Haldane and May, 2011; Battiston et al., 2012). Related work in agent-based modelling (ABM) captures heterogeneity, adaptation and emergent macroeconomic patterns (Farmer and Foley, 2009a; Axtell and Farmer, 2025). A further line of research in opinion dynamics explores how beliefs co-evolve through interaction (Deffuant et al., 2000; Galam, 2008), often incorporating mechanisms such as homophily (McPherson et al., 2001) or preferential attachment (Barabási and Albert, 1999; Newman, 2003) to model the formation of stable clusters. Additionally, epidemic-style contagion models provide tractable analogies for understanding the spread of financial distress (Acemoglu et al., 2015).

Not all of these approaches are equally well grounded in empirical reality. As Castellano et al. (2009) and Sobkowicz (2009) note, some models rely on stylised behavioural assumptions. Nevertheless, they broaden the analytical toolbox for studying systemic fragility. For example, Javarone and Armano (2013) demonstrated that perceptions of similarity can drive clustering and imitation even without fundamental economic links. By analogy, financial institutions facing uncertainty may mimic peers not simply due to fundamentals but because of expectations about others’ actions. Traditional general equilibrium theory explains such coordination through asymmetric information, yet offers

limited means with which to model dynamically co-evolving expectations (e.g. Morris and Shin, 2002). In contrast, the framework developed by Javarone and Armano (2013) represents similarity between agents in a simple geometric way, thus making it possible to simulate how groups, opinions and herding emerge over time.

Among the data-driven alternatives, agent-based modelling (ABM) has emerged as one of the most promising approaches for understanding systemic risk in modern financial systems. Unlike DSGE models, which rely on equilibrium assumptions, representative agents and linearised dynamics, ABM offers a micro-founded, bottom-up framework in which instability can arise endogenously from interactions among heterogeneous agents. Agents adapt, learn and respond to evolving conditions, thereby allowing the modelled economy to exhibit realistic phenomena such as leverage cycles, liquidity hoarding, fire sales and credit crunches without having to impose them exogenously.

Recent work shows that ABM has moved well beyond conceptual demonstration and is now empirically grounded and policy-relevant. As was emphasised by Borsos et al. (2025), ABM is already used within central banks to assess macro-financial stability, evaluate macroprudential tools and conduct stress-testing (also under Knightian uncertainty, i.e. when probabilities are not well-defined and perceptions of risk become endogenous). Likewise, Axtell and Farmer (2025) showed that ABM can be calibrated to match a wide range of macroeconomic and financial regularities – fat-tailed return distributions, clustered volatility, firm dynamics, credit cycles and wealth inequality, often outperforming DSGE in replicating empirical data. Crucially, unlike DSGE, ABM frameworks explicitly model belief formation and shifting perceptions of risk and uncertainty, thus allowing fear, confidence and narrative-driven expectations to affect system dynamics. One of the key strengths of ABM is its ability to reproduce systemic fragility and nonlinear contagion as emergent properties of interaction networks. This connects directly to the theory of self-organised criticality: complex financial systems may evolve towards critical states where small shocks can trigger cascades. This mechanism has been demonstrated in macro-financial contexts, e.g. Aleksiejuk et al. (2002).

Empirically calibrated ABM are now being deployed at scale. Early efforts such as EURACE (Deissenberg et al., 2008) demonstrated feasibility and more recent contributions have strengthened data realism. Poledna et al. (2021) quantified systemic risk from overlapping portfolios, thus showing how common asset holdings create contagion channels comparable to interbank exposures. The CANVAS model (Hommes et al., 2022) incorporates heterogeneous expectations and bounded rationality into monetary-fiscal transmission. Wiese et al. (2024) developed a macro-financial ABM calibrated to OECD data that links housing markets, credit networks and wealth heterogeneity. A related contribution is the MACROPRU model, which applies ABM-style behavioural mechanisms to macroprudential policy analysis (Muellbauer and Kaszowska-Mojša, 2023).

Together, this new generation of empirically grounded ABM challenges the DSGE paradigm by capturing how systemic risk is co-created by interaction networks, feedback loops and evolving perceptions of risk and uncertainty. Rather than treating beliefs as exogenous or rational, ABM endogenises opinion dynamics and expectation formation, thereby offering a richer foundation for analysing financial instability and macroprudential policy.

Final remarks

In this chapter, we have examined the most important aspects of systemic risk and uncertainty, largely from a theoretical standpoint. We began with Knight's foundational distinction between risk and uncertainty, then explored key reinterpretations such as Bewley's (1986) theory of inertia and the *status quo*, which remain relevant for understanding financial crises. We showed how risk and uncertainty can be embedded within the general equilibrium framework through Arrow's contingent claims model and subsequent extensions, while also considering how heterodox approaches reinterpret rationality and incomplete preferences.

Building on this, we analysed the concept and nature of systemic risk itself, highlighting its endogenous and exogenous dimensions as well as its spatial and temporal manifestations in procyclicality and contagion. These discussions established a bridge between theoretical constructs and empirical applications. We then reviewed the mainstream and heterodox measurement techniques from VaR and Expected Shortfall through to Systemic Expected Shortfall, CoVaR and the wider spectrum of systemic risk analytics. Finally, we surveyed alternative modelling approaches with particular attention being paid to agent-based models as tools that are able to capture the endogenous dynamics of instability.

Together, these perspectives illustrate that systemic risk cannot adequately be understood within the confines of the equilibrium-based, representative agent models. Instead, it requires a multidimensional approach that integrates insights from both mainstream and heterodox traditions and that pays close attention to the dynamic, interactive and often nonlinear processes by which crises unfold. In the following chapters, we turn to the empirical analysis of the 2008 crisis in the United States and the EU where these theoretical considerations provide a foundation for interpreting the observed dynamics of systemic instability.

Notes

1. Hereby, *inference* is understood as the “ideal or complete one based on uniformity of association of predicates and which can be formulated in universal propositions” and not as judgement, common sense or intuition, *see*: Knight (1921, p. 212).
2. Analysing the example of fire insurance contributed to the popularisation of the distinction between risk and uncertainty in terms of insurable and non-insurable phenomena.
3. It is possible to demonstrate that the former type can be reduced to the latter on the basis of an empirical law of large numbers.
4. *See* Knight (1921, pp. 217–18) for discussion of the paradox on homogeneous grouping.
5. “The statistical probability r of some outcome y is then equal to the numerical proportion or relative frequency of a certain outcome (y) in a reference class of empirically tabulated trials (xs). The statistical probability of y might then be written $p_x(y) = r$ ” (Rudne, 1998, p. 543)
6. As in the third category mentioned by Knight (1921).
7. The proofs of these results have already been provided by Smith (1961); Aumann (1962, 1964) and Walley (as presented in Hand, 1993).
8. We do not discuss CoVaR here, as it is covered by Olszak (2015) and noted in the introduction.
9. MES is computed as the average of an institution’s returns during the worst 5% of market days; *see* Acharya et al. (2017).
10. This distinction is also emphasised by Acharya et al. (2017).

2 Systemic Risk and the 2008–2009 U.S. Financial Crisis: Causes, Course and Consequences

As the financial crisis originated in the United States before spreading to Europe, any assessment of systemic risk in the European Union (EU) must begin with an analysis of its American roots. This chapter therefore investigates how systemic vulnerabilities developed in the U.S. financial system, how they triggered the crisis and how systemic risk influenced its progression and wider economic impact. The opening section distinguishes between the vulnerabilities within the system and the immediate triggers of the U.S. financial crisis. Two broad sets of causes are then considered. The first concerns the deregulation processes and affordable housing policies. The second relates to the macroeconomic factors that are not directly linked to deregulation or to the public guarantees for the government-sponsored enterprises that generated moral hazard. Particular attention is paid to the global savings glut hypothesis and to the internal and external imbalances. The section concludes with an assessment of how systemic risk was generated and amplified in the years preceding the crisis. The second section turns to crisis management and reform in the United States. It reviews the principal explanations of the crisis, examines the dynamics of systemic risk during the turmoil. The third section addresses the main effects of the U.S. financial crisis, which are grouped into three categories. The first is the impact on the financial system itself including the systemic risk it entailed. The second concerns the wider economy since systemic risk cannot be reduced to mechanisms within the financial sector alone. Following the De Brandt and Hartmann (2000) perspective that systemic risk arises from the interaction between finance and the real economy, the analysis considers both the macroeconomic impacts and distributional consequences in the United States. Finally, the global dimension is highlighted, thus showing how the systemic nature of the crisis contributed to contagion in Europe, affected the world economy and paved the way for the discussion in the next chapter on the role of systemic risk and uncertainty in the development of the EU crisis. In this and the following chapters, we begin to substantiate the book's central hypothesis: that the relative role of systemic risk was greater in the course and consequences of the crisis than in its origins owing to the feedback effects that characterised the U.S. experience.

2.1 System Vulnerabilities and Triggers of the Financial Crisis in the United States

On 2 September 2010, Ben Bernanke, Chairman of the Federal Reserve, testified before the Financial Crisis Inquiry Commission in Washington, DC. His testimony attracted considerable attention among both researchers of the financial crisis and the media because of the distinction he drew between the

“vulnerabilities” and “triggers” of the 2007–2009 financial crisis (Bernanke, 2010). According to Bernanke, “the triggers of the crisis were the particular events or factors that touched off the events of 2007–09 – the proximate causes –”, whereas “the vulnerabilities were the structural and more fundamental weaknesses in the financial system and in regulation and supervision that served to propagate and amplify the initial shocks”.¹ In his testimony, Ben Bernanke argued that the most important trigger was “the prospect of significant losses on residential mortgage loans to subprime borrowers that became apparent shortly after house prices began to decrease”. At the same time, excessive leverage, liquidity and maturity mismatches, weaknesses in regulation and risk management within major institutions, market concentration and the speculative use of derivatives were cited as key examples of vulnerabilities. In the view of the Chairman of the Federal Reserve, years of regulatory neglect had made the system more susceptible to shocks and thus more vulnerable. Nonetheless, this was not a direct cause of the crisis – it was not a trigger. Although Ben Bernanke observed that “the system’s vulnerabilities, together with gaps in the government’s crisis-response toolkit, were the principal explanations of why the crisis was so severe and had such devastating effects on the broader economy”, it is difficult to avoid the impression that, in 2010, he shifted responsibility for the crisis onto external shocks to the system. Nonetheless, the official rhetoric about the subprime crisis has shifted over the years. In 2010, during his testimony, B. Bernanke emphasised that [the trigger was] the *prospect* of significant losses on residential mortgage loans to subprime borrowers. In 2012, when referring to his earlier testimony, he replaced the expression “the prospect of significant losses” with “*developments* in the market for subprime mortgages”. Although this change might appear to be minor – in both cases he referred to the central problem of subprime lending – in practice, it is crucial. It reshapes how we understand the crisis, the nature of systemic risk and the evolution of the system.

In his 2010 testimony, B. Bernanke observed: “with more than \$1 trillion in subprime mortgages outstanding, the potential for losses on these loans was large in absolute terms; however, judged in relation to the size of global financial markets, prospective subprime losses were clearly not large enough on their own to account for the magnitude of the crisis”.² The emergence of the crisis was therefore not the result of an external shock in the sense that is understood by mainstream economics. More broadly, it also illustrates the problems that arise when systemic risk is treated as an exogenous factor. Nonetheless, whenever the mainstream explanation appears to be incomplete, behavioural and heterodox approaches offer a viable alternative. “\$1 trillion in subprime mortgages” was not a shock *per se* that caused the crisis. It was “the prospect” – the perception of loss – that truly mattered.

The combination of such a trigger and the interaction of systemic vulnerabilities brings us closer to the problem of the endogenous nature of systemic risk in the sense of Danielsson’s work (Danielsson and Shin, 2003; Danielsson et al., 2013). The expression “*developments* in the market for subprime mortgages were a prominent example of a trigger of the crisis” directs attention not to a single shock but to a process – to changes in the spatio-temporal structure of the system. This interpretation aligns more closely with heterodox approaches and the notion of the endogenous nature of systemic risk. However, once systemic risk is seen as endogenous, the distinction between triggers and vulnerabilities becomes blurred. All elements influence the behaviour of the system across time and space. In this spirit, we analyse the causes of the crisis in this chapter. We begin by outlining the possible causes of the crisis that have been linked to the domestic politics and regulation of the United States over the years. We then examine the external conditions of the world economy, which are also highlighted in the literature as potential causes. The list is by no means exhaustive. In this chapter, we concentrate only on those aspects that are in our view most relevant to the problem under study and to the research objectives.

2.1.1 The Deregulation Process and Affordable Housing Policies in the United States

In order to clarify the causes of the 2008–2009 financial crisis,³ it is necessary to return to the economic and regulatory changes that took place in the United States after the Great Depression. In

the years that followed, a number of regulations were introduced to restructure the real and financial sectors and to mitigate the risk of another major downturn. Understanding the rationale behind these regulations as well as the subsequent changes in regulatory frameworks is crucial for determining whether there was a causal link between deregulation and the financial crisis in the United States.

2.1.1.1 From the Glass–Steagall Act to the Gramm–Leach–Bliley Act

After the Great Recession, a number of new regulations were introduced in the United States to mitigate systemic risk and to restore financial stability (Carpenter et al., 2016).⁴ In 1933, the Securities Act introduced the requirement for Initial Public Offering (IPO) registration and disclosure in the primary securities market. In 1934,⁵ the Securities and Exchange Commission (SEC) was established to regulate the secondary securities market and to prevent fraud.⁶

In 1933, the Banking Act established the Federal Deposit Insurance Corporation (FDIC), which guaranteed deposits up to a certain level and helped to prevent bank runs. The Act also created the Federal Open Market Committee (FOMC) under Section 8 and prohibited lending to Federal Reserve executive officers. In addition, it introduced Regulation Q, which set ceilings on deposit interest rates. Nonetheless, Regulation Q made an exception for institutions specialising in mortgage lending, which were permitted to charge an interest rate 0.25% higher than the ceiling. This provision encouraged the growth of the real estate sector (Banking Act, 1933, Sherman 2009). One of the most important provisions of the Banking Act was the abolition of universal banking after the Great Depression and the introduction of a separation between commercial and investment banking under the Glass–Steagall Act.⁷ The financial system of the United States is in large part the outcome of the framework established by the Glass–Steagall Act and the deregulation processes that gathered momentum from the 1980s onwards. In 1998, the Federal Reserve made a controversial decision that allowed the merger of Travelers Group Inc. with Citigroup, a move widely regarded as contrary to the Act (Simpson Thacher & Bartlett LLP, 1998). In November 1999, President B. Clinton declared that the separation of commercial and investment banking was no longer necessary or appropriate. In the same year, the Gramm–Leach–Bliley Act of 1999 was adopted, abolishing the separation of financial institutions' activities (GLB, 1999). This regulatory change has been viewed by some economists not necessarily as a direct cause of the 2008–2009 crisis but as an alteration of system conditions that made the financial sector more vulnerable and increased the likelihood of a crisis (White, 2010). Others, however, defend the argument that there was no causal link between the approval of the GLB Act and the crisis (McDonald, 2016; Mahoney, 2018). The rationale for introducing and maintaining the Glass–Steagall Act shifted significantly between 1933 and 1998 and was shaped over time by broader deregulation processes.

The main arguments for introducing the Glass–Steagall Act were, firstly, consumer protection against the speculative use of funds by financial institutions and the associated risk of loss (White, 1986) and secondly, the limitation of conflicts of interest (Kroszner and Rajan, 1994). However, the provisions of the Act were at least as controversial in 1933 as they are today. Moore (1934) did not confirm that the involvement of commercial banks in risky investment activity was detrimental to either the securities market or to consumers. Since the 1930s, counter-arguments against the introduction of the Glass–Steagall Act have also been raised. Critics argued that its provisions would reduce the competitiveness of deposit banks, lower their profits by limiting their activities and diminish the benefits of diversification. Some economists also maintained that securities were less risky than mortgage loans (Benston, 1990). Since the early 1940s, concerns about a decrease in the competitiveness of commercial banks, linked to restrictions on their activities, were increasingly raised (White, 1986).

In 1963, a regulation was proposed that would have allowed commercial banks to offer consumers common stocks and other securities functioning as mutual funds. However, this regulation was struck down by the Supreme Court in the case *Investment Company Institute v. Camp*, on the grounds that it conflicted with the Glass–Steagall Act (Supreme Court of the United States, 1971). In the 1960s,

for the first time, Regulation Q, which had been introduced in the 1933 Banking Act to set ceilings on deposit interest rates, began to have a significant impact on the market (Wilmarth Jr., 2017). Customers started to withdraw funds from banks on a large scale in order to reinvest them at higher interest rates, which led to a number of bankruptcies among financial institutions in the 1960s and 1970s. During the same period, commercial banks began to advise clients on investments in capital markets. By the late 1970s, residential mortgage financing through securitisation had emerged.

In the 1970s, competition for commercial banks from investment firms and non-banking institutions increased significantly. As a result, the first reforms were introduced to allow commercial banks to underwrite municipal revenue bonds under the revised Glass–Steagall Act (White, 1986). In addition, since 1974 depositors have been permitted to withdraw funds periodically in order to purchase securities. From 1978 onwards, banks were also authorised to securitise residential mortgages.

Deregulation processes in the United States began during the presidency of R. Reagan, who took office in 1981 and encouraged commercial banks to conduct investment activities through subsidiaries and affiliates. In 1980, the Depository Institutions Deregulation and Monetary Control Act (DIDMCA) was adopted, allowing competition between banks and market mutual funds (Sherman, 2009).⁸ In 1982, the Garn–St. Germain Act was passed, loosening the specialisation of thrifts in mortgage lending and allowing them to compete with money market mutual funds (Cornett and Tehranian, 1990). While this Act increased competition in the market, it also altered its configuration and heightened risk by eliminating interest rate ceilings on deposits. Moreover, during the 1980s another crisis struck the economy. The financial sector was poorly protected and conditions were unfavourable. The Federal Savings and Loan Insurance Corporation (FSLIC) reported that “bailing out all the insolvent institutions in 1983 would have cost the FSLIC around \$25 billion but the fund held only \$6.3 billion in reserves at the time” (Sherman, 2009). In addition, accounting standards were relaxed, which permitted thrifts to write off losses over a ten-year period. The spread of the doctrine of Reaganomics was equally important for shaping market processes.

As a consequence of the changes in the first half of the 1980s, investment banking expanded at the expense of the traditional mortgage lending business. However, in the second half of the decade, conventional mortgages regained importance. The boom in the real estate market in the mid-1980s was supported by the Tax Reform Act of 1986. Unfortunately, this also later triggered an outflow of deposits from thrifts, which led to a new wave of bank failures in the market (Sherman, 2009).

In 1987, the Competitive Equality in Banking Act (CEBA) was passed. Under the CEBA, investment banking or affiliate securities activities were permitted within the limits of Sections 20 and 32 of the Glass–Steagall Act (Baradaran, 2012). The Board of Governors of the Federal Reserve System authorised “limited underwriting activities for Bankers Trust, J. P. Morgan and Citicorp with a 5% revenue limit on Section 20 ineligible securities activities” (Jones and Critchfield, 2005).

The most important changes in lending and investment activities in securities, however, occurred after A. Greenspan became Chairman of the Federal Reserve in 1987.⁹ In 1989, the Financial Institutions Reform, Recovery and Enforcement Act (FIRREA) was adopted and the Federal Reserve “expanded Section 20 underwriting permissibly to corporate debt and equity securities, subject to a revenue limit” (Jones and Critchfield, 2005). FIRREA abolished the FSLIC fund and transferred its responsibilities to the FDIC. The Office of Thrift Supervision was created and the Resolution Trust Corporation (RTC) was established to enable the orderly liquidation of institutions. In the second half of the 1980s, about 50% of institutions operating in the market were dissolved (Sherman, 2009).

Beginning in 1984, consolidation processes in the financial sector began.¹⁰ According to Jones and Critchfield (2005), “at year-end 1984, there were 15,084 banking and thrift organisations.¹¹ By year-end 2003, that number had fallen to 7,841: a decrease of almost 48%”. Consolidation was mainly the result of mergers and acquisitions and of 2,698 bank failures and thrift closings during the period between 1984 and 2003 with 75% occurring between 1987 and 1991. In contrast, from 1994 to 2003 only 66 institutions failed. The decrease “was partially offset by the entry of 3097 new banking organisations between year-end 1984 and year-end 2003” (Jones and Critchfield, 2005). At the same

time, as the number of institutions in the market decreased, total assets in the industry increased from \$3.3 trillion in 1984 to \$9.1 trillion in 2003 (Jones and Critchfield, 2005). The distribution of assets, however, was not uniform. A characteristic feature of the U.S. financial sector was the high concentration of assets and deposits in major institutions.¹²

During the period of deregulation, a number of studies were published showing the effects of separation (White, 1986; Kroszner and Rajan, 1994). Concurrently, discussions began on the competitive position of U.S. banks in the global market. In most countries, no separation of activities had been introduced with Japan being a notable exception. For that reason, many U.S. banks began underwriting securities through their foreign branches. Maintaining such regulation in the context of the development and integration of financial markets was increasingly viewed as inappropriate.

In 1991, the Federal Deposit Insurance Corporation Improvement Act (FDICIA) was approved. In 1994, the Riegle–Neal Interstate Banking and Branching Efficiency Act was adopted, “which permitted banks and bank holding companies (BHCs) to purchase or open banks or establish subsidiary banks in any state nationwide” (Hanc, 2004). In 1995, the Supreme Court ruling in *NationsBank v. Valic* allowed banks to sell annuities. In 1996, the Court ruling in *Barnett Bank v. Nelson* overturned state restrictions on bank insurance sales (Hanc, 2004). Moreover, in the same year the Federal Reserve announced the elimination of many firewalls between bank and non-bank subsidiaries within BHCs (implemented one year later) and raised the limit on revenue from Section 20 eligible securities activities from 10% to 25% (Hanc, 2004).

In 1998, the most significant merger in the banking sector was announced between Travelers Insurance Group and Citicorp (Carow, 2001). The objective was to create Citigroup, Inc., a multinational investment banking and financial services corporation. The planned merger was controversial because it stood in contradiction to the Glass–Steagall Act that had been introduced after the Great Depression.¹³ The company’s consultations with A. Greenspan, Chairman of the Federal Reserve, R. Rubin, U.S. Secretary of the Treasury and even President B. Clinton, resulted in a one-year legal dispensation during which new rules for mergers were enacted. This major merger marked an important step towards fundamental change in the U.S. financial system. Indeed, in 1999 Congress adopted the Gramm–Leach–Bliley (GLB) Act,¹⁴ which “authorised financial holding companies (FHCs) to engage in a full range of financial services such as commercial banking, insurance, securities and merchant banking; gave the Federal Reserve, in consultation with the Treasury, discretion to authorise new financial activities for FHCs; gave the Federal Reserve discretion to authorise complementary activities for FHCs; established the Federal Reserve as the umbrella regulator of FHCs; provided low-cost credit to community banks; reformed the Community Reinvestment Act; and eliminated the ability of commercial firms to acquire or charter a single thrift in a unitary thrift holding company” (Hanc, 2004). The consequences of the Gramm–Leach–Bliley Act were profound and critical in the context of the future financial crisis as the legislation abolished restrictions on banking, securities and insurance operations, thereby exposing institutions to new risks. Moreover, the Act disrupted the division of responsibilities among individual regulatory agencies, thus reducing their overall effectiveness.

Institutions began using derivative instruments which, in addition to their role in hedging risk, increasingly came to be employed primarily for speculative purposes.¹⁵ In addition, “derivatives [did] not involve the actual transfer of assets, so a buyer often [did] not own the underlying asset” (Sherman, 2009). Among the most popular derivatives used prior to the crisis were Collateralised Debt Obligations (CDOs) and Credit Default Swaps (CDSs).¹⁶ At the end of the 1990s, B. Born, the Chairwoman of the Commodity Futures Trading Commission (CFTC), proposed regulating the OTC derivatives market. Her position was strongly opposed by B. Bernanke, R. Rubin and L. Summers. B. Born resigned and left the CFTC in mid-1999.¹⁷

At the turn of 1999 and 2000, Senator P. Gramm sought further deregulation and restrictions on CFTC and SEC oversight. In 2000, following the intervention of P. Gramm and L. Summers, the Commodity Futures Modernization Act (CFMA) was adopted without debate or amendment. It “exempted derivatives from regulation and made a special exemption for energy derivative trading that

would gain notoriety as the ‘Enron loophole’” (Sherman, 2009). The Act prevented the Commodity Futures Trading Commission from regulating most over-the-counter derivative contracts including credit default swaps.

In 2004, the SEC debated the regulation of investment banks. In the same year, the net capital rule was relaxed (U.S. SEC, 2004) and the Consolidated Supervised Entities (CSE) programme for investment banks was introduced. Moreover, brokerage firms were no longer required to submit mandatory reports on their business activities and assets. Instead, voluntary reporting was introduced and risk monitoring relied solely on internal company models. On 28 April 2004, the SEC convened to consider lifting the limits on leverage for investment banks.¹⁸

After the dot-com crisis and the 2008–2009 financial crisis, the effectiveness of separating commercial and investment activities in the context of universal banking in the United States was examined by researchers. Focarelli et al. (2011) analysed whether “commercial banks’ involvement in investment banking activities might have had an impact on the intensity of their underwriting standards”. The authors studied the activities of investment banks and the Section 20 subsidiaries of commercial banks prior to the implementation of the GLB Act in 1999 but after the relaxation of rules on the complete separation of commercial and investment institutions. Their objective was to determine whether commercial banks were more likely to underwrite riskier securities in order to gain market share and increase returns. Using a sample of 4,000 corporate debt securities, they examined default rates. The study shows that “securities underwritten by commercial banks’ subsidiaries have a higher probability of default than those underwritten by investment houses” (Focarelli et al., 2011). According to this research, the hypothesis cannot be rejected that the adoption of the GLB Act encouraged commercial banks to increase their market share while misjudging credit risk. A number of economists argue that the repeal of the Glass–Steagall Act in the 1990s strengthened conflicts of interest and provided incentives for banks to take excessive risks.¹⁹ In retrospect, it is difficult to assess whether these costs outweighed the gains from diversification. It is also important to note that the Glass–Steagall regulation itself did not prevent the creation of institutions that were too big to fail or too interconnected to fail as was illustrated in the CRS Report (Carpenter et al., 2016) by the example of J. P. Morgan & Co. After the introduction of the regulation, the J. P. Morgan & Co. conglomerate was forced to split its commercial and investment banking businesses.²⁰ However, the regulator did not impose limits on the size and scope of operations, nor did it regulate the links between these institutions with other market participants. As the CRS Report emphasised, “other potential sources of financial crisis include ‘irrational exuberance’ for a traditional bank product, capital flight in anticipation of a sharp currency devaluation and settlement failures for products used as collateral for securities trades. The Glass–Steagall Act was not designed to prevent these other sources of financial instability”.

2.1.1.2 The GSEs’ Activity Before the Subprime Crisis

In the United States, efforts have long been made to promote home ownership among low- and middle-income households. In 1932, the Federal Home Loan Bank Act²¹ was adopted to lower the cost of home ownership. Under this Act, the Federal Home Loan Bank System, a government-sponsored enterprise, was created to support mortgage lending, foster community investment and provide liquidity to member institutions (Gissler and Narajabad, 2017). One year later, the Home Owners’ Loan Act was passed, establishing the Home Owners’ Loan Corporation (HOLC) (Gilbert, 1986). The key role of HOLC was to refinance mortgages in order to slow the rate of foreclosures.²² In 1933, the Federal Home Loan Bank Board was established to oversee thrifts. In 1934, the Bureau of Federal Credit Unions was created.²³ In the same year, the National Housing Act was enacted and the Federal Housing Administration (FHA) was established. From that point on, mortgages issued by FHA-approved lenders were backed by the government.

In 1938, the Federal National Mortgage Association (FNMA), commonly known as Fannie Mae, was established (FHFA OIG, 2017). Fannie Mae was created as a government-sponsored enterprise

(GSE) with the primary purpose of increasing the availability of credit without requiring borrowers to apply through thrifts (DiVenti, 2009). In 1954, under the Federal National Mortgage Association Charter Act, Fannie Mae was transformed from a government agency into a mixed public-private ownership corporation.²⁴

In 1968, the Housing and Urban Development (HUD) Act was enacted. Under its provisions, the Government National Mortgage Association (Ginnie Mae) was established to promote home ownership. In the same year, Fannie Mae also shifted its business activity towards a greater share of mortgages for middle- and low-income families (Bartlett, 1969). In 1970, the Emergency Home Finance Act was adopted, leading to the creation of the Federal Home Loan Mortgage Corporation (Freddie Mac) to expand the secondary market for mortgages and sell them as mortgage-backed securities (Bartke, 1972). Fannie Mae and Freddie Mac pursued different business strategies during the 1970s and 1980s (HUD, 1996; DiVenti, 2009). In the case of Freddie Mac, the purchase of mortgages was primarily intended to issue mortgage backed securities (MBS),²⁵ whereas Fannie Mae retained loans in its portfolio. This difference in strategy was crucial during the crisis of the 1970s amid prevailing inflationary pressures. The greater effectiveness of Freddie Mac's strategy influenced the fact that MBS came to play an increasingly important role in U.S. economic history and, later, in the financial crisis.

Although the creation of Fannie Mae and Freddie Mac was meant to enable low- and moderate-income households to own property and was consistent with the Community Reinvestment Act of 1977 (CRA), little attention was paid to the potential systemic losses associated with the problem of moral hazard (Avery et al., 2003; Hillier, 2003; Haltom, 2011). When President G. H. Bush was elected, greater emphasis was placed on enabling low- and middle-income households to own property. In 1992, the Housing and Community Development Act (the 1992 Act) was passed, which expanded the role of the GSEs and introduced percentage targets for the availability of properties for low- and middle-income households.²⁶ The new legislation also altered the goals for the total number of dwelling units financed through mortgage purchases (FHFA OIG, 2017). In 1999, Fannie Mae further increased its lending to areas covered by the Community Reinvestment Act of 1977. Raising these targets generated more systemic risk than initially estimated, particularly given the growing role of securitisation and errors in risk assessment associated with it.

A number of regulations were introduced in the 2000s to curb negative practices in the mortgage market but most of them were relaxed or completely abolished by 2004. Gradually, the proportion of loans granted to households with low creditworthiness increased relative to other households. During this period, banks specialised in providing household mortgages guaranteed by the GSEs, often without verifying creditworthiness and sometimes using negative amortisation²⁷ or other predatory practices.²⁸ As a result, the share of subprime loans in total lending increased. Under favourable conditions, the *perceived* risk seemed relatively low. However, between 2004 and 2006, the proportion of subprime loans rose sharply (Mayer and Pence, 2008).

The low interest rate policy in the period preceding the crisis encouraged the development of credit refinancing mechanisms. When the trend reversed – with rising interest rates and falling property prices – many households were unable to refinance their loans. As a consequence, mortgage delinquencies increased. At the same time, demand for mortgage-backed securities decreased, thus placing many financial institutions in a difficult position.²⁹

In 2003, President G. W. Bush called for an in-depth audit of Fannie Mae and Freddie Mac. In the same year, the Office of Federal Housing Enterprise Oversight (OFHEO) published a report that revealed accounting discrepancies within both entities (OFHEO, 2004). To illustrate the scale of the problem, one can cite Citigroup's performance in the period 2006–2008, as described by Richard M. Bowen III, Business Chief Underwriter for Correspondent Lending in the Consumer Lending Group at Citigroup, in his testimony before the Financial Crisis Inquiry Commission (Bowen III, 2010). In 2006, as many as 60% of mortgages purchased by Citi from around 1,600 mortgage companies were defective in the sense that they were poorly documented and did not meet regulatory requirements. By 2008, this share had risen to 80% (Bowen III, 2010).

In 2005, inaccuracies were detected in the activities of the GSEs and the legitimacy of their operations was questioned.³⁰ Proposed reforms such as the Federal Housing Enterprise Regulatory Reform Act³¹ and the Federal Housing Finance Reform Act of 2005 ultimately failed and were never adopted.³² In the mid-2000s, interest in MBS among unregulated investment banks increased, which resulted in weaker underwriting standards. In addition, investment banks insured these instruments through credit default swaps, which further obscured market participants' ability to assess risk exposures.

In July 2008, the U.S. Treasury Department and the Federal Reserve sought to reassure public opinion that the role of the GSEs in the market would not change. At the same time, they provided access to the Federal Reserve's low-interest loans and removed the prohibition on the Treasury Department purchasing GSE stock. These measures not only failed to calm market sentiment but also heightened concerns about the condition of the GSEs, the stability of financial markets and the prospect of bailouts. Moreover, they could not counteract the unfolding financial crisis, which had its roots in the real estate market and subprime lending (Swagel, 2009).

In principle, the Glass–Steagall Act did not prohibit commercial banks from holding mortgages in the form of MBS. In particular, it did not forbid securities backed by Fannie Mae or Freddie Mac. However, the Act did restrict the holding of riskier private-label mortgage-backed securities. This restriction functioned more as a prudential norm than as a direct consequence of the separation of investment and commercial banking and in fact could have persisted in the regulatory framework even after the repeal of the Glass–Steagall Act in 1999. The GSLA did not influence underwriting standards by creating incentives for originators but it did address conflicts of interest and restrained aggressive behaviour by commercial banks seeking to expand market share. The Act also lacked provisions concerning maturity mismatches and sudden decreases in collateral values. As a result, while the GSLA might have partially mitigated the severity of the crisis, it probably would not have prevented it.

Geithner (2014) observed that “[s]ome critics (...) saw the core problem as the gradual rollback and Clinton-era repeal of the Depression-era Glass–Steagall limits on bank activities, which allowed commercial banks with insured deposits to get involved in investment banking. But most of the firms at the centre of the crisis – Bear, Lehman, AIG, Merrill, Fannie, Freddie – were basically unaffected by the repeal of Glass–Steagall (...). And traditional banking – making loans, especially real estate loans – also ended up being quite risky. WaMu, Wachovia, IndyMac and hundreds of smaller institutions that blew up during the crisis were basically overextended banks and thrifts and not the far-flung financial conglomerates that were made possible by the disappearance of the Glass–Steagall partition”. Geithner further emphasised that the business activities of Citi and Bank of America might have been less risky and systemic risk consequently lower. Nonetheless, “the most damaging failures happened to firms operating on just one side of the divide” (Geithner, 2014).

The post-crisis debate on whether the Dodd–Frank Act should include measures similar to the provisions of the Glass–Steagall Act did not result in the adoption of such provisions in 2010. Instead, the discussion focused on limiting the speculative use of funds and restricting proprietary trading by depository institutions, affiliates, subsidiaries and brokers through the Volcker Rule. In the Glass–Steagall sense, the Volcker Rule restricted banking institutions from investing in or cooperating with, hedge funds and funds that were not registered with the SEC or the The Commodity Futures Trading Commission (CFTC). In addition, the Act addressed issues of mortgage underwriting origination and securitisation standards for mortgage-related products. The Dodd–Frank Act of 2010 also preserved Sections 16 and 21 of the Glass–Steagall Act, thereby continuing to limit certain bank investment activities (U.S. Congress, 2010a).

2.1.1.3 Evaluation of the Impact of Deregulation and Affordable Housing Policies on Systemic Risk

It is not easy to determine whether the financial crisis was a direct consequence of the deregulation policy in the United States since the 1980s. While deregulation could have played a contributing role

in the crisis, yet it evolved over many years in response to changes in market structure, competition and the globalisation of finance. Simply preserving the *status quo* under these new conditions would not have yielded favourable outcomes for the U.S. economy or its financial system. The Financial Crisis Inquiry Commission concluded that there was no clear causal relationship between deregulation and the crisis (GPO-FCIC, 2011). By contrast, experts at the American Enterprise Institute (AEI) identified a link between the crisis and the affordable housing policies of the U.S. Department of Housing and Urban Development in the 1990s (Pinto, 2011; Wallison and Pinto, 2012; Wallison, 2017). This interpretation has been contested. Critics argue that affordable housing policies played at most a marginal role, pointing instead to private-label securitisation, predatory lending and weak regulation as the main drivers of the crisis (Immergluck, 2009). Opinions remain ambivalent. Gattuso (2008) observed that many people who suffered from the financial crisis blamed President G. W. Bush's Republican administration (Morgan and Davies, 2010; Baker, 2015),³³ however, others dismissed many of the arguments supporting these claims (Pethokoukis, 2012).³⁴ While the regulation was far from perfect, it provided at least a legal framework for using CDSs (Gattuso, 2008). On the other hand, it is difficult to overlook the fact that deregulation was the main factor that increased the risks borne by all market participants—depositories, consumers and financial institutions alike—and that it also generated problems of adverse selection and moral hazard. Entities were increasingly willing to take on greater risks and to make decisions that imposed costs on other market participants, i.e. generating externalities. Banks extended loans at higher interest rates to households with weaker credit ratings. It was precisely these lower-creditworthiness households that accepted unfavourable credit conditions and higher interest rates, counting on the possibility of refinancing their loans almost indefinitely (Shiller, 2007). The entire system was further underpinned by questionable government guarantees for the activities of the GSEs. Market failures were not corrected by appropriate regulation, yet it is worth noting that excessive regulation could also have impaired the system. At the heart of the crisis were not only the decisions made on Wall Street but above all of the decisions of households that became indebted to levels far beyond their incomes, often signing contracts they did not fully understand. Banks exploited this vulnerability by extending such contracts. The introduction of certain consumer protection measures, which were later incorporated into the Dodd–Frank Act, could have limited these practices. Nonetheless, it is difficult to prove a direct causal link between deregulation processes and the misconduct of banks and financial institutions. According to the AEI Report, deregulation was not itself a direct cause of the crisis. The immediate trigger was the widespread granting of subprime loans, which accounted for around 25 million mortgages (approximately 50% of all mortgages). The wave of insolvencies in this market led to the collapse of the asset-backed securities market in 2007 and subsequently to the failure of Lehman Brothers in 2008 (Wallison, 2009). Despite these arguments, P. Krugman repeatedly stressed that it was Reagan's policies that led to “two massive financial disasters during the last quarter of a century”, namely the crisis of the 1980s and the crisis of 2008 (Bunch, 2010). According to Krugman (2009), the lowering of lending standards was directly linked to the deregulation process initiated in the United States during the 1980s. P. Krugman (2011) also explored the issue of causality between inequality and crises in a presentation for the Luxembourg Income Study (Krugman, 2011), asking whether inequality itself creates macroeconomic vulnerability. Krugman connected inequality to the crisis but above all pointed to political shifts as drivers of inequality and to deregulation policies as contributors to the crisis. He began his research by analysing the idea of underconsumption. According to this hypothesis, the economy was unable to produce what was demanded by middle-class consumers. Krugman, however, presented empirical data indicating that the problem was not underconsumption but rather overconsumption. According to Krugman's hypothesis, the higher expenditure of the wealthy also encouraged greater spending by the middle class. To maintain a level of consumption that was disproportionate to their incomes, middle-class households became increasingly indebted, which in turn heightened their financial fragility. The deregulation of banking activities meant that households willing to borrow were increasingly targeted by financial institutions offering loans, even when these households had very low creditworthiness. In the next section, we

turn to other causes of the crisis focusing in particular on macroeconomic determinants and the expansionary monetary policy pursued in the years preceding the outbreak.

2.1.2 *The Macroeconomic Causes of the U.S. Crisis and Policy Responses*

During the crisis, Palley (2009) published a study entitled *America's Exhausted Paradigm: Macroeconomic Causes of the Financial Crisis and Great Recession*.³⁵ Palley argued that although “financial deregulation and financial excess are important parts of the story”, they are not the whole story. He situated the roots of the crisis in the neo-liberal model of economic growth, which depended on a continuous rise in debt and asset prices to sustain high growth rates. Ultimately, this model produced critically unsustainable levels of debt and severe inequality. Palley emphasised that while most studies concentrate on market failures in the housing and credit markets, the deeper cause of the crisis lay in the adoption of a specific model of economic growth. This model not only supported the creation of the housing bubble but also fostered the very conditions that generated market failures. In the 1980s a more sustainable model of economic growth was rejected, largely because of the experience with rising inflation in the 1970s and early 1980s. From that time onwards, U.S. economic policy sought to maintain growth through increased borrowing and asset price inflation. The growth model that emerged was characterised by the rising importance of the financial sector and reliance on cheap imports from developing countries. At the same time, the indebtedness of households and firms steadily increased and income inequality widened as a consequence of the adopted model (Palley, 2012).

Palley (2009, 2012) also linked these developments to structural changes in manufacturing employment. According to his data, between 1980 and 1990 manufacturing employment grew during expansionary phases of the cycle but never recovered to its pre-1980 levels. From 1991 until the onset of the crisis, manufacturing employment decreased even during expansions. This decrease is often attributed to a general increase in productivity. However, overall productivity growth during this period was actually lower than in earlier decades (Sprague, 2017; Blecker, 1996). Instead, much of the contraction in manufacturing employment can be explained by offshoring and cheap imports.

In line with the growth strategy adopted in the 1980s, the persistence of a chronic deficit was not necessarily perceived negatively but rather as an optimal choice by economic agents. However, the U.S. current account deficit expanded year after year, widening the gap with Asian economies and creating global imbalances on an unprecedented scale (Bernanke, 2005, 2007). Data on the current account deficit illustrate the magnitude of the problem: foreign imbalances rose most sharply during the 1990s and 2000s.³⁶ Internal imbalances, in turn, were reflected in the decoupling of wages from productivity growth. Economic policy played an active role in shaping this growth model and in deepening both internal and global imbalances. The main components of U.S. economic policy included measures to increase labour market flexibility, reliance on market self-regulation and the pursuit of employment levels below full employment.³⁷ These policies were reinforced by globalisation and by adherence to the principles of the Washington Consensus, which promoted free trade, capital mobility and the use of cheap labour (Palley, 2012).

The shift in the underlying assumptions also affected perceptions of the role of monetary policy. Given that the economy increasingly relied on asset price inflation, it is striking that, during this period, the interaction between monetary policy and policies aimed at ensuring financial stability was so poorly understood. In most cases, the idea of “leaning against the wind” was also rejected. Since the 1980s, expansionary phases of the U.S. economy have been marked by rising indebtedness and increasing asset prices. During these periods, the debt service-to-income (DSTI) ratio rose sharply, despite a significant decrease in interest rates. Palley presented data showing that the DSTI ratio rose from 0.9% in 1980 to 14.3% in 2007. He also emphasised the systemic role of house-price inflation. To support his thesis, he presented data on average home price inflation (%), average CPI inflation (%) and excess house-price inflation (%) during three periods of expansion: the “Reagan expansion”, the “Clinton expansion” and the “Bush–Cheney expansion”. Data presented by Palley (2009) show

that house price inflation significantly outpaced consumer price inflation in several periods prior to the financial crisis. While in 1987–1990 house prices were rising moderately faster than general prices, the period 2001–2006 was marked by a pronounced divergence: average home price inflation reached almost 11%, compared to just 2.5% CPI inflation. This indicates a rapid accumulation of excess house price inflation in the early 2000s, signalling the emergence of a housing bubble. The increase in debt is closely linked to the rise in asset prices as these assets serve as collateral for loans. This dynamic is particularly dangerous because a fall in asset prices creates the need to provide additional collateral. When borrowers are unable to do so and speculative bubbles burst alongside declining incomes the number of insolvencies in the economy rises ultimately leading to crisis as was also discussed by Minsky (1986). The growth model that is based on increased consumption financed through rising indebtedness is unsustainable. Following a phase of rapid expansion and the formation of a speculative bubble, the inevitable burst has adverse effects not only on the U.S. economy but also on the global economy (Reinhart and Rogoff, 2008).

The dependence of the American economy on cheap imported goods was largely shaped by the country's economic policy including trade and exchange rate policies. In 1994, a special free trade agreement was signed between the United States, Canada and Mexico (NAFTA). The strong dollar and the relocation of production abroad made it possible to obtain higher margins when selling final goods in the United States. As Palley noted, after the peso crisis of 1994, it remained cheaper to produce goods in Mexico and then import them into the United States. Such a change in market conditions led to a reorganisation of the economic systems of the Member States but also to significant job losses in the United States – a development that was the subject of heated debate among economists (Blecker, 1996, 1997).³⁸ After the Asian crisis of 1997, followed by the crises in Russia (1999) and in Turkey, Argentina and Brazil (2000), a policy response similar to that adopted after the Mexican crisis was applied. At the same time, these economies became increasingly dependent on American loans, which over time deepened global imbalances (Radelet and Sachs, 1998; Eichengreen, 2002). While the accumulation of surpluses by developing countries may bring them tangible short-term benefits, global imbalances are not beneficial to any party in the medium and long term. Following the emergence of the financial crisis, imports of goods from developing countries decreased, leading to production cuts and widespread job losses in those economies. Another negative consequence of the U.S. deficit was the accumulation of Treasury bills, particularly by China, which later became a powerful bargaining chip in negotiations with the United States (Dooley et al., 2003; Prasad, 2009).

The pursuit of an active trade- and exchange-oriented policy that was focused on imports reshaped the production model in the United States. The negative effects of this policy were not visible during the expansionary phase but became particularly acute during the downturn. In principle, economic growth in the expansionary phase was driven by increased consumption financed through borrowing and by rising asset prices, which were paradoxically justified by alleged productivity gains linked to the development of modern technologies in the late 1990s and prior to the dot-com crisis (Palley, 2009).

Perelstein (2009), in the article *Macroeconomic Imbalances in the United States and Their Impact on the International Financial System*, analysed how current account imbalances and financial instability are transmitted to other countries. As the author notes, the academic debate is divided between the monetarist and sceptical approaches. Nonetheless, both perspectives concentrate on whether current account imbalances are sustainable given the domestic conditions of the U.S. economy. The main shortcoming of such analyses is that they often omit or insufficiently account for, the global integration of capital markets. As Perelstein (2009) points out, “there is a global financial dependence on the U.S. in addition to its political dominance; and that the U.S. macroeconomic imbalances cannot be resolved without affecting the rest of the world whose financial systems are dependent on dollars supplied by the U.S. through its current account deficit”.

Perelstein (2009) analysed two main approaches to external imbalances. According to the core approach, which is mainly rooted in monetarism, maintaining a current account imbalance does not

necessarily pose a problem for a national economy (Mann, 2002). Proponents of this view argue that the U.S. dollar is of a fundamentally different nature than other currencies, which implies that the deficit should not be perceived as a negative phenomenon. From this perspective, imbalances are expected to be corrected over the long term by the internal forces of the global economy. On the other hand, representatives of the heterodox approaches argue that the U.S. current account deficit is unsustainable and that maintaining it over a longer period will have serious consequences for the global economic and financial system (Edwards, 2005; Perelstein, 2009). Although prior to the crisis, this view was supported mainly by heterodox economists, with only a few exceptions among the mainstream, the crisis itself gave this approach greater credibility. From within the mainstream, Obstfeld and Rogoff (2004) warned about unsustainable deficits, noting: “with the United States today absorbing roughly 70 % of the current account surpluses of China, Japan, Germany and of all the world’s other surplus countries, the increasingly popular view that the current situation is sustainable seems unlikely. This is all the more true when one considers that government deficits rather than high investment now account for the lion’s share of the U.S. current account deficit”. Before the crisis, Krugman (2007) highlighted the system’s intrinsic instability, while Summers (2004) pointed out that “the willingness of investors to accept claims on the U.S. might not last forever”.

Somewhere between the two extreme approaches to current account imbalances lies the view of Bernanke (2005). He argued that such imbalances may prove unsustainable in the long run but result not only from domestic factors in the United States but above all from excess savings in Asian countries, which must be offset by a deficit in the United States. According to this perspective, the problem of external imbalances can only be resolved by addressing the challenges faced by developing countries. Global imbalances are further aggravated by the fact that the majority of foreign exchange reserves are held by Asian economies – 59% of world reserves, of which 22% belonged to China (Lim, 2006). This accumulation reflects both the legacy of the Asian financial crisis and the precautionary policy of reserve accumulation aimed at preventing similar crises in the future. Bernanke (2005) noted that the persistent U.S. current account deficit has been linked to a decrease in savings since the second half of the 1990s, while the investment rate during this period remained largely unchanged. In the United States, the problem of twin deficits can be observed although between 1987 and 2001 there was a divergence between the budget deficit and the current account deficit (Cavallo, 2005). Unlike in the EU, where fiscal deficits are constrained by formal rules, in the United States there were no such restrictions. Moreover, both public and external deficits contributed to the expansion of credit, which later played a role in the emergence of the crisis.

According to Perelstein (2009), “the transmission of the U.S. trade deficit to the financial markets goes through the payment mechanism for the U.S. excess export that is paid for by crediting foreign exporters with dollar balances in U.S. bank account”. The author described the vicious circle linking the United States and the global economy. Excessive consumption in the United States also drove a higher demand for foreign products and, consequently, imports. Buyers settled these transactions with “dollar balances that are used to buy bonds issued by the U.S. government to finance their budget deficit. In this way the budget deficit is used to finance the U.S. current account deficit and bring an unbalanced economy into temporary equilibrium”. The problem arises when the asset bubble bursts, creating disruptions not only in the U.S. economy but also in all countries dependent on dollar outflows (Perelstein, 2009).

Between 1997 and 2000, the use of new technologies and speculation in the securities of modern technology companies increased dynamically. In 2000–2002, the dot-com bubble collapsed and the value of most technology companies’ shares fell sharply. In addition to the low interest rates since 1998 and the Taxpayer Relief Act of 1997, Greenspan’s promotion of investment further encouraged investors to enter the stock market (Batra, 2005). Since the early 2000s, the number of CDS transactions increased from an outstanding nominal value of \$106 trillion in 2001 to \$531 trillion in 2008. This growth resulted from technological developments, further deregulation and increasing confidence in self-regulation of risk (Sherman, 2009; Dobos et al., 2011). After the bursting

of the dot-com bubble, which was undoubtedly the result of speculative activity by investment banks, the U.S. economy slowed significantly. The recession deepened further after the terrorist attack of September 11, 2001. Following the attack, the stock market collapsed and the NYSE suspended trading for four sessions (Kennard and Hanne, 2015). Companies listed on the stock market lost about \$5 trillion in market value between March 2000 and October 2002. Only about half of technology companies survived the dot-com crisis. In response to the economic and financial downturn, A. Greenspan decided to lower interest rates even further (Labonte and Makinen, 2008; Blinder, 2014; Belongia and Ireland, 2016).³⁹ Some experts argue whether the prolonged low interest rate policy contributed to the formation of a bubble in the U.S. housing market. The lower cost of financing households and firms primarily increased housing purchases and household consumption, partly domestic and partly from imports, as was already mentioned. However, it is worth remembering that the objectives of the Federal Reserve at that time were to reduce inflation and support economic growth. The policy pursued during this period helped to achieve these goals. After the crisis, a debate emerged on whether monetary policy should also explicitly aim at mitigating excessive increases in asset prices.⁴⁰ In mid-2004, the Federal Reserve began raising interest rates, thus aggravating the situation of indebted households by tightening repayment conditions. Because the preceding period of low interest rates had been marked by refinancing activity and the granting of loans to subprime applicants, the first signs of the subprime crisis appeared between 2005 and 2007.

2.1.3 The Build-Up of Systemic Risk Before the U.S. Financial Crisis

In the post-dot-com crash period, consolidation in the U.S. financial sector intensified. The market came to be dominated by the five major investment banks – Goldman Sachs, Morgan Stanley, Lehman Brothers, Merrill Lynch and Bear Stearns, two large financial conglomerates – JP Morgan and Citigroup, three insurance companies – AIG, MBIA and AMBAC, as well as the three key credit rating agencies – Moody's, Standard & Poor's and Fitch (Jones and Critchfield, 2005; Wheelock, 2011; Kozak, 2013). All of these institutions were extremely interconnected through securitisation. Moreover, from the early 2000s, they expanded their activities by undertaking increasingly risky decisions and investments. In 2003, the Federal Reserve issued revisions to Regulation K. These regulatory changes facilitated operations outside of the United States and reduced requirements for foreign banks operating domestically. From that point on, it became possible to invest up to 20% of capital and surplus in edge corporations⁴¹ (Johnson, Jr. and McLaughlin, 2013). In addition, eligibility requirements for foreign exemptions from the non-banking prohibitions of Section 4 of the Bank Holding Company Act were also liberalised.

In addition to the growth of derivative trading and higher leverage, key market players sought profits through financial innovations. AIG began selling CDS on an ever-increasing scale. For investors holding CDOs, CDS contracts acted as a form of insurance: the CDS buyer paid AIG a quarterly premium and in the event of a decrease in the CDO's value, the insurance company covered the investor's loss. Unlike ordinary insurance, however, speculators could purchase swaps for derivatives they did not own and the same derivatives could be insured multiple times. CDS turnover was unregulated. AIG was not required to hold reserves to cover potential losses; in practice, it not only failed to maintain such reserves but also paid substantial employee bonuses (totalling \$3.5 trillion). When CDS values fell, AIG faced severe difficulties.⁴²

In 2006, Goldman Sachs went a step further. Rather than selling toxic derivatives, the bank downplayed their risks while promoting them as high-quality investments. By purchasing CDS swaps from AIG, Goldman was able to bet against CDO instruments it did not even own, thereby profiting from a decrease in their prices. Similar strategies were followed by Paulson & Co., Morgan Stanley, Tricadia and Magnetar, all of which threatened the stability of the financial system.

One should bear in mind that prior to the crisis, the U.S. financial system exhibited many of the problems that microprudential and macroprudential regulation seeks to address. Firstly, there were failures of information, rationality and principal–agent relationships. Asymmetric information

between originators, arrangers, investors and insurers meant that risks that were embedded in complex financial products were systematically underestimated. Rating agencies, which were paid by the very institutions whose products they rated, faced clear conflicts of interest and routinely assigned investment-grade ratings to securities that were backed by subprime mortgages. Weak incentives within banks further exacerbated problems: remuneration structures were closely tied to short-term profits, thus encouraging excessive risk-taking and the distribution rather than retention of credit risk through securitisation. The originate-to-distribute model undermined loan quality as originators had little incentive to properly assess borrowers' creditworthiness, which shifted the risk downstream to unwitting investors.

Secondly, there was no macroprudential supervision in place to limit vulnerabilities, contain triggers or mitigate the transmission and impact of systemic shocks. Regulatory oversight remained fragmented across multiple agencies with overlapping mandates, none of which had responsibility for monitoring system-wide leverage, cross-exposures or liquidity mismatches. Risk accumulated silently in the shadow banking system, where investment banks, hedge funds and structured investment vehicles operated outside the perimeter of traditional regulation. Interconnectedness through derivatives markets and repo financing created dense channels for contagion, meaning that the failure of a single institution could quickly propagate throughout the system. In this environment, rising leverage, weak underwriting standards and excessive maturity transformation generated systemic fragilities that remained largely invisible to supervisors until the crisis erupted. Moreover, the expectation of public support for large, interconnected institutions – reinforced by previous government interventions – generated moral hazard and encouraged the growth of firms that were considered to be “too big to fail”, which further amplified systemic risk.

2.2 Financial Crisis Management and Reforms in the United States

Previously, we discussed the causes of the financial crisis in the United States. In this subsection, we will enumerate the phases of the financial crisis from the American perspective and comment on the most important policy and regulatory responses in the United States. Analyses of the policies and regulations adopted after the crisis enable us to understand which measures affected the European regulatory framework and which measures adopted in the EU countries were country-specific or inspired by U.S. solutions. The post-crisis global financial systems were deeply affected by the adoption of the Dodd–Frank Act of 2010 (U.S. Congress, 2010a). For that reason, we dedicate a separate section to the evaluation of this Act. The measures recommended in the de Larosi re Report in the EU were strongly influenced by the provisions of the Dodd–Frank Act even though the causes and the course of the crisis differed between the United States and EU countries (Larosi re Report, 2009).

2.2.1 The Phases of the U.S. Financial Crisis

The course of the financial crisis in the United States can be divided into four main phases, separated by key dates in the history of the crisis.⁴³

On 9 August 2007, BNP Paribas announced the suspension of operations by three hedge funds specialising in U.S. mortgage debt. As a result of falling real estate prices, the rise in defaults on the property market and the decrease in demand for mortgage-backed securities, major financial institutions began to record losses. In total, at the beginning of 2007, financial institutions wrote down their holdings of subprime mortgage securities by \$10.5 billion (Rosefielde and Mills, 2013). The initial problems of Bear Stearns, Merrill Lynch, Goldman Sachs, Morgan Stanley, Lehman Brothers and Citigroup were primarily liquidity problems, which in the case of Bear Stearns (Hallaron, 2009; Ryback, 2011) and Lehman Brothers developed into insolvency issues (Larcker and Tayan, 2010;

McNamara and Metrick, 2019; Wiggins et al., 2019). The collapse of Lehman Brothers on 15 September 2008 is widely recognised as the beginning of the crisis.

Lehman Brothers failed after the refusal of the U.S. government to provide support. Its collapse fundamentally altered the perception of market rules. Until September 2008, it was widely assumed that the government would step into rescue any endangered institution as had previously been the case with Bear Stearns. From that moment onwards, the market began to reassess the risks posed by too-big-to-fail institutions and to consider the role of contagion and domino effects more seriously. The rise in uncertainty deepened the problem of distrust among market participants. The banking market froze, counterparty risk became central and mutual transactions stalled. After the collapse of Lehman Brothers, the interbank market was paralysed and around \$170 billion was withdrawn from U.S. money market funds within a week (Afonso et al., 2011).⁴⁴

After the outbreak of the financial crisis, particularly the turbulence related to the case of Lehman Brothers, the Federal Reserve decided to cut interest rates. The first steps in international cooperation within the G20 group were also undertaken. After the collapse of Lehman Brothers, financial institutions⁴⁵ were in a difficult position not only because of their mutual obligations to failed institutions but also because of their holdings of MBSs and CDSs in their portfolios. As a result of the heightened uncertainty in the market, a wave of securities sales took place at discounted prices (*margin calls*). The problems of subsidiaries further worsened the situation of parent institutions, which were required to provide them with funds. In addition, institutions undertook further activities in search of profit, increasing the risks not only to their own operations but also to financial stability. During the crisis, investment institutions such as Goldman Sachs and Morgan Stanley had to receive support in the form of access to Federal Reserve credit lines, while the GSEs – Fannie Mae and Freddie Mac – were taken over by the federal government. The largest insurer, AIG, received public financial support (a bailout) amounting to over \$100 billion (Webel and Labonte, 2010; Davidoff Solomon and Zaring, 2015; Rasmussen and Skeel Jr., 2017). The crisis of financial institutions reached its peak in September and October 2008. The next stage of the financial crisis was marked by the reforms initiated at the London G20 summit on 2 April 2009 (Bradford and Linn, 2010). Following the measures that had been adopted in the United States in 2009, the end of the recession was declared in that country. However, this did not mark the end of the *global* crisis.

On 9 May 2010, the International Monetary Fund (IMF), the European Commission (EC) and the European Central Bank (ECB) – the so-called Troika – provided financial assistance to Greece (IMF, 2010). During this period, the nature of the crisis and the type of uncertainty associated with it also changed. Concerns about the government's potential solvency were added to the problems of the banking crisis and the uncertainty surrounding the state of the European banking system and the future of the Euro Area.⁴⁶ After 9 May 2010, the debt crisis emerged, which will be discussed in more detail in the next chapter on the development of the crisis in the EU countries. Although this stage of the crisis is generally described as the debt crisis of the EU peripheral countries, in the United States it was also a period of heightened uncertainty. In May 2010, it was announced for the first time that the rating of U.S. debt had been downgraded. The downgrade also contributed to sharp decreases in the stock market, which further unnerved investors and distorted their market strategies.

A final symbolic date often cited in the press is 5 August 2011, which is described as “the day when U.S. hegemony was lost”.⁴⁷ On that day, it was recognised that the Chinese economy was overtaking that of the United States. Press commentaries also referred to China's special strategy, which was linked to maintaining its current account surplus and holding foreign exchange reserves in dollars as was previously discussed.

2.2.2 *Systemic Risk in the Course of the Financial Crisis in the United States*

According to the aforementioned explanation by B. Bernanke, “with more than \$1 trillion in mortgages outstanding, the potential for losses on these loans was large in absolute terms; however, judged in relation to the size of global financial markets, prospective subprime losses were clearly

not large enough on their own to account for the magnitude of the crisis”. Therefore, why the course and the effects of the crisis were so severe remains an open question. Previously, we analysed several factors that influenced the structure of the financial system and made it more vulnerable. In particular, we discussed the processes of deregulation and the affordable housing policies in the United States and we also highlighted the Federal Reserve’s low interest rate policy, which facilitated the formation of a bubble in the real estate market and fostered an unsustainable growth model of the U.S. economy. In this sub-chapter, we review how systemic risk evolved during the crisis, what factors amplified external shocks to the system, which mechanisms transmitted these shocks and what kinds of externalities, spillover and feedback effects emerged. In particular, the analysis focuses on two dimensions of systemic risk – spatial and temporal – and the related problems of contagion and procyclicality.

Bullard et al. (2009) began a discussion of systemic risk by explaining how information asymmetry affects counterparty risk. Due to the existence of asymmetric information, institutions may bear far greater risk than is apparent.⁴⁸ Under conditions of low interconnectedness, the insolvency of one contract would bring losses only to the direct counterparty. However, increasing financial innovation and securitisation not only intensified the links between institutions but also blurred the relationship between the “risk seller” and the “risk buyer”. The simple insurance mechanisms against excessive counterparty risk also proved to be unreliable under the conditions of securitisation as was demonstrated by the case of AIG’s use of CDSs in the United States. Experts from the Federal Reserve Bank of St. Louis further highlighted a second mechanism in the market – the existence of information cascades. Information asymmetry means that only one side of a transaction can be fully informed about its actual conditions. When new information is revealed to certain entities, they adjust their decisions, which are then closely followed by other market participants. In many cases, markets act as carriers of real information about the quality of financial instruments; however, this is not always the case. In some instances, uncertainty itself generates real systemic risks. The generation of systemic risk in the United States was not only related to real transaction links between the entities in the market but also resulted from the flow of information and decision-making under conditions of asymmetric information. At the same time, the disclosure of information about the position of a particular bank could trigger mass withdrawals of funds, thereby amplifying its initial problems and affecting the entire financial system. The perception of risk in the United States was also strongly shaped by the activities of the credit rating agencies. A downgrade of a given instrument acted as a catalyst for negative changes in the subsequent phases of the crisis, thus highlighting the problem of information transfer and risk perception in the system. Within the American financial framework, a downgrade was synonymous with the obligation to provide additional collateral, which was particularly difficult during the crisis. The issue of falling asset prices serving as collateral was analysed by Brunnermeier and Pedersen (2009). In this sense, the rating agencies were able to shape real market dynamics both before and during the crisis.

However, informational frictions alone cannot fully explain the scale of systemic instability during the crisis. Alongside these mechanisms, structural vulnerabilities that were embedded in the architecture of the US financial system played a crucial role. In particular, the high degree of interconnectedness and opaque bilateral exposures significantly amplified the transmission of shocks across institutions.

In fact, one of the main reasons for systemic risk in the United States was the high degree of interconnectedness and the lack of regulation of the over-the-counter (OTC) derivatives market (Leduc et al., 2017). Before the crisis, there were essentially no regulations governing this market and transactions were conducted through bilateral negotiations between parties that were not required to report them to the regulator. This led to a significant lack of transparency. Another factor that contributed to systemic risk in the United States was the very high level of financial leverage, which meant that the majority of funds were obtained through debt issuance. The ratio of external debt to equity was substantial and during the crisis, it reached extreme levels of around 33%. At such levels of leverage, losses of just 3% were sufficient to bankrupt an institution. Given that such practices

were common across the United States, the scale and severity of the problem were considerable. The Government-Sponsored Enterprises GSEs, Fannie Mae and Freddie Mac, which in principle were meant to guarantee secure mortgages for middle-income American families, operated with very high levels of leverage.

In addition to leverage and opacity in the derivatives markets, systemic instability was exacerbated by liquidity and maturity mismatches, which further increased institutional vulnerability to negative external shocks (Leduc et al., 2017). Brunnermeier and Pedersen (2009) analysed the liquidity and credit crunch of 2007–2008 and identified four economic mechanisms through which the mortgage crisis amplified into a severe financial crisis: borrower's balance sheet effects, lending channel, runs on financial institutions and network effects. The first mechanism occurs when the value of assets falls more quickly than gross worth increases, which means that an investor can borrow less on the markets. Assuming leverage remains constant, an investor is forced to sell an asset at an undervalued price. If a larger number of investors behave in a similar manner, asset values can decrease significantly in a short period of time. In extreme cases, some institutions may adopt strategies that force other investors to liquidate their positions at fire-sale prices (Brunnermeier and Pedersen, 2005, 2009). An additional mechanism further strengthened the effects of the first spiral. In this regard, the authors pointed out that this creates a vicious cycle: higher haircuts lead to de-leveraging and sales, which in turn entail higher margins and subsequent sales. Adrian and Shin (2010) confirmed the existence of such mechanisms empirically in the case of investment banks. The second type of mechanism operates through the lending channel. In the event of liquidity constraints in the market, lenders restrict the supply of credit and tighten lending conditions. The mechanisms tied to the lending channel are closely related to the problem of moral hazard in monitoring and to precautionary hoarding. As Brunnermeier and Pedersen (2009) explained: "Moral hazard arises when the net worth of the intermediaries' stake falls because intermediaries may then reduce their monitoring effort, forcing the market to fall back to direct lending without monitoring". Holmström and Tirole (1997, 1998) also emphasised that precautionary hoarding arises "if lenders are afraid that they might suffer from interim shocks and that they will need funds for their own projects and trading strategies". The identification of both mechanisms in the interbank market after the crisis outbreak was further analysed by Afonso et al. (2011). The third mechanism was associated with runs on financial institutions during the crisis. This mechanism was limited, though not completely eliminated, by the establishment of deposit insurance. Nonetheless, during such a severe crisis as that of 2008, many clients decided to withdraw funds from banks owing to heightened uncertainty. The main reasons were, firstly, that in the event of collapse, the late movers would receive less or nothing and secondly, that in the case of liquidity problems, banks attempted to obtain liquid assets through fire sales. The final group of mechanisms operated through network effects, which transmitted shocks across the financial system. Financial institutions were linked through a dense network of contractual obligations, such as interbank lending, derivatives positions and collateralised funding. When one institution faced distress or insolvency, its inability to meet obligations immediately affected its counterparties, thus spreading losses and liquidity shortages across the network. This interconnectedness amplified systemic fragility, transforming what could have remained isolated institutional failures into a global financial crisis.

Although the mechanisms described above explain how systemic vulnerabilities emerged and propagated throughout the financial system, they do not account for the institutional and policy responses that followed. The unprecedented scale of the crisis forced US authorities to intervene in order to stabilise financial markets, restore confidence and contain systemic risk. Consequently, attention shifted from diagnosing the sources of instability to designing policy measures that were aimed at mitigating the crisis and preventing its recurrence. This context provides the foundation for an examination of the regulatory and supervisory reforms that were undertaken in the United States.

2.2.3 Policy and Regulatory Response in the United States

During the financial crisis, a number of policy actions aimed at systemic risk mitigation were undertaken. At the same time, extensive discussions began on how to reform the American financial system. In the first case, the authorities targeted the too big to fail institutions as well as the resolution of insolvent financial institutions. The business activity of too-big-to-fail institutions had been associated with excessive risk-taking prior to the crisis (Seelig, 2003; Hurley, 2010; Dudley, 2012; Kaufman, 2013). In addition, the state aid guarantee under stress conditions generated a moral hazard problem (Allen et al., 2015; Mitchell, 2016). From the institutional point of view, the introduction of macroprudential supervision over the financial sector was proposed (Hanson et al., 2011; Elliott et al., 2013; Fischer, 2015). One of the main goals of the macroprudential supervisor would have been the oversight of too-big-to-fail institutions and institutions that enjoyed public guarantees such as Fannie Mae and Freddie Mac as well as the prevention of excessive risk-taking by these entities. At the same time, the possibility of implementing restrictions on the concentration of activities was discussed. In this context, there was a debate on the potential reintroduction of provisions of the Glass–Steagall Act. Furthermore, emphasis was placed on the need to implement mechanisms that would automatically require adjustments by institutions if their capital fell below the required level.

However, before long-term regulatory reforms could be implemented, the crisis deepened and required immediate intervention. The high level of insolvencies announced by households led to a decrease in the prices of derivatives, which further worsened the situation in the financial markets as well as in the banks that held them on their balance sheets. In particular, when the prices of securities began to fall, these assets lost their liquidity. The deteriorating situation prompted the Federal Reserve to cut interest rates to 2% in 2007 and to grant loans amounting to USD 41 billion (Firlej, 2011).

With market stress intensifying, policy responses expanded from liquidity provision to large-scale financial assistance. A number of discretionary interventions were undertaken such as the assistance granted to AIG in September 2008 by the U.S. Treasury and the Federal Reserve in the form of loans and capital injections. On 13 February 2008, President G. W. Bush signed the Economic Stimulus Act of 2008. The total cost of this bill was estimated at USD 152 billion for 2008 (Shapiro and Slemrod, 2009).

On 18 September 2008, following discussions between Treasury Secretary H. Paulson and Federal Reserve Chairman B. Bernanke, it was decided to implement an emergency bailout programme for the banking system amounting to USD 700 billion. The Troubled Asset Relief Program (TARP), also called the Emergency Economic Stabilization Act, was signed into law on 3 October 2008 by President G. W. Bush (Miron, 2009; Austin and J. G. Ritter, 2008; Bianco, 2010).

The federal government's bailout prevented the collapse of further institutions in the market. However, the heightened uncertainty led to difficulties in lending and further decreases in the prices of financial and real estate assets. It should be noted that although some institutions survived due to the bailout, their share prices in the financial markets continued to decrease (Ncube, 2016). Falling stock prices in the financial markets and real estate also affected the real sector, where an increase in the unemployment rate and, above all, losses in wealth were observed.

As the recession deepened and financial distress extended to the real economy, the policy focus shifted from emergency market support to macroeconomic stabilisation. After the elections, on 17 February 2009, President B. Obama signed the American Recovery and Reinvestment Act of 2009 (ARRA) (Brass et al., 2009). It was a stimulus package with an estimated cost of USD 787 billion. In total, almost USD 1 trillion was spent. However, critics argued that only one-third of this amount was spent effectively. It was also criticised that the same individuals who had contributed to the creation of the *status quo* in financial markets were then appointed to implement the reforms.

Yet fiscal intervention alone could not address the structural weaknesses that were revealed by the crisis, which led to calls for regulatory overhaul. On 11 December 2009, the House of Representatives passed bill H.R.4173, the Wall Street Reform and Consumer Protection Act of 2009 and on 15 April 2010 the Senate introduced bill S.3217, the Restoring American Financial Stability Act of 2010 (U.S.

Congress, 2010b). Finally, on 21 July 2010, the Dodd–Frank Wall Street Reform and Consumer Protection Act was enacted (U.S. Congress, 2010a).

In 2009, in response to the crisis in the financial markets, President B. Obama presented a series of regulatory and institutional proposals (Obama, 2009). The proposals focused primarily on consumer protection, regulating the operations of too-big-to-fail institutions, regulating shadow banking and regulating the OTC derivatives market.⁴⁹

B. Obama's proposals, along with Congress and Senate's amendments, in particular the Volcker Rule and the Durbin Amendment (Volcker, 2010; Durbin, 2010), formed the foundations of the Dodd–Frank Wall Street Reform and Consumer Protection Act adopted in 2010 (U.S. Congress, 2010a).

By public opinion, the Dodd–Frank Act was perceived not only as the only consensus that could be reached during this period but also as the only set of solutions that were proposed at that time. Meanwhile, at least to some extent, the substantive discussion of regulatory and institutional changes contained in the proposals of the Dodd–Frank Act and in the alternative, the Paulson Plan (2008),⁵⁰ obscured the post-crisis necessity to make quick decisions and the need for political success.

However, the reform debate at the time was far from unanimous and competing proposals offered alternative visions of post-crisis financial governance. Paulson's plan, among others, presented a more Hayekian attitude, emphasising some of the advantages of the "spontaneous order of the market" (Paulson Jr. et al., 2008). The plan aimed to reform and extend the role of the President's Working Group, which brought together representatives of the Treasury, the Federal Reserve, the SEC and the CFTC. The main objective of the reform, according to the Paulson proposal, was to ensure the stability of the entire financial system and to reject partial solutions that focused only on selected segments of the financial markets. The plan also highlighted the need to consolidate the activities of the U.S. Securities and Exchange Commission (SEC) and the U.S. Commodity Futures Trading Commission (CFTC).

Ultimately, however, it was the institutional architecture of the Dodd–Frank Act that shaped the new framework for systemic risk oversight. The provisions of the first chapter of the Dodd–Frank Act established the Financial Stability Oversight Council (FSOC) and the Office of Financial Research (OFR).⁵¹ The first of these institutions is responsible for regulations concerning systemic risk, while the second provides analyses of the financial system. One of the main criticisms of institutional reform in the United States concerns the role of the FSOC vis-à-vis the Federal Reserve, which remains active not only in monetary policy and economic stabilisation but also in mitigating systemic risk in the financial sector. In addition to systemic oversight, the legislation also addressed the problem of resolving failing financial institutions. As part of the second chapter of the Dodd–Frank Act, the resolution of financial institutions was regulated and the Federal Deposit Insurance Corporation (FDIC)-run resolution mechanism was established in place of the former orderly liquidation authority mechanism. One of the main objections to this solution was that the FDIC would decide whether and how the claims of clients are repaid, which de facto gives the institution considerable economic and, in effect, political authority, since the mechanism is not subject to supervision or judicial control.⁵²

Furthermore, the reform extended to supervisory restructuring that was aimed at addressing the regulatory failures that had been revealed by the crisis. As part of the following sections of the Dodd–Frank Act, the Office of Thrift Supervision (OTS), the supervisory agency that made some of the most significant supervisory errors, including those involving AIG, Washington Mutual and IndyMac, was eliminated.⁵³ Some of the competences of this agency were transferred to the Office of the Comptroller of the Currency (OCC). The new regulations also introduced higher deposit guarantees, raising the insured limit to USD 250,000 (Allen et al., 2015).

The main purpose of higher deposit insurance was to counteract runs on banks. However, while this provision aimed to enhance depositor confidence, it also raised concerns about unintended consequences. Nevertheless, setting deposit insurance at too high a level alters institutions' incentives to bear risk, which can ultimately increase systemic risk. In addition, the Dodd–Frank Act established the Office of Minority and Women Inclusion (OMWI) within financial regulatory agencies.

In parallel with deposit insurance reform, the Act also expanded regulatory oversight beyond traditional banking. The fourth chapter of the Act requires advisers of high-risk institutions such as hedge funds and investment funds to register with the SEC. This provision provoked significant controversy. Opponents of the solution summarised their stance as follows: “SEC resources will be diverted from monitoring advisers who manage the assets of average retail investors to monitoring the assets of wealthy investors who invest in private funds” (Peirce and Broughel, 2013).

Moreover, the reform agenda extended to areas that had previously operated outside federal oversight. Subsequently, legal and institutional changes concerning the insurance sector were introduced. Under the Dodd–Frank Act, the Federal Insurance Office (FIO) was established to cooperate with the Treasury (Brown, 2013). The main objective of this institution is to supervise the insurance sector. FIO works alongside FSOC and the Federal Reserve in identifying systemically important institutions. One of the main criticisms directed at the FIO was the lack of substantive preparation for establishing supervision over the insurance sector and the insufficient regulation of the issues underlying AIG’s problems.

At the same time, restrictions on proprietary trading were introduced in order to limit speculative risk-taking by large financial institutions. The next part of the Dodd–Frank Act extends the competences of the Federal Reserve and introduces the Volcker Rule (Marlatt and Beck, 2015; Krawiec and Liu, 2015; Bao et al., 2016; ABA, 2017).

In addition to regulating bank activity, the Act also introduced new transparency obligations for the derivatives markets. Chapter six of the Act grants regulatory competences over the OTC markets to the CFTC and SEC. It also introduced the obligation to submit transaction reports to regulators and emphasised the special role of clearinghouses (Collard, 2015; Garslian, 2016; McCaffrey, 2016; Duffie, 2016).

Furthermore, the Dodd–Frank Act strengthened the macroprudential supervision mechanisms. The seventh chapter covers the competences of the FSOC in identifying activities and institutions that potentially threaten the stability of the financial system as well as those of the Federal Reserve and CFTC in defining risk management standards for such institutions.

In addition to systemic oversight, supervisory reforms were also implemented to address governance weaknesses. The ninth chapter consolidates SEC competences and establishes additional offices: the Office of the Whistleblower, the Office of the Investor Advocate, the Office of Credit Ratings and the Office of Municipal Securities. The SEC reform was primarily introduced in response to the Madoff scandal (U.S. Securities and Exchange Commission, 2012).

The main objection to this part of the Act was the insufficient reform of the activities and supervision of credit rating agencies. Although some provisions addressed transparency, many critics argued that deeper structural reforms were also necessary. The transfer of authority over the rating agencies to the SEC did not, in itself, solve the problems that were posed by inadequate risk classification. Moreover, the issue of risk transmission through securitisation was insufficiently addressed.

According to the new regulation of credit rating agencies (CRAs), the agencies were required to publish the statistical models and methodological assumptions applied when calculating ratings. The introduction of greater transparency was intended to enable market participants to assess the legitimacy of the ratings issued by CRAs. Nonetheless, despite these measures, concerns regarding conflicts of interest in the ratings industry persisted. Changes aimed at limiting conflicts of interest were also introduced, though only to a rather limited extent (Dimitrov et al., 2015).

Finally, the Dodd–Frank Act also addressed consumer protection, which had been a major source of market abuse prior to the crisis. According to the provisions of the Act, the Consumer Financial Protection Bureau (CFPB) was created. The Act also introduced the Durbin Amendment, which controls fees for the use of debit cards. Opponents of the amendment argued that it distorted the price mechanism in the market. The activities of the CFPB are subject to periodic evaluation by Congress and the Federal Reserve. A hallmark of the American regulatory regime is the emphasis on consumer protection. Misleading practices of financial institutions played a significant role in

the causes and development of the crisis. The goals of the CFPB were to regulate the offer and provision of consumer financial products and services, to increase transparency and to guarantee equal treatment of clients regardless of social, racial or economic conditions (Smith and Zywicki, 2014).

In addition, the Dodd–Frank Act introduced changes regarding the maintenance of additional capital by systemically important institutions and incorporated the leverage ratio (LR) into prudential measures. For these institutions, a requirement was imposed not to exceed a debt-to-equity ratio of 15. Institutions with assets exceeding USD 10 trillion are also required to perform regular stress tests. The Act further regulated the issue of bonuses and monetary rewards for shareholders and directors.

Despite these prudential measures, several provisions of the Act continued to provoke debate over its effectiveness and scope. Another important set of provisions concerned the sale of shares and bonds held by the public sector, the reduction of the Troubled Asset Relief Program (TARP) and the obligation for the Federal Housing Finance Agency (FHFA) to submit a report on the financing of real estate investment to Congress. The main wave of criticism focused on the reduction – rather than the elimination – of TARP, whose operations generated substantial costs for the federal budget. More broadly, the Dodd–Frank Act did not itself present plans for financing real estate investment, but only required the FHFA to prepare such a plan.

However, the overall assessment of the Act remains deeply contested. The assessment of the implemented solutions is not a simple matter.⁵⁴ Immediately after the reform was enacted, some experts argued that the Dodd–Frank Act did not address the problems of mortgage loans and mortgage-backed securities. It was also pointed out that, beyond tackling too-big-to-fail institutions, issues of systemic risk – in particular contagion and procyclicality – were not fully understood or resolved. Some of the regulations concerning institutions that were deemed too important to fail may in fact have exacerbated problems of moral hazard and externalities rather than counteracting them. Moreover, the document ignored the case of the government-sponsored institutions Fannie Mae and Freddie Mac. Before the crisis, these institutions operated on principles very similar to those they continued to follow after the Act's implementation.

Walter et al. (2010) analysed the accuracy of the provisions of the Dodd–Frank Act. According to the authors, the reform identified the problem of institutions that are too-big-to-fail, introduced limitations on their excessive risk-taking and imposed restrictions on proprietary trading through the Volcker Rule, partly referring back to the tradition of the Glass–Steagall Act. In this way, the Act sought to address the problem of moral hazard. In addition, new regulations targeted the most non-transparent market, namely the derivatives market, by introducing requirements for centralised clearing and the publication of prices, volumes and exposures, which were deemed crucial for the proper functioning of this market. However, the authors pointed out that the key institutional structures were not fundamentally changed. In most cases, the agencies that had been blamed for the crisis were simply granted additional competences. From this perspective, the Act was criticised for addressing the symptoms rather than the structural causes of systemic instability. The main shortcomings of the Dodd–Frank Act, according to the authors, were that it did not address the mispricing of pervasive government guarantees throughout the financial sector, nor did it solve the problem that financial institutions fail to take account of the externalities they create for the system when making decisions. In addition, the regulation focused on institutions rather than on their functions, while large parts of the shadow banking sector remained outside of regulatory oversight.

A more extensive critique of the Act was provided in a later study by the same authors in the book *The Dodd–Frank Act and the New Architecture of Global Finance*.⁵⁵ The authors presented a rationale for the regulation of the Dodd–Frank Act based on the theory of market failures. According to their perspective, the main market failure was the emergence of systemic risk, which was related to the low level of aggregate capitalisation in the financial sector. Following Myers (1977), institutions are not themselves willing to raise capital due to the debt overhang problem. Even if financial institutions are aware that they generate negative externalities for the financial system, they have no incentive to prepare for crises, assuming that the costs will be partly borne by other market

participants. The implementation of a Pigouvian tax could, in principle, correct such externalities (Korinek, 2011; Perotti and Suarez, 2011; Farhi and Werning, 2016). Acharya and Richardson (2012) noted that although the possibility of introducing such a tax was discussed, it was not included in the Dodd–Frank Act.

On the other hand, the reform also allowed the regulator to address another market failure – moral hazard. Even if all entities maximise their utility in the system by withdrawing funds from banks, the outcome does not have to be socially efficient. In such cases, intervention in the form of establishing a deposit insurance agency can improve market efficiency. However, the existence of high public deposit guarantees increases the problem of moral hazard. For this reason, the regulatory mechanisms that were introduced after the crisis increasingly focused on altering incentives rather than relying solely on market discipline. In this context, the Dodd–Frank Act introduced mechanisms that provide institutions with additional incentives to limit their risk, thereby reducing their contributions to the deposit insurance fund. Moreover, the Act established supplementary capital buffers for too-big-to-fail institutions and reintroduced mechanisms that were reminiscent of those under the Glass–Steagall Act, which were designed to mitigate moral hazard.

Despite these measures, significant criticisms of the reform persisted. A critical argument raised by Walter et al. (2010) against the Act concerns its overemphasis on the provisions of the Basel III framework. Although the rationale for higher capital requirements appears justified (Admati et al., 2010; Duffie, 2012), the complementary measure of asset restrictions that were imposed by the Volcker Rule is also significant. From a theoretical perspective, this solution seems warranted, yet it highlights the problem of regulatory arbitrage and the scope for shadow banking activities. The adoption of the Volcker Rule together with higher capital requirements was intended to reduce the cost of capital maintenance by financial institutions. In practice, however, this solution did not achieve its intended goal and regulators ultimately required banks to increase their capital base. Acharya and Richardson (2012) also emphasised that the principal threat of relying primarily on higher capital requirements is the continued purchase of financial products that behave like carry trades⁵⁶ (Coval et al., 2009; Acharya and Richardson, 2012).

However, the most fundamental criticism concerned the unchanged foundations of capital regulation. Although the Dodd–Frank Act closed a number of loopholes that had contributed to the crisis, the approach to capital-based regulation remained largely unchanged. The main novelties were the inclusion of off-balance sheet activities in the computation of capital requirements and the obligation to centrally clear derivatives on the OTC market. Nevertheless, the overall rationale and framework of capital regulation did not change. A central weakness of this approach is that a model that is based on risk weights cannot effectively reduce systemic risk since risk weights are not adjusted upward when aggregate systemic risk increases. In this regard, experts have proposed alternative measures based on exposures to aggregate risks (Walter et al., 2010; Duffie, 2011; Brunnermeier et al., 2012).

The Dodd–Frank Act also introduced the leverage ratio (LR) in line with the Basel III recommendations, but in the United States, the LR requirement is stricter, i.e. 6.5% compared to 3% under Basel III and applies only to bank holding companies with at least USD 50 billion in assets or designated SIFIs. Acharya and Richardson (2012) are also sceptical about the introduction of countercyclical buffers, pointing out that institutions receiving additional funds during periods of high volatility — when potential returns are also higher — may in fact become more inclined to take additional risks. This highlights an inherent paradox in prudential regulation: mechanisms that are designed to promote stability may, under certain conditions, amplify procyclical behaviour instead.

The ideal solution has not been the introduction of a complementary measure to the model based on capital requirements, namely the Volcker Rule. According to the Volcker amendment, banks can conduct all commercial and investment activities as financial intermediaries but they cannot engage in “proprietary trading, principal investing, commodity speculation and hedge fund and private equity fund management” (Acharya and Richardson, 2012). While the theoretical logic of this measure appears to be sound, its implementation has been highly contentious. While the principle itself appears justified, the problem of moral hazard arises. The rule permits institutions that are guaranteed

by the FDIC or by GSEs such as Fannie Mae and Freddie Mac to invest on their own account but at lower than market rates. This regulatory asymmetry prompted debate over whether the Volcker Rule effectively curtailed risk-taking or merely shifted it into less transparent areas of the financial system. In addition, some economists argue that the Volcker Rule prohibiting proprietary trading effectively limits financial institutions' ability to diversify risk (Thakor, 2012; Manasfi, 2013; Schultz, 2014). In this context, Acharya and Richardson (2012) explained that from the point of view of systemic risk, this argument is not convincing. Idiosyncratic risk is diversifiable, whereas systemic risk is not. Even a well-diversified activity of a financial institution may pose a threat to the stability of the financial system. This issue was analysed from a theoretical perspective by Freixas et al. (2007) and from an empirical perspective by DeYoung and Roland (2001); Stiroh (2004, 2006); Stiroh and Rumble (2006).

Beyond the Volcker Rule, criticism also extended to the cumulative impact of post-crisis regulation. In addition to the legitimacy of selected elements of the regulation, a debate emerged among banking practitioners about the problem of overregulation as a response to the financial crisis. It was noted that, in principle, no thorough cost–benefit analysis had been carried out prior to the implementation of such a large number of new regulations and operational changes. Consequently, many practitioners questioned whether the overall compliance burden outweighed the benefits of enhanced stability.

Acharya and Richardson (2012) also partially criticised the approach to regulating the systemic risks generated by systemically important financial institutions (SIFIs). Although the criteria for identification such as interconnectedness, substitutability, size, leverage, liquidity risk and maturity mismatch and existing regulatory scrutiny are justified, the key issue is not only the individual risk of these institutions but their contribution to system-wide risk. In other words, the reform focused on the attributes of individual entities rather than on their dynamic interdependence within the system. The Dodd–Frank Act's regulations do not sufficiently account for comovement and codependence, factors that underpinned the development of the 2008 crisis (Adrian and Brunnermeier, 2008; Huang et al., 2009b; Walter et al., 2010; Bisias et al., 2012; Billio et al., 2012).

The assessment of the Dodd–Frank Act in retrospect is equally challenging. According to Skeel (2016), by 2015 only 63% of all regulations had actually entered into force, while 20% had already passed their implementation deadlines. The author also pointed out that despite the adoption of the Volcker Rule, JP Morgan trader B. Iksil generated a loss of USD 62 billion through proprietary trading, even though JP Morgan was active not only in investment banking but also in commercial banking. This example underscored that the presence of regulatory prohibitions did not necessarily prevent excessive risk-taking in practice.

In cases where the Volcker Rule did prohibit specific activities by certain institutions, shadow banking entities stepped in to take over their role. The scale of this phenomenon, however, is difficult to estimate. Several years after the crisis, no substantive measures were taken in relation to Fannie Mae and Freddie Mac apart from placing both institutions into conservatorship.

Another set of controversies arose from the implementation of systemic oversight powers. The American Bar Association argued that the discretionary designation of financial institutions as systemically important by the Financial Stability Oversight Council (FSOC) was essentially unlawful. Some institutions that were required under the new regulations to raise capital and submit a resolution plan to the regulator each year challenged these decisions in court. In practice, the FSOC's recognition of the resolution plans was highly discretionary and did little to increase transparency regarding the structure of systemically important institutions and their market roles. Representatives of the Bar also questioned the Orderly Liquidation Authority under Title II, which in exceptional cases permitted the Treasury, the Federal Reserve and the FDIC to take over a failing institution. Since no statutory time existed to file a petition in federal court between the decision and the actual takeover, in practice such decisions could not be appealed.

The debate on central clearinghouses added yet another layer of complexity to the post-crisis regulatory framework. The establishment of central clearing houses was also widely debated. While

many experts argue that the creation of OTC trading platforms and the imposition of disclosure requirements were necessary steps to bring order to the derivatives market, an equally strong view holds that such reforms merely transformed institutions able to generate systemic risk into a different type of institution that continues to generate systemic risk.

Skeel (2016) further argued that it would be more appropriate to replace the Volcker Rule's outright bans with incentives designed to discourage proprietary trading. This line of reasoning reflected a broader shift in post-crisis policy discourse – from prescriptive regulation towards incentive-based frameworks. At the same time, incentives encouraging institutions to shift towards shadow banking should be limited. Skeel also recommended raising the asset threshold for classifying institutions as systemically important,⁵⁷ while maintaining close supervisory oversight.

Critics warned that an excessive regulatory burden might produce unintended structural consequences. The imposition of excessive regulatory burdens on medium-sized institutions could otherwise push them towards bankruptcy given their limited ability to compete with the largest financial institutions. Paradoxically, this could further increase the market dominance of the very largest systemic and too-big-to-fail entities.

Nevertheless, some policymakers and Federal Reserve officials emphasised the positive outcomes of the reform. In February 2017, Stackhouse (2017), the Executive Vice President of the Federal Reserve Bank of St. Louis, noted that the Dodd–Frank Act's central purpose was to reduce risk-taking by institutions whose size or activities posed the greatest threat to financial stability.

In her view, the Act introduced prudential standards that enhanced the resilience of the financial system and limited the systemic consequences of institutional failures. For institutions with more than USD 50 billion in assets, higher capital requirements were imposed. In addition, the Comprehensive Capital Analysis and Review (CCAR) and Dodd–Frank Act Stress Testing (DFAST) were introduced.⁵⁸ DFAST is conducted by financial institutions and validated by the Federal Reserve, thus ensuring credibility in reported capital data. Stackhouse positively assessed the implementation of these measures along with the Comprehensive Liquidity Assessment and Review (CLAR) that had been introduced in 2012 for the largest institutions and the requirement for cyclical Resolution and Recovery Plans.

Empirical indicators suggest that these prudential measures improved the overall system resilience. According to Federal Reserve experts, these measures significantly strengthened the resilience of banks as was evidenced by the increase in the total risk-based capital ratio from 11.2% to 13.9% between 2007 and December 2016 and the Tier 1 risk-based capital ratio from 8% to 12.3% in the same period (Stackhouse, 2017).

While regulatory reforms sought to restore confidence in the financial system and prevent another crisis of similar magnitude, their implementation generated both economic and political controversy. To fully understand their significance, it is necessary to examine the broader economic and social consequences of the financial crisis in the United States and beyond.

2.3 Consequences of the Financial Crisis in the United States

Having examined the causes and dynamics of the crisis as well as the role of systemic risk in its propagation, we now turn to its consequences. The crisis produced far-reaching effects on the U.S. financial system, the real economy and society, with systemic repercussions extending well beyond the financial sector.

2.3.1 Impact on the U.S. Financial System and Systemic Risk

According to IMF estimates, the subprime crisis caused losses of around \$1 trillion in the global banking system between January 2007 and September 2009, of which roughly 60% were borne by U.S. banks (Guillén, 2015). These losses triggered a wave of institutional failures and restructurings

that reshaped the structure of the U.S. banking sector. Eventually, after the crisis, the U.S. financial market became even more consolidated than before. Baily et al. (2015) analysed the evolution of the “big four” banks and the wider financial sector in the United States in the aftermath of the crisis. Their report was the first to present the balance sheets of the four largest banks that survived. In 2008, the U.S. government encouraged stronger institutions to acquire those that were in distress. As a result, market consolidation accelerated dramatically with the emergence of four dominant banks: JP Morgan Chase, Bank of America, Citigroup and Wells Fargo. The Federal Reserve, the Federal Deposit Insurance Corporation (FDIC) and the Treasury Department facilitated several of these consolidations, including JP Morgan Chase’s acquisition of Bear Stearns, Bank of America’s merger with Merrill Lynch and its acquisition of Countrywide Financial and Wells Fargo’s acquisition of Wachovia. In addition, Goldman Sachs and Morgan Stanley amended their operating charters to become depository institution holding companies (Baily et al., 2015). Although the share of total assets held by these banks rose significantly in 2008, it decreased somewhat after the adoption of the Dodd–Frank Act.

The crisis also led to a fundamental shift in the balance sheet structure and business models of the largest U.S. banks. At the end of 2007, JP Morgan held \$1.6 trillion in assets. Bear Stearns’ assets fell from \$399 billion at the beginning of 2008 to \$289 billion by mid-year when the merger occurred. Washington Mutual had \$550 billion in assets at the time of its merger. As Baily et al. (2015) noted, “the acquisition of Bear Stearns provided JP Morgan with value through its investment banking clients and securities business. Washington Mutual provided an expansion of JP Morgan’s deposit base and loan portfolio and the company was also the beneficiary of a general flight to safety”. The composition asset holdings of the four largest banks changed significantly after the crisis. The role of trading assets decreased, while holdings of interest-bearing deposits increased. From 2008 to 2014, the volume of total loans and leases also decreased. As Baily et al. (2015) observe: “In the pre-crisis period, asset growth was driven overwhelmingly by loans and leases with further significant contributions from trading assets, total securities, reverse repo, interest-bearing balances and other assets such as accrued interest receivable and net deferred tax assets. In the post-crisis period, however, asset growth has been driven almost entirely by interest-bearing balances, total securities and reverse repo”. This shift reflects both the prolonged low interest rate environment and the incentives created by new regulatory requirements under the Dodd–Frank Act. On the liabilities side, the increase in deposit bases was substantial and was largely driven by the acquisitions of smaller banks. Bank income increased until 2007 but then slumped, at least until 2014. The main change after the crisis was the decrease in securitisation income. Baily et al. (2015) emphasised that securitisation income fell sharply at the onset of the crisis with the largest losses observed at JP Morgan and Citi in the period 2007–2008. Nevertheless, by 2014, the profitability of the largest banks had still not returned to pre-crisis levels.

Despite regulatory efforts to reduce concentration and systemic risk through the Dodd–Frank Act, one set of systemically important institutions was effectively replaced by another that may be even more dominant. The role of the shadow banking sector increased—if not directly as a result of the crisis, then at least as a consequence of the regulatory arbitrage and activity migration that was driven by the post-crisis regulation.

2.3.2 Impact on the Real Economy and Distributional Effects in the United States

While the financial crisis initially manifested itself within the financial system, its effects were rapidly transmitted to the real economy, thereby generating deep and persistent macroeconomic disruptions. Systemic risk, therefore, cannot be understood solely in terms of financial market instability; it also encompasses the feedback mechanisms between finance and the wider economy, including the distributional consequences for households, firms, sectors and regions.

The immediate effect of the financial crisis in the United States was the slowdown of economic growth, which was followed by a recession that lasted from the third quarter of 2008 to the first

quarter of 2010. Despite the official announcement of the end of the recession in the United States, the effects of the worst crisis since the Great Depression persisted. The most serious consequences were, above all, socio-economic changes and structural shifts within industries. In this section, we will focus on analysing the impact of the financial crisis and systemic risk on the real economy, that is, on households, enterprises and industries. We will also discuss the distributional effects in the United States.

It is challenging to conduct research on welfare changes after the crisis based solely on the partial available data. It is also difficult to identify unequivocally which social groups suffered most as a result of the crisis. Such research requires adopting a long-term perspective and correcting for the imperfections of statistical data. Nevertheless, it is worth attempting to assess the impact of the crisis on welfare and social inequality in order to understand that the increase in systemic risk and its materialisation in the form of a crisis, brought about changes not only in the financial system but also with direct consequences for the economy and society. This dimension of the effects of the crisis remains relatively underexplored in the literature.

Households were among the first to experience the economic consequences of the crisis. It is worth noting that between June 2007 and November 2008, households in the United States lost on average more than a quarter of their net worth (Hurd and Rohwedder, 2010).⁵⁹ These estimates were based on the American Life Panel (ALP) survey. Based on the respondents' answers, the authors sought to determine what percentage of the American population found themselves in a difficult financial situation immediately after the 2008–2009 financial crisis. They defined individuals in a difficult financial situation as those who were unemployed, were overdue on more than two instalments of a housing loan and/or were owners of property whose estimated value was lower than the value of the loan.

According to the survey results, in November 2008, 13% of the population was in the most serious financial situation and by 2009 this figure had increased by four percentage points to 17%. At the same time, almost 40% of respondents had experienced financial difficulties at least once during this 17-month period. According to the survey, three-quarters of respondents were forced to limit their spending. In most cases, the reduction in spending on goods was related to the need to repay loans and reduce debt (80% of respondents), while 70% reported a decrease in income over the period and 45% reported a change in the labour market status. These figures reveal the scale of financial distress among U.S. households in the early phase of the crisis. In addition, about half of the respondents explained their reduced expenditure in terms of a decrease in the value of the assets they held, particularly real estate (45%) and stock holdings (35%). Households also lost a large share of their pension savings. At the beginning of 2009, households with pension assets had seen them decrease in value by an average of 30%.

The crisis also reshaped household expectations and risk perceptions including expectations regarding the possibility of generating income from stock market investments. In November 2008, respondents estimated the probability of achieving a positive return on stock market investments at around 60%, whereas in earlier surveys this probability had been assessed at 90%. This illustrates the reluctance to invest in the stock market and the general pessimism about the behaviour of the financial markets and the economy during this period. Over a five-year horizon, respondents estimated the probability of achieving a positive return at only 56.4% in 2008 and at 51.3% in 2010.

A direct implication of these developments was a sharp contraction in household consumption in the United States between 2007 and 2010. Lee et al. (2010) analysed U.S. consumption after the 2008 crisis using IMF data. According to their research, personal consumption expenditure fell to 95% in the second quarter of 2009. The authors also estimated that the “U.S. household consumption and savings rate will settle at 89.5% and 5-7%, respectively over the next several years”. A significant decrease in wealth and consumption led to increased uncertainty in the markets and lower growth prospects in subsequent years, which in turn resulted in a tightening of credit availability and creditworthiness conditions. In addition, after the outbreak of the crisis, the labour market situation in the United States deteriorated markedly. Between 2008 and 2009, the unemployment rate rose

from 5% to 10%. The unemployment rate, which was relatively high by U.S. standards, remained close to 12% in 2013. The difficult situation in the labour market limited the ability of American households to repay their debts. In 2010, around 6 million properties were foreclosed on by financial institutions, primarily from low- and middle-income households. Borrowers who were able to service their loans often found themselves with negative equity, i.e. debt that exceeded the market value of their property. It is worth noting that real estate prices fell by 20% compared to 2006. Total home equity in the United States dropped from \$13 trillion in 2006 to \$8.8 trillion in mid-2008 (Elwell, 2013).

The destruction of household wealth was unprecedented in both scale and duration. When we observe changes in wealth at the national level, it should be noted that one direct consequence of the financial crisis was a 25% loss of net worth and a rise in indebtedness among certain social groups. Median household wealth in the United States decreased by 35% between 2005 and 2011. The decrease in household wealth was not only linked to the housing debt crisis but also to the fall in the value of the securities that were held by households. In addition, the stock market crash led to a 22% decrease in total retirement assets compared to 2006. The loss of wealth by American citizens was therefore not only temporary; most importantly, the crisis eroded life-cycle savings. During the crisis, total retirement assets dropped from \$10.3 trillion in 2006 to \$8 trillion in mid-2008. During the same period, savings and investment assets (excluding retirement savings) fell by \$1.2 trillion, while pension assets decreased by \$1.3 trillion (Bricker et al., 2011).

Moreover, the decrease in wealth was uneven across the income distribution, which raised important distributional concerns. A detailed study by the Federal Reserve based on a sample of 4,000 households who responded to survey questions between 2007 and 2009 showed that the total wealth of 63% of households decreased during that period. According to the data, 77% of the richest families recorded a significant loss of wealth, while only 50% of less affluent households experienced similar decreases. Based on this simplified analysis, one might conclude that the wealthiest households — those that were heavily invested in securities — suffered the most and that the degree of inequality could paradoxically have decreased. This surprising conclusion became the subject of research by N. Fligstein and Z. Rucks-Ahidiana of the University of California, Berkeley.

Fligstein and Rucks-Ahidiana (2015) investigated the effects of the financial crisis on household wealth in retrospect. According to their findings, after the crisis, the wealthiest households ultimately increased their holdings — “the rich got richer” — and inequality in the United States widened. This finding challenges earlier assumptions that the crisis may have reduced inequality by disproportionately affecting high-income households.

The impact of the financial crisis on different segments of the income and wealth distribution was uneven. Among the richest 10%, whose portfolios were highly diversified, rebuilding wealth to pre-crisis levels was relatively less difficult. By contrast, in the case of less affluent households⁶⁰ — whose main asset was real estate — restoring wealth to pre-crisis levels proved to be extremely difficult due to heavy credit burdens and the general decrease in property prices.

The divergence in post-crisis recovery was closely linked to differences in asset structure and indebtedness. Inequalities between social groups are not only explained by the differentiation of the assets that are held but also by the level of indebtedness. In the first stage of the crisis, the largest losses were incurred by the richest households, who suffered decreases in real estate, stock market and business values. According to the Survey of Consumer Finances Panel Reports for 2007–2009, real estate prices fell by 21%, the stock market by nearly 50%, while in 2009 the cumulative decrease was only 23% (Bricker et al., 2011).⁶¹

Yet over time, these patterns reversed. In the longer term, however, as economic conditions improved, the more affluent households were able to recover their funds. By contrast, low- and middle-income families lost relatively the most, both in terms of current assets and retirement savings (Bricker et al., 2011; Bosworth, 2012; Wolff, 2012; Grinstein-Weiss et al., 2013).

A detailed breakdown of wealth composition helps to explain why the recovery was so uneven. Wolff (2012) presented data on the relationship between property ownership, total wealth and income.

For the top 1% of the income distribution, 9.4% of total wealth was attributable to property ownership. In the case of the next 19% of the distribution, this share rose to 30.1%.

In the case of households in the 80% of the wealth distribution, the share of real estate assets in total income amounted to 66.6%. Wolff (2012), however, not only presented data on the share of real estate in total assets, income and overall wealth but also information on the ownership of companies, pension funds and stocks. For the wealthiest 1%, 50.3% of their wealth was associated with business activity and 33.2% to pensions and stocks. In the next group (19%), 25.6% of their wealth originated from business activity and 35.4% from pensions and stocks. Among other households (20th–80th percentile), only 8.9% came from business activity and 17.3% from pensions and stocks.

This explains why the fall in property prices had a disproportionately negative effect on less affluent households. According to these data, the impact of the decrease in property prices on the wealth of less affluent households was greater than on the upper middle class (80th–99th percentile) and the top 1%. As the author explained, among 90% of the population, there was a very high rate of foreclosures, which meant that despite the fact that property prices began to rise again after 2009, these households had little chance of regaining their previous level of wealth. As Wolff (2012) pointed out, “over 13 million households were foreclosed on in between 2007 and 2012. In the peak years of foreclosures, 2009–2010, almost 3 million households were foreclosed on each year”.

Summarising, the financial crisis deepened existing structural inequalities in the United States by eroding household wealth, increasing indebtedness and weakening financial security. Its distributional effects were long-lasting and disproportionately burdened lower- and middle-income households.

2.3.3 Impact on the World Economy and European Contagion

Although formally the crisis in the United States ended in 2009, its effects have persisted globally for many years. The transmission of financial distress from the United States to other advanced and emerging economies revealed the deeply interconnected nature of the global financial system. In the next chapter, we will analyse the impact of the financial crisis on the economy and the banking sector in the EU countries. We will also attempt to answer the question of to what extent the crisis in Europe was triggered by the financial crisis in the United States and to what extent did it result from accumulating internal imbalances in individual countries. Paradoxically, we again encounter the problem of external imbalances, which were previously discussed in the case of the United States but this time from the perspective of EU countries. In Europe, external imbalances influenced the structure of the Union and, according to some commentators, even led to a “two-speed Europe” (Campiglio, 2017). Moreover, the international dimension of systemic risk became evident as uncertainty and contagion amplified vulnerabilities across borders. The special role of uncertainty in generating and amplifying systemic risk will also be analysed.

Irrespective of the outbreak of the 2008–2009 financial crisis and the subsequent debt crisis of 2010–2014, it is worth highlighting some universal changes that took place globally in the banking system after the crisis. Claessens and van Horen (2014) observe that “while banks from OECD countries reduced their foreign presence, those from emerging markets and developing countries expanded abroad and doubled their presence. Especially advanced countries hit by a systemic crisis reduced their presence abroad”.

These developments indicated that the financial crisis accelerated a reconfiguration of global banking with significant implications for cross-border capital flows and financial stability. Understanding how these global shifts interacted with regional vulnerabilities is essential for analysing the crisis in Europe.

2.4 The Central Role of Systemic Risk in the Course and Effects of the U.S. Financial Crisis

Understanding the role of systemic risk in the financial crisis of the United States is a necessary starting point for any assessment of its later impact on Europe. The American experience revealed how the accumulation and propagation of systemic vulnerabilities can transform local financial imbalances into global economic disruptions. In this context, the analysis that follows seeks to verify the hypothesis that the relative importance of systemic risk is greater in explaining the course and effects of the crisis than its initial causes.

The history of the American crisis is closely tied to the development of financial markets and investor behaviour. It is a history that casts doubt on the theory of market efficiency and the rationality of agents. It is undoubtedly a story about how the decisions of agents can shape the behaviour of a system but also how the regulatory and institutional framework affects the behaviour of individuals. Above all, however, it can be understood as the history of breaking the *status quo* in Bewley's sense followed by the self-organisation of economic and social systems under risk and uncertainty.

The term self-organised criticality originates from dynamic systems theory but it has also been adopted in the social sciences. Self-organisation of a system refers to the property of dynamical systems to arrange their microscopic behaviour in a way that is independent of spatial and temporal scales. This resembles the critical behaviour observed at the critical point of phase transitions. However, in contrast to ordinary phase transitions, systems displaying self-organised criticality do not require the external tuning of control parameters; rather, the system evolves and *organises itself* into critical behaviour (Golyk, 2012). By analogy, this concept has been used metaphorically to describe the behaviour of economic, financial and social systems and at times to discuss possible paradigm shifts in the social sciences. It may also serve as a useful framework for studying the emergence and dynamics of financial and economic crises.

Since the 1980s, deregulation has been undertaken in the United States in order to increase the efficiency and competitiveness of its financial institutions in the global marketplace. Although, after the financial crisis, deregulation processes were identified as one of the vulnerabilities that contributed to the crisis, the implementation of these changes was fully justified by micro- and macroeconomic theory as well as by practical needs at that time. The fundamental error lay not in the pursuit of efficiency and competitiveness of individual institutions through the self-regulation of risk but in the assumption that their individual strategies would not overlap in ways that could endanger the system. Only the adoption of alternative approaches enables us to understand that the relative role of systemic risk in explaining the causes, course and effects was greater in the course and effects of the crisis owing to what we have termed feedback effects and amplification mechanisms.

This rhetoric of overlapping strategies and of crisis as an avalanche is much closer to the logic of the sandpile model than to the rhetoric of market failures that is familiar from mainstream economics. The history of the American crisis begins with markets and agents' behaviour and their attitudes towards risk. Understanding the problems of moral hazard and the externalities that were generated by the activities of too-big-to-fail institutions is crucial but it does not provide a complete picture. Likewise, the role of *information* cascades. In mainstream economics, cascades are related to information asymmetry or incompleteness. In the dynamical systems, the "avalanches" are not necessarily related to information but are an *intrinsic* feature of the system.

Crises are commonly thought of in a one-directional way. Factors such as deregulation and affordable housing policies affect agents' behaviour, increasing the riskiness of their decisions, which in turn leads to financial fragility and instability of the financial system. However, this explanation of the causes and mechanisms of a crisis is only partial. The *financial* crisis in the strict sense ended in the United States relatively quickly. The market was reorganised and a few key players emerged after a series of mergers, acquisitions and bailouts. Highly indebted households ceased to take on additional risk simply because the system was reorganised and conditions had changed. But this is not where the story ends. The reorganisation of the system during and after the crisis led to an *increase* in systemic risk. Here, feedback effects played a central role.

In the mainstream view, as represented by Bond et al. (2011), financial market failures affect the real economy through the asset price channels and investment decisions. Using an asset pricing model and an informational approach, they describe the relationship between share prices and the decisions of executives, investors, employees and regulators. However, this approach does not sufficiently emphasise that behind share prices stand people whose decisions have real economic consequences. When analysed at the meso- and macroeconomic levels, these decisions and their interactions over time and across sectors generate systemic risk in the sense described by De Brandt and Hartmann (2000).

The financial crisis reshaped the wealth of individuals and society as a whole. At the same time, inequality increased, which is arguably the main *systemic* threat to the stability of the macro-financial system in the future. Based on exhaustive research conducted in between 2013 and 2017 and summarised in this chapter, we argue that the relative role of systemic risk and uncertainty in explaining the causes, course and effects of the crisis was greater in its course and consequences than in its origins.

Of course, our understanding of systemic risk and uncertainty must continue to evolve. The COVID-19 pandemic, technological shifts linked to artificial intelligence and their implications for employment, climate change and rising geopolitical uncertainty all reshape how we understand these issues. Each of these developments has the potential to alter our assessment of systemic vulnerabilities and the sources of macro-financial instability. Nonetheless, the analysis presented here focuses on the years following the global financial crisis as this period most clearly illustrates the evolution of endogenous sources of systemic risk.

Final remarks

We presented two main groups of causes of the financial crisis discussed in the literature: deregulation combined with affordable housing policies and the macroeconomic causes of the crisis. We then demonstrated that the arguments in favour of deregulation as the primary cause of the financial crisis in the United States are not conclusive. On the one hand, deregulation and affordable housing policies increased the fragility of the system. On the other hand, however, they enhanced the efficiency of the system and were required in the face of financial market development and integration. The direct causal link between deregulation and the crisis has never been verified or proved and opinions in the literature remain divided. Later, we also discussed the macroeconomic causes of the crisis with particular emphasis on the internal and external imbalances that were related to the unsustainable growth model of the United States. The unsustainability of this model was linked to the excessive growth of consumption and imports coupled with the decrease in the competitiveness of the American economy. This specific growth pattern supported the creation of the housing bubble and further highlighted the problem of market failures.

We evaluated the level of systemic risk in the United States prior to the financial crisis. Before the crisis, systemic risk was moderate and remained mostly contained until 2007 when the subprime crisis emerged. However, the accumulation of imbalances and vulnerabilities within the financial system led to the generation of systemic risk and to the amplification of external shocks once the crisis began. We also presented the main phases of the financial crisis in the United States and analysed the role of systemic risk during its course. As the crisis unfolded, the importance of systemic risk increased significantly due to the amplification mechanisms within the financial system and the feedback effects with the real economy. We further discussed how the regulatory reforms adopted after the crisis sought to address the weaknesses of the U.S. financial system and mitigate systemic risk. We also examined the impact of the crisis on the financial system, the real economy and the global financial system with particular emphasis on European contagion. We stressed that systemic risk should not be understood solely as a problem that is confined to the financial system. The generation of systemic risk and the amplification of shocks inevitably have broader impacts on the

economy and society. We analysed the impact of the crisis on inequality in the United States, while in the next chapter, we will comment briefly on the distributional effects in EU countries. In the following chapters, we will also investigate how an increase in systemic risk and the application of macroprudential policies may themselves generate distributional effects.

Finally, we confirmed the hypothesis that, in the case of the United States, the relative role of systemic risk in explaining the crisis was greater in its course and effects than in its causes due to the presence of feedback effects and amplification mechanisms. In the next chapter, we will test the same hypothesis for the EU countries.

Notes

1. Both citations are taken from Bernanke's speech at the Russell Sage Foundation and The Century Foundation Conference Rethinking Finance in New York, 13 April 2012, in which he referred back to his testimony before the Financial Crisis Inquiry Commission in 2010 (Bernanke, 2010, 2012).
2. He went on to add: "Indeed, daily movements in global equity markets not infrequently impose aggregate gains or losses equal to or greater than all the subprime mortgage losses incurred thus far."
3. This book assumes that the crisis began on 15 September 2008 with the collapse of Lehman Brothers, although the first symptoms had already appeared in 2007.
4. The principal arguments for and against the Glass–Steagall Act are set out in the Congressional Research Service (CRS) Report (2016) and the General Accounting Office (GAO) Report (1988). The CRS Report also examines the provisions of the Dodd–Frank Wall Street Reform and Consumer Protection Act of 2010, adopted in response to the 2008–2009 financial crisis. The Dodd–Frank Act did not reinstate Glass–Steagall but introduced mechanisms intended to discourage risky strategies by financial institutions and to enhance consumer protection. The GAO Report analysed Regulation K, which permitted U.S. commercial banks to engage overseas in activities prohibited domestically, particularly in the United Kingdom, in order to maintain the international competitiveness of U.S. banks.
5. These reforms were the outcome of the Pecora Commission, which identified the sources of systemic risk and proposed a reform plan to prevent future crises (U.S. Senate Committee on Banking and Currency, 1934).
6. In 1974, the Commodity Futures Trading Commission (CFTC) was created as the federal regulator of the futures market.
7. Sections 16, 20, 21 and 32 of the Banking Act of 1933. Section 21 "prohibited non-banks from accepting deposits, while Sections 16, 20 and 32 prevented depository institutions from affiliating with securities firms or engaging in certain securities activities" (Carpenter et al., 2016).
8. The DIDMCA also removed the competitive advantage of thrifts over banks by abolishing interest rate ceilings on deposits. For more detail, see Sherman (2009).
9. He served as Chairman of the Federal Reserve of the United States from 1987 to 2006.
10. All quantitative data in this paragraph are taken from Jones and Critchfield (2005).
11. Thrift organisations were defined as commercial bank and thrift holding companies, independent banks and independent thrifts.
12. The consolidation and concentration in the U.S. market were a result of external and internal factors analysed by Berger et al. (1995, 1999) and Shull and Hanweck (2001).
13. It is also significant that R. Rubin later worked as Vice Chairman of Citigroup.
14. Also known as the Financial Services Modernization Act.
15. For discussion about the purposes of using derivatives, see Stout (1999).
16. For explanations of derivatives and their role in the U.S. crisis, see Barnett-Hart (2009); Stanton and Wallace (2011); U.S. Senate, Permanent Subcommittee on Investigations (2011); and Colón (2016).
17. It was not until 2009 that she was awarded a prize, alongside S. Bair (FDIC), for warning of the consequences of the unregulated derivatives market.
18. In 2004, the average leverage was approximately 33%. This increase was particularly alarming because a 3% reduction in profits would have rendered a bank insolvent.
19. On the other hand, many institutions – particularly governmental ones – supported the view that even after the repeal of the Act, mechanisms that should have prevented conflicts of interest remained in place, see e.g. Wallison (2017).
20. Since then, commercial banking activities were carried out by J. P. Morgan, while investment banking was undertaken by Morgan Stanley.
21. Amended by the Financial Institutions Reform, Recovery and Enforcement Act of 1989.
22. The HOLC operated until 1951.
23. In the 1970s, the National Credit Union Administration assumed the responsibilities of the Bureau of Federal Credit Unions.
24. Since 1968, Fannie Mae has been a publicly traded company. The transformation of its legal form also provided tax exemptions.
25. The first mortgage-backed securities were issued in 1981 (Lucas and Torregrosa, 2010).

26. See G. H. Bush's Statement on Signing the Housing and Community Development Act of 1992, 28 October 1992.
27. The use of negative amortisation and predatory lending was widespread. For example, bait-and-switch methods were used by Countrywide Financial, which was sued by California Attorney General Jerry Brown for unfair business practices.
28. Relaxed underwriting standards in 1996 encouraged weak and fraudulent practices in the 2000s. At the beginning of 2000, a subprime borrower typically had a FICO score of 660 or lower; by 2005, this threshold had been reduced to 620. Each year, less documentation and collateral were required. The extreme case was the so-called NINJA loans—"no income, no job, no asset verification required" mortgages (Aitken and Aitken, 2011). For more on underwriting standards before the crisis and following quantitative easing, see Hartman-Glaser et al. (2014).
29. In July 2007, Bear Stearns, one of the major players in the market, announced severe financial and liquidity problems. Not only did U.S. institutions invest heavily in MBS but so too did foreign institutions, which contributed to instability across global markets (Gorton, 2009; GPO-FCIC, 2011).
30. For more on inconsistencies and legacy issues, see Goodman et al. (2015).
31. See Shadow Statement No. 221 of the Shadow Financial Regulatory Committee (2005).
32. The failure to adopt these reforms was widely perceived as the result of lobbying. This hypothesis was later confirmed in a formal analysis by IMF experts (Igan et al., 2009).
33. For instance, Democratic Leader N. Pelosi stated that "the Bush Administration's eight long years of failed deregulation policies have resulted in our nation's largest bailout ever, leaving the American taxpayers on the hook potentially for billions of dollars", while B. Obama, during his presidential campaign, argued that "the biggest problem in this whole process was the deregulation of the financial system".
34. Scholars such as Calomiris (2000, 2008) and Rajan (2010) have argued that the financial crisis was rooted less in the deregulation of the Bush years and more in long-standing structural imbalances, flawed incentives and excessive risk-taking, both domestically and globally.
35. The same perspective was later developed in his book *From Financial Crisis to Stagnation: The Destruction of Shared Prosperity and the Role of Economics* by Palley (2012). Palley's arguments were also supported by Meltzer et al. (2013) and Stiglitz (2016a).
36. It is worth noting that the problem of external imbalances is not unique to the United States but rather a feature of the global economy (Bordo, 2005; Chinn and Ito, 2008; Chinn et al., 2012). In the European context, this issue has been analysed by Holinski et al. (2012) and Atoyan et al. (2013).
37. In contemporary rhetoric, this has been reframed as maintaining a "natural" rate of unemployment rather than striving for full employment.
38. The effects of NAFTA have been analysed in detail in the Congressional Research Service Report, see Villarreal and Fergusson (2017). The trade and welfare effects of NAFTA were studied by Caliendo and Parro (2015). In 2017, the Trump administration reopened negotiations to reform the agreement.
39. Beginning in November 2000, the Federal Reserve reduced its federal funds rate from 6.5% to 2.10% in November 2001. After the terrorist attack, the U.S. economy entered a recession and the Federal Reserve decided to cut interest rates further down to 1% in July 2003. From July 2003 to June 2004, interest rates remained unchanged.
40. For more information about leaning against the wind, refer to Weill (2007), Filardo and Rungcharoenkitkul (2016), Svensson (2017), and Gouriou et al. (2018).
41. Edge corporations are specialised banking institutions, authorised and chartered by the Board of Governors of the Federal Reserve System, permitted to engage in international or foreign banking activities. They may be organised or owned by foreign banks operating in the United States, subject to Regulation K and approval of the Board (Code of Federal Regulations, 2023; Board of Governors of the Federal Reserve System, 2023).
42. One employee, S. Denis, tried to warn AIG in 2007 but was dismissed instead.
43. Guillén (2015) provided a timeline in *The Global Economic & Financial Crisis: A Timeline*. Due to space constraints, we limit this section to the presentation of four phases of the financial crisis in the United States.
44. The mechanisms of systemic risk generation and amplification in the interbank market after the Lehman collapse were analysed by Gai (2013).
45. In particular, it is important to distinguish the role of structured investment vehicles, hedge funds and other unregulated institutions from the shadow banking sector.
46. Antoniadou (2013) provides an interesting LSE study on the perception of the Greek crisis and the support programmes in the media worldwide.
47. See, for example, Elliott (2011), *Global Financial Crisis: Five Key Stages 2007–2011*, *The Guardian*, 5 August 2011.
48. The problem of asymmetric information and systemic risk has also been analysed by Biais et al. (2009), Beltran and Thomas (2010), Bhattacharya et al. (2012), López-Espinosa et al. (2015), and Miller (2017).
49. In addition, the experts emphasised the need to make changes in pro-cyclical accounting standards.
50. The Paulson Plan, i.e. the Department of the Treasury *Blueprint for a Modernized Financial Regulatory Structure*, should not be confused with the later Paulson proposal that was a part of the TARP, approved in 2008.
51. For a discussion of the activity of FSOC and OFR and their relationship to systemic risk, see Nili (2015). For an analysis of how Knightian uncertainty affects systemic risk regulation and the functioning of FSOC in practice, especially in the MetLife case, see McCoy (2017).
52. For additional studies on the resolution of financial institutions, see Fitzpatrick IV et al. (2011); Fitzpatrick IV and Thomson (2011b,a); Bliss and Kaufman (2011).
53. For an evaluation of the effects of the dissolution of the thrift regulator (OTS), see Granja and Leuz (2020).

54. For critical assessments of the Dodd–Frank Act, *see*: Walter et al. (2010); Ludwig (2012); Thompson (2012); Republican Staff (2014); Wallison (2015); Baily et al. (2017); Yellen (2017); for proposals to repeal the Dodd–Frank Act *see*: Michel and Furth (2017). On whether systemic risk is a Dodd–Frank fallacy, *see* Kupiec (2017).
55. Also in the article, based on the material presented in the book *Implications of the Dodd–Frank Act* written by Acharya and Richardson (2012).
56. Carry trade occurs when higher-yielding securities are purchased using lower-yielding, short-term securities. Such strategies were extensively used by Fannie Mae and Freddie Mac.
57. Currently set at \$50 billion.
58. For a comprehensive evaluation of the Federal Reserve’s stress testing regime, *see*: Flannery et al. (2016).
59. Moreover, American households were heavily indebted. Household debt in relation to GDP grew steadily from 1980 to 2011. In 1980, household debt as a percentage of disposable income was 68%, rising to a peak of 128% in 2007, before falling to 112% by 2011. Household debt as a percentage of nominal GDP increased from 47% in 1980 to 94% in 2009, before declining to 77% in 2012, *see*: FRED database.
60. This group includes social groups requiring special attention, in particular African Americans and Latinos.
61. Similar surveys, including the Eurosystem’s Household Finance and Consumption Survey (HFCS), are conducted in Europe under the Household Finance and Consumption Network coordinated by the ECB.

3 The Role of Systemic Risk and Uncertainty in the Development of the EU Crisis

In the previous chapter, we analysed the relative role of systemic risk in explaining the causes, course and effects of the 2008–2009 crisis in the United States. We demonstrated that its role was greater in the course and effects of the crisis than in the causes, mainly due to the existence of feedback effects. Nonetheless, the crisis did not end in 2009 when the recession was officially declared over in the United States. Its consequences extended beyond the American financial system and the real economy, thus strongly affecting the global economy and in particular the European Union (EU). The systemic risk that had been generated within the U.S. financial system was transmitted to the EU where the initial shock was further amplified. At the same time, internal vulnerabilities in many EU countries – especially in the peripheral states – made the crisis significantly more severe even though some core EU economies appeared relatively resilient to external shocks.

We present the generation and amplification of systemic risk in the EU countries by type. Our analysis covers the PIIGS countries, the Scandinavian, Baltic and Central and Eastern European states, the EU core countries and the United Kingdom. Particular emphasis is placed on the peripheral countries where the sovereign debt crisis was most acute. Within each group, we selected a few representative cases for a more detailed examination. The remaining countries were then compared against these key examples, which in our view best illustrate the dynamics of systemic risk within each category.

3.1 Systemic Risk in the PIIGS Economies

The group of countries often labelled as PIIGS encompasses relatively diverse economies, which nonetheless shared the common feature of high debt levels. Within this group, our analysis concentrated on Spain where private sector indebtedness was particularly pronounced and Greece where public debt was especially burdensome. In the Greek case, subsequent revisions revealed that official statistics had understated the true extent of public indebtedness, thereby complicating the assessments of fiscal sustainability. In both countries, perceptions of risk and uncertainty played a decisive role in amplifying systemic risk.

In this analysis, both the spatial and temporal dimensions of systemic risk were examined together with the related issues of contagion and procyclicality. It is argued that verification of the central hypothesis required, above all, that the vulnerabilities of financial systems and the processes and mechanisms through which risk was generated and amplified must be properly understood.

Recognition of the feedback effects that arose between the financial system and the real economy, which served to reinforce and prolong the episodes of instability, was also required.

3.1.1 *Spain*

3.1.1.1 *Business and Financial Cycles in Spain since the 1950s*

In the 1950s, the Spanish economy received support from the United States in the form of long-term loans and fixed assets. Under conditions of autarky, the inflow of foreign funds and resources contributed to rising prices and a decrease in Spain's foreign reserves. In 1957, a government of technocrats was established, which sought to redefine the foundations of economic policy.

The new approach was codified in the Plan of Stabilisation of 1959 (*Plan de Estabilidad de 1959*). Its objectives included stabilising the currency, partially liberalising the economy, adopting a restrictive fiscal stance with limits on public spending, reducing state intervention in the centrally planned system and opening Spain to foreign direct investment. The immediate outcome of the Stabilisation Plan was a decrease in inflation though this was accompanied by a temporary slowdown in growth during the adjustment period of 1958–1960. In the medium term, however, the reforms generated strong economic expansion between 1959 and 1973 (Quintana, 1984, 1986), a period that is widely regarded as the golden age of Spanish economy.

Building on this momentum, the 1960 Plan for Development of the Spanish Economy (*Plan de Desarrollo de 1960*) promoted industrialisation in key centres such as Madrid, Catalonia and the Basque Country, while also encouraging the specialisation of agricultural regions, particularly Extremadura. Two years later, the Act on the Regulation of Banking Activity (*La Ley de Ordenación Bancaria de 1962*) initiated a process of liberalisation in the activities of credit institutions. Between 1963 and 1969, twenty-two new institutions were created, a further 5 appeared between 1972 and 1973 and 7 more between 1975 and 1978 (Aceña, 2005). During this time, a clear separation of activities was maintained – similar to the model that had been established in the United States under the Glass–Steagall Act – with 20 institutions operating as industrial banks and 14 as commercial banks. The Act also simplified the procedures for establishing savings banks.

The favourable trajectory was interrupted in 1973 when Spain entered a recession following the oil shock triggered by the Yom Kippur war. After the death of General Franco in 1975, the downturn deepened. In 1976, GDP growth remained modestly positive at around 1.5% yet unemployment and inflation rates were persistently high. In an effort to address double-digit inflation rate, the Pact of Moncloa (*Pactos de Moncloa*) was signed in 1977 (Presidencia del Gobierno, 1978). This agreement, which brought together the government, opposition parties and major trade unions – including CNT (*Confederación Nacional del Trabajo*), CC.OO. (*Comisiones Obreras*) and UGT (*Unión General de Trabajadores*) – introduced a devaluation of the peseta and restrictions on wage growth, particularly in the public sector (Mañas, 2008).

In 1977, reforms were also introduced in the regulation of savings banks including their organisation and internal governance. The economic crisis coincided with a severe banking crisis, which followed a period of rapid credit expansion (Anguren Martín, 2011, 2017). During this episode, the financial sector was restructured, most notably through a wave of mergers among commercial banks and savings banks (*cajas de ahorro*). The banking crisis ultimately affected 56 banks and 23 banking companies (*empresas bancarias*) (Aceña, 2005). Its causes were both external (exogenous) and internal (endogenous) to the system. Among the most important were the proliferation of the inefficient institutions that had been created after the 1962 liberalisation of the banking sector, the industrial crisis and the subsequent wave of corporate bankruptcies that increased non-performing loans as well as the absence of effective supervisory mechanisms by the Bank of Spain and of adequate insolvency procedures.

The Deposit Guarantee Fund (*Fondo de Garantía de Depósitos*) identified the main imperfections of the system that contributed to the crisis. Firstly there was excessive competition to acquire clients

between the existing and newly established banks. Secondly, the rise in interest rates after 1977 increased financing costs. In addition, the high operating costs of the financial institutions placed further strain on the market structure. Moreover, an increase in high-risk investments and risk concentration together with the lack of standardised accounting rules and practices had a negative impact on the Spanish financial system (Aceña, 2005).

Anguren Martín (2011, 2017) noted that it is possible to distinguish five phases of the declining business cycle that coincided with episodes of banking crisis in Spain: 1974–1975, 1980–1982, 1991–1993, 2001–2002 and 2009–2014. By contrast, Sala Ríos et al. (2016), using data since 1970, drew attention to the limited synchronisation of the business and financial cycles in Spain. At the same time, they argued that in Spain, the business cycle influenced, with a lag, the volume of loans granted to the non-financial corporate sector. Despite these different econometric findings, there is no doubt that in the period 1977–1985 the Spanish authorities had to confront both an economic slowdown and a banking crisis. The regulatory changes that had been introduced in response to the banking crisis of the 1980s shaped the structure of the Spanish financial system that persisted at least until the global financial crisis of 2009 (Aceña, 2005; Cuervo García, 1988).

In 1978, *Corporación Bancaria SA* was established as an institution that grouped the banks in which the Bank of Spain had intervened. In 1982, the socialist party led by F. González won the elections. The main objectives of the economic policy pursued in this period were to reduce inflation and to devalue the peseta in order to improve the competitiveness of the Spanish economy. However, the decrease in inflation was accompanied by greater wage flexibility (*la moderación salarial*) than in the pre-1982 period (Kennedy, 2013). In 1986, Spain joined the European Economic Community. The inflow of funds from Member States contributed to dynamic economic growth up until the crisis of 1992. At the same time, these funds were used to reform the banking sector, in particular to promote the internationalisation of the banks' activities.

In 1992, public investment in Spain increased substantially, driven above all by the organisation of the Olympic Games in Barcelona and the Expo exhibition in Seville. At the turn of the 1980s and 1990s, the government had already introduced policies to support the real estate sector. Rising asset prices – particularly in property and stock markets – stimulated both consumption and production. This expansionary phase was interrupted by the crisis of the European Exchange Rate Mechanism (ERM) in the early 1990s, which pushed unemployment rate to nearly 20%. The 2009 crisis is frequently compared with this earlier episode. As Mañas (2008) observed, in both cases, Spain's growth model was underpinned by investment in real estate and construction though in the 1990s the public sector played a greater role through support for public investment, whereas in 2009, the private sector was heavily indebted and public finances remained relatively balanced. In both episodes, the liberalisation of financial markets, persistent current account imbalances and a decrease in competitiveness were central factors.

From 1992 onwards, despite the lingering effects of the downturn, economic policy was increasingly geared towards meeting the convergence criteria for entry into the single currency. This required, above all, bringing public debt to below 60% of GDP, reducing the public deficit to 3% of GDP and limiting the inflation rate to 2%. From 1995, Spain entered a new expansionary phase of both the business and financial cycles (Sancho, 1997; Fuentes Quintana, 1998; IME, 1998).

This period of dynamic economic growth, which averaged around 3.5% GDP growth per annum, lasted uninterrupted until early 2008. Negative real interest rates, together with policies promoting investment in real estate and construction, fuelled an unprecedented credit boom. Property prices rose by more than 30% (Bellod Redondo, 2008), while strong inward migration from Central and Eastern Europe increased demand for housing, construction and tourism-related employment (Pajares, 1998). Yet during this expansionary phase, significant imbalances accumulated: a real estate bubble formed, competitiveness eroded and monetary policy remained excessively accommodative. Interest rates, which had been lowered globally in response to the dot-com crisis and the 2001 terrorist attacks in the United States, remained below levels that were consistent with Spain's cyclical position. Inflation

in Spain persistently exceeded the euro area average, thus leading to further losses in competitiveness, while the current account deficit increased to 9% of GDP by 2007 (Feito, 2006).

Private sector debt expanded rapidly, rising from 94% to 191% of GDP between 2000 and 2007. Credit to households for house purchases grew by up to 25% annually in December 2005, while lending to construction companies expanded at rates of up to 44% annually in December 2007 (BdE, 2017c). Real estate investment doubled over this period and reached 12% of GDP – five percentage points higher than the euro area average. Employment in the real estate sector rose by nearly one million, according to data from the Social Security System (*Seguridad Social*) (BdE, 2017c).

Although fiscal policy remained countercyclical and stabilising – Spain recorded a budget surplus in 2006–2007, thereby reducing public debt to 37% of GDP (Álvarez Martínez, 2021) – this apparent strength masked rising vulnerabilities. Budget revenues became heavily dependent on the phase of the business and financial cycle, while private indebtedness surged. At the same time, favourable tax treatment of property purchases and new legislation that permitted the development of previously non-urbanised land added fuel to the real estate boom. Experts also pointed to risks that were associated with the low reserves that were being held by financial institutions, particularly banks and savings banks, which in 1999 maintained one of the lowest loan reserve ratios in the OECD (Claessens et al., 2012).

When the global financial crisis erupted in 2008, Spain entered a prolonged downturn. The collapse of its growth model, which had been centred on construction and real estate, exposed structural weaknesses in the banking sector – most notably in the governance and operations of the savings banks. Institutions such as the Banco de España, the IMF and the OECD had already drawn attention to these risks and policy strategies were in preparation to address them. However, implementation was derailed by the external shock of the U.S. subprime crisis and the subsequent global slowdown (BdE, 2017c). Between 2012 and 2013, Spain faced the combined impact of the global financial crisis, a domestic banking sector crisis and the euro area sovereign debt crisis. From 2014 onwards, a period of stabilisation gradually set in with the financial sector being strengthened and economic and social conditions returning to a more normal footing.

Spain's experience during these years also carried broader implications for the EU. The deep interconnections between sovereign debt, banking fragility and macroeconomic imbalances underscored the limitations of the existing regulatory and supervisory frameworks. The Spanish case, together with parallel developments in other Member States, informed the debate that eventually led to the creation of the banking union and the strengthening of macroprudential supervision in the EU. In this sense, Spain's trajectory can be read not only as a national crisis narrative but also as a pivotal case in the evolution of European financial governance.

3.1.1.2 Building up of Vulnerabilities in the Expansion Phase of the Cycle in Spain (2000–2007)

In the period between 2001 and 2007, credit supply grew much faster than nominal GDP. In 2000, all of the credit institutions in the financial system granted loans worth €527 billion in total, which was equivalent to 81% of nominal GDP. By 2004, credit had increased 1.7 times and by the end of 2007 it had almost doubled. The credit granted by savings banks in the period between 2000 and 2007 rose by 266%, while that granted by banks increased by 182% (BdE, 2017c). During this period, the number of loans granted for the purchase of real estate by both banks and savings banks and cooperatives increased by 252%. Regarding loans to non-financial enterprises, they were granted primarily to companies in the construction sector and firms that provided services in the real estate sector. The volume of loans granted to construction and real estate companies grew by around half again as much as in other sectors of the economy. This increase concerned mainly savings banks. In the expansionary phase of the economy, there was no sudden increase in non-performing loans until 2005 (BdE, 2017c). In principle, in the entire period that was analysed, the non-performing loans (NPL) ratio did not exceed 1% (the ratio for mortgage loans was approx. 0.5% and for other purposes up to a maximum of 2%). Provisions to cover credit losses and credit risk were at an adequate level.

By 2007, banks and savings banks had adopted similar business strategies with the operations of savings banks usually subject to higher risk and, consequently, a slightly higher NPL ratio.

The value of government bonds being held by the system in the period between 2000 and 2005 averaged €100 billion with the highest value recorded in 2003 (€114 billion). From 2006 onwards, depository institutions began to reduce their holdings of government bonds and reached only €34 billion in December 2007. In 2000, the share of government bonds in the assets of all institutions was 8.8%, whereas in 2007 it had fallen to 2.8%. The share of government bonds in the balance sheet of savings banks was greater than in the case of banks: 10.2% in 2000 and 3.8% in 2007 for savings banks compared to 7.9% in December 2000 and 2.2% in December 2007 for banks (BdE, 2017c).

During the expansionary phase of the cycle, deposits constituted the principal source of financing for financial institutions. Between 2000 and 2007, deposit volumes grew by 109%, which corresponded to an average annual growth rate of approximately 11%. The increase in loans was higher than the increase in deposits, which can be observed from the evolution of the loan-to-deposit (LTD) ratio. This ratio rose from 93% in December 2000 to 155% in December 2007 (BdE, 2017c).

Prior to the crisis, the Spanish financial system was widely regarded as being solvent and among the most resilient to external shocks. Between 2000 and 2007, the average return on equity (ROE) of both banks and savings banks consistently exceeded 12%, peaking at around 20% in 2007 (BdE, 2017c). Notably, there was little difference in performance between the two types of institutions. Between 2000 and 2014, the solvency ratio was set at 8%. Over the period that was analysed, regulatory changes were introduced in the calculation of the ratios following the implementation of the Basel Committee's Agreements – Basel II in 2008 and Basel III in 2014.

In 2000–2007, the capital of banks increased significantly by 155% in absolute terms. Similarly, the highest-quality Tier 1 capital increased by 118% over the same period. Growth was recorded for both banks and savings banks with risk-weighted assets rising at an average annual rate of 14.2%, more sharply in the case of savings banks than of banks. All institutions met the applicable capital requirements (BdE, 2017c). In the same period, sectoral concentration limits, internal risk assessment mechanisms and new accounting standards were also introduced in Spain to address weaknesses in the financial system and to counteract the build-up of risks, imbalances and other vulnerabilities during the expansionary phase of the cycle.

The Bank of Spain introduced a series of changes to accounting standards over the years. In 1991, it adopted Resolution (*Circular*) No. 4/1991, which required banks to apply the precautionary principle when collecting provisions for credit risk. In 2000, in order to limit the cyclical component of credit risk provisions, accounting standards were modified and dynamic provisioning was introduced. In 2004, the International Accounting Standards (IAS) were implemented, which had been adopted in Europe by Regulation No. 1606/2002 of 19 July 2002 and in Spain through Resolution No. 4/2004.

Between 2000 and 2007, the Bank of Spain engaged in relatively effective but still largely microprudential, supervision. During the expansionary phase, it conducted audits of the largest banks to ensure solvency. In the case of two systemically important banks – Santander and BBVA – cyclical inspections were undertaken to monitor potential risks from their activities. By contrast, savings banks were not subject to comparable periodic inspections and as a result the main vulnerabilities arose in this sector. In 2004, regulatory mechanisms were introduced that subsequently entered into force in most EU countries in 2008–2009 following the publication of the Basel II provisions (Basel Committee on Banking Supervision, 2006). After consultations with financial institutions in Spain, the use of internal models was made possible. To a large extent, however, the Bank of Spain's approach remained microprudential with oversight focused on ensuring the solvency of institutions and on meeting capital requirements. In 2012, the document *An analysis of supervisory procedures at the Bank of Spain and proposals for reform* (*Análisis de los procedimientos supervisores del Banco de España y recomendaciones de reforma*) was published, which emphasised the need to introduce macroprudential supervision.

The risks in the expansionary phase were closely associated with the operations of savings banks. The business activity of these institutions generated risks for the system, primarily due to their specific

legal form. According to their statutes, savings banks were required to pursue social objectives and to conduct activities for the benefit of the local community. At the same time, however, they were profit-oriented institutions, which gave rise to a conflict of interests. In many cases, savings banks were managed in agreement with or directly by, representatives of the Autonomous Communities who were supposed to ensure the fulfilment of their social goals. In practice, however, this often led to the inefficient management of funds, thereby aggravating the situation of savings banks and increasing systemic risk. In 2002, Act No. 44/2002 of 3 November introduced a requirement that representatives of public authorities could not hold more than 50% of the voting rights in the general assembly (BdE, 2017c). Despite this regulation, the associations of savings banks with the authorities of the Autonomous Communities remained very strong until the outbreak of the financial crisis in Spain in 2009. In addition, during the period between 2000 and 2007, risks related to the concentration of savings banks in the real estate and construction sectors steadily increased.

3.1.1.3 The Contraction Phases of the Cycles and the Crisis in Spain (2009–2014)

In mid-2007, when the first bankruptcies occurred and uncertainty in the markets increased in the United States, the end of the expansionary phase of the cycle and the first symptoms of economic slowdown were also observed in Spain. In 2005, the ECB had raised interest rates. At the same time, the change in the phases of the financial and business cycles affected the real estate market. There was a visible slowdown in the demand for apartments and a gradual moderation of price increases in the real estate market while supply remained high. In 2007, economic growth was still positive, mainly due to the contribution of the export sector to output (BdE, 2017c). At the beginning of 2008, an economic slowdown was expected in Spain, the euro area and the global economy. However, the Spanish authorities did not anticipate a severe recession (BdE, 2017c). Nonetheless, many internal factors contributed to the recession in Spain, including a decrease in demand for housing, rising private and external debt, higher interest rates since 2005, increased uncertainty and a fall in exports due to the decrease in international trade during the crisis. In mid-2008 and at the beginning of 2009, cumulative private consumption decreased by 4.5%, investment in the construction sector by 21% and total investment by 27%. Between 2008 and 2009, 1.5 million people lost their jobs and the unemployment rate rose by 8 percentage points to 18.7% (BdE, 2017c). In response to the severe loss of jobs, the government adopted an expansionary fiscal policy that not only relied on automatic stabilisers but also on a range of discretionary measures. To a large extent, the state budget ceased to collect additional revenue from real estate taxation, which further deteriorated the position of both the central budget and the majority of autonomous community budgets. From a central budget surplus of 2% of GDP in 2007, the deficit widened to 11% of GDP in 2009. The current account deficit amounted to 9.2% of GDP in 2007 and to 3.9% of GDP in 2009. The decrease in the deficit was mainly due to a fall in imports of 5.6% in 2008 and 18.3% in 2009 as well as a decrease in exports of 0.8% and 11%, respectively (BdE, 2017c). The CPI fell by 0.3% compared to the previous year. For the first time since 1999, the difference between the Spanish inflation rate and the average inflation rate in the euro area was negative. In the case of the real estate market, property prices fell by 10% in the fourth quarter of 2009 compared to their peak in the third quarter of 2007. Investment in new real estate decreased by 35% in the period between 2007 and 2010, while employment in the construction sector fell by 1 million.

On the supply side, the effect of the crisis was more limited as many investment projects had already been initiated before 2008. After the outbreak of the crisis, around one million apartments were constructed (BdE, 2017c). The surplus of supply over demand led to a fall in property prices. The fall in real estate prices reduced the collateral value of loans granted, thereby triggering mechanisms similar to those that had been observed at the beginning of the subprime crisis in the United States. The condition of the Spanish financial sector after the global crisis remained relatively solid owing to its low exposure to U.S. financial instruments. Nevertheless, during this period, the sector's exposure to its own real estate market was excessive, thus creating a significant risk associated with business

activity in the construction and property sectors, particularly given the cyclical nature of economic processes. In addition, as Spanish institutions increasingly relied on external financing from foreign markets, raising funds after the outbreak of the global financial crisis became both more difficult and costly. In the period between 2007 and 2011, the share of non-performing loans rose from 0.8% in 2007 to 8% in 2011. Of these, in the years 2007–2009, 45% were linked to the real estate sector. Credit to the non-financial sector began to decelerate from 2008 onwards. Between 2009 and 2010, credit to the non-financial sector contracted by 0.2% (BdE, 2017c).

The decrease in lending was associated with lower household expenditure, a loss of trust in financial institutions and markets and a rise in perceived risk. The sharpest contraction was observed among savings banks, whereas commercial banks continued to grant loans, albeit at a slower pace than before the crisis. During the crisis, total loans to households still increased slightly by 0.3%, while corporate loans fell markedly by 6.2% between 2007 and 2011 (BdE, 2017c).

From 2010 onwards, the global economy entered a period of stabilisation. In Spain, however, the adjustment process lasted longer than in the more competitive economies. The main obstacles to recovery were the high indebtedness of both the public and private sectors as well as the deterioration in the resilience of the banking sector due to the losses in the real estate and construction industries. Another persistent challenge was the high unemployment rate, particularly among young people (approximately 48%).

Nonetheless, by the end of 2010, the situation of the Spanish economy had deteriorated further as market uncertainty increased following the crises in Greece and Ireland. The spread of Spanish government bonds over German Bunds exceeded 200 basis points at the end of 2010, which significantly hindered the ability of financial institutions and enterprises to obtain funding on foreign markets (BdE, 2017c). Moreover, the situation was exacerbated by a shift towards restrictive fiscal policy, which was in line with the direction set within the EU. Cuts in public spending and increases in taxation had an adverse impact on households, their consumption and corporate investment, which in turn further weighed on the economy and growth prospects. In 2010, the government approved the Fiscal Consolidation Plan for 2010–2013. According to this programme, a deficit reduction of 1.6 percentage points in 2010 and 2.3 percentage points per year between 2011 and 2013 was envisaged. The main pillars of fiscal consolidation were the increase in VAT in July 2010 and the abolition of tax deductions for investment in the real estate sector as of January 2011. In the same year, reforms of the labour market and pension system were also approved and minimum capital requirements for financial institutions were raised. From 2010 onwards, the revival of international trade supported Spain's export sector. Household consumption recovered slightly although investment in real estate continued to decrease. The number of loans granted to households and non-financial corporations continued to though the pace of contraction eased – from 2% in 2009 to 0.4% in December 2010. In 2010, the public deficit stood at 9.4% of GDP and the debt-to-GDP ratio at 60% (BdE, 2017c). At the beginning of 2011, the IMF, OECD, European Commission and the Bank of Spain projected positive economic growth of 0.8% of GDP per annum. However, rising uncertainty in the euro area financial markets had an adverse impact on the growth rates of the Member States. In Spain, under these conditions of heightened financial market uncertainty, both financial institutions and the public administration continued to face difficulties in securing external financing.

The increase in the cost of obtaining financing since 2010 was partly passed on to clients, particularly households and small and medium-sized enterprises. Ultimately, in 2011, economic growth was negative, amounting to –1% of GDP. The unemployment rate remained high and reached 23% at the end of 2011. During this period, the number of apartments purchased fell by 30%, while real estate prices decreased by 11%. Loans granted to the private sector also decreased by 3% in 2011 compared with the previous year. In 2011, the budget deficit stood at 9.6% of GDP, while public debt rose to 69% of GDP, more than 30 percentage points above the 2007 level (BdE, 2017c). Both the central government deficit and the debt-to-GDP ratio exceeded the targets that had previously been set in the Fiscal Consolidation Plan. Between December 2007 and December 2011, the value of government bonds that were held by financial institutions, particularly banks, rose by 145%. Owing

to lower interest rates and reduced credit demand, investment in government bonds became a safe option. Over the same period, the ECB launched programmes to improve the situation of banks that were experiencing difficulties in obtaining funds on international markets. From 2011 onwards, central bank deposits increased for the first time since 2008. The value of the loans-to-deposits (LTD) ratio of credit institutions decreased in 2011 compared to its 2007 level (BdE, 2017c). After the 2009 recession, profitability in the financial sector fell sharply; the average return on equity (ROE) decreased from 20% in 2007 to 3% in 2011, while return on assets (ROA) dropped to 0.17%. Between 2007 and 2011, the total capital of banks increased by 26.8% and Tier 1 capital by 53%. In contrast, in the case of savings banks, total capital fell by 14% and Tier 1 capital by 2% (BdE, 2017c). Over the same period, the aggregate capital ratio of banks rose by 2 percentage points and reached 11.6% in December 2011, while the Tier 1 ratio rose by 3 percentage points to 10.2%. For savings banks, the capital ratio increased by 1 percentage points to 12.9% and the Tier 1 ratio rose by 2 percentage points to 10.1% in December 2011 (BdE, 2017c). In 2010, the non-performing loan (NPL) ratio temporarily decreased. However, the second stage of the recession in 2011 once again contributed to an increase in NPLs on balance sheets of banks.

3.1.1.4 *The Crisis Management in Spain (2008–2014)*

After 2008, as the economy entered the contraction phase of the business cycle, the situation of the financial sector also deteriorated. In that year, only partial measures were adopted to mitigate the slowdown. Financial institutions were provided with liquidity in order to strengthen the confidence of depositors and investors in the Spanish financial system (*Medidas destinadas a reforzar la liquidez de las entidades financieras y la confianza de depositantes e inversores*). A change in the crisis-management strategy and financial sector reform occurred in March 2009 after problems in one of the key savings banks on the market – Caja de Ahorros de Castilla-La Mancha – were revealed. In 2009, measures to restructure and consolidate the financial sector were introduced (*Medidas de reestructuración y consolidación del sector financiero*), which were commonly known as FROB I. In 2010, further reforms to strengthen financial institutions and to restructure the savings banks sector were adopted (*Reforzamiento de la solvencia de las entidades de crédito*), which were referred to as FROB II. Among the most important interventions and reforms was the creation of the high-quality asset fund FAAF (*Fondo para la adquisición de activos financieros de alta calidad*) with resources of between €30 and €50 billion and the development of a guarantee system for selected issuances.¹ Between November 2008 and January 2009, four auctions of funds for banks were held, eventually benefiting 54 financial institutions. In October 2010, a new mechanism for granting government guarantees was adopted as part of an EU-wide plan. According to this mechanism, the government could guarantee the temporary issuance of new securities on the secondary market by Spanish credit institutions. The total volume of guarantees in 2008–2009 amounted to €69.7 billion (BdE, 2017c).

Even before the EU Directive 2009/14/CE was adopted, Spain passed Royal Decree 1642/2008 of 10 October 2008, which raised the minimum guaranteed amount from €20,000 to €100,000. This measure was intended to strengthen confidence in financial institutions during the crisis (BdE, 2017c). During the crisis, the Deposit Guarantee Fund, together with the Bank of Spain, repeatedly assisted financial institutions. However, following the intervention in the case of the La Mancha savings bank (*Caja de Ahorros de Castilla-La Mancha*), the authorities decided to formalise the resolution procedures. In July 2009, the Fund for Orderly Bank Restructuring (FROB, *Fondo de Reestructuración Ordenada Bancaria*) was created under Royal Decree 9/2009 of 26 July 2009. The aims of FROB were to manage institutions that were in difficulty, to oversee mergers and acquisitions in the financial system and to support the strengthening of financial institutions' own funds (BdE, 2017c).

During the crisis, the structure of the market changed significantly, see [Table 3.1](#). Restructuring processes in the financial sector mainly concerned the savings banks. As a result, the number of groups fell from 46 at the end of 2007 to 15 by the end of 2011. In June 2010, additional measures

Table 3.1 Restructuring of the financial sector in Spain.

Institution(s)	Date	Amount	Assets
Catalunya Caixa (merger of Catalunya, Taragony and Manresa)	March 2010	1.250	76.600
CEISS (merger of Caja España and Caja Duero)	March 2010	525	45.700
SIP Gorup BMN (merger of Murcia, Penedes, Sa Nostra, Granada)	June 2010	915	73.000
SIP Banco Financiero y de Ahorros (merger of Madryt, Bancaja, Avila, Segovia, Rioja)	June 2010	4.465	328.000
(Layetana e Insular de Canarias) Nova Caixa Galicia Banco (merger of Caixa Galicia and Caixanova)	June 2010	1.162	73.500
Unnim (merger of Sabadell, Tarrasa, Manlleu)	July 2010	380	28.500
SIP Banca Civica (merger of Navarra, Canarias, Burgos in April 2010)	December 2010	977	45.900
(merger of Caja Sol and Caja Guadalajara in December 2010)			
Total		9.674	671.200

Source: BdE (2017c).

were adopted to reorganise financial institutions, in particular the savings banks, with a focus on cleaning their balance sheets of toxic assets. After the adoption of Real Decree-Law 11/2010 of 9 July 2010, the reform of the savings bank sector commenced. In particular, measures were introduced to allow easier access to financing on capital markets, to modify the management of savings banks and to implement further institutional changes. Following the approval of the reform, a savings bank could either be transformed into a commercial bank by changing its statutory objectives or it could become part of the Institutional Protection System (*Sistema institucional de protección*, SIP).

In 2011, another reform of the financial system was introduced, which was centred on new regulations concerning capital requirements, as domestic legislation was aligned with the measures established under Basel III and the EU Capital Requirements Directives. At the same time, the second phase of the Fund for Orderly Bank Restructuring (FROB II) was launched. The legal basis for this reform was Real Decree-Law 2/2011 of 18 February 2011. The basic capital requirement was set at 8% for most institutions and 10% for entities with a lower capacity for raising high-quality capital. In cases of failure to meet the requirement, the Bank of Spain could impose restrictions on profit distribution, dividend payments and payments to management. Under FROB II, it also made it possible for institutions that did not meet capital requirements and faced difficulties in raising funds on the markets to be directly supported by FROB for a period of up to five years (BdE, 2017c). In Real Decree No. 771/2011 of 3 July 2011, additional requirements were introduced regarding the methods for identifying, measuring and controlling liquidity risk as well as the remuneration principles of senior staff depending on the level of risk incurred by the institution. Moreover, In Real Decree–Law 16/2011 of 14 October 2011, the three deposit guarantee funds of banks, savings banks and cooperatives were merged. In addition, on the basis of the Resolution of the Bank of Spain (*Circular del Banco de España*) No. 5/2011 of 30 November 2011, new regulations regarding the transparency of balance sheets, particularly exposure to the real estate sector, were implemented.

In March 2011, the Bank of Spain announced estimates of undercapitalisation of banks in relation to the newly adopted Basel III capital requirements. Thirteen institutions were identified as being undercapitalised. The Bank of Spain approved a new strategy to raise the missing funds. Four institutions turned to private investors for financing. Bankia and Banca Cívica raised funds on the stock market. Banco Mare Nostrum (BMN) issued securities in the form of preferential shares with voting rights. Liberbank made internal financial adjustments to meet the requirement. In the case of Barclays and Deutsche Bank, the funds were provided by their parent banks. Bankinter and Bankpyme both conducted procedures to obtain external capital and transferred funds within the group. Caja España de Inversiones, Salamanca y Soria and Caja de Ahorros y Monte de Piedad (CEISS) – itself the product of an earlier merger between Caja España and Caja Duero – were subsequently merged with Unicaja. This transaction formed part of the wider consolidation of the Spanish savings banks sector, which had been undertaken during the restructuring process to strengthen financial stability and improve institutional resilience. Four institutions – NovaCaixaGalicia, Catalunya Caixa, Unnim Banc, S.A. (Unió de Caixes de Manlleu, Sabadell y Terrassa), and Caja de Ahorros del Mediterráneo (CAM) – applied for FROB's financial support (BdE, 2017c).

The largest undercapitalisation, amounting to €2.8 billion, was observed in the case of CAM. In July 2011, the Bank of Spain prepared a restructuring plan for CAM under FROB, which assumed a merger with Banco Sabadell. The Deposit Guarantee Fund approved financial support in the form of €5.4 billion. In most cases, the merger of savings banks was conducted through SIP. Conducting mergers in the case of institutions that were closely linked to a given region was particularly difficult. Mergers that were implemented through SIP allowed institutions to maintain operations in their region and preserve their name and legal status, while at the same time being subject to control through SIP (BdE, 2017c).

In the period 2010–2011, the emphasis was placed on increasing the transparency of the financial sector's activities. For this purpose, stress tests were performed to provide information on the system's resilience. The results of the first round of stress tests were published on 23 July 2010. These tests were based on balance sheet data as of 31 December 2009 and the scenarios included analyses for the following two years. The study covered 27 banking institutions including the groups of savings banks undergoing or having completed restructuring. In particular, the loan portfolios for the real estate and construction sectors were examined. According to the results, no institutions recorded Tier 1 capital below the required minimum. In 2011, further stress tests were conducted, coordinated by the European Banking Authority (EBA). These tests covered 93% of the EU financial system. In this study, the minimum Tier 1 capital requirement was set at 5%. According to the results, the average CET1 ratio was 8.6% and no institutions fell below the established threshold. In the same year, the EBA decided to recapitalise the main institutions of the EU financial system. In Spain, five key market players were included in the stress tests. The adopted scheme required institutions to maintain a CET1 ratio of 9% in order to strengthen market confidence in system stability. An additional buffer was also required for institutions with high exposure to sovereign debt.

Although by 2012 the United States had already recovered from the financial crisis, a second recession struck the EU. This downturn primarily affected the peripheral economies – Spain, Italy, Portugal and Ireland. The deepest contractions were recorded in Spain, Italy and Portugal where GDP decreased by between 4% and 5% and in Greece where output fell by around 10%. By contrast, growth in the core economies was weaker but remained positive with Germany expanding by 1.3% and France by 0.8%. At the beginning of 2012, the risk premium remained at a high level. The bond spread fell by 500 basis points for Italian bonds, 350 basis points for Belgian and Spanish bonds and 80 basis points for French bonds compared to November 2011 (BdE, 2017c). Nevertheless, risk premia were still significantly higher than at the beginning of 2011. In April 2012, market uncertainty increased in relation to the situation of the Spanish and Italian economies. The main concerns were the weak state of public finances and doubts over the resilience of the banking systems in these countries. At the same time, in Greece, uncertainty grew regarding the country's future within the EU

and euro area in particular. In July 2011, Cyprus, which was strongly exposed to the Greek banking sector, required financial assistance.

After the emergence of the sovereign debt crisis in Greece, uncertainty increased over the future of the euro area and the single currency. This uncertainty adversely affected other countries, in particular the EU peripheral countries, where doubts arose about the stability of the financial system, the further increase in public deficits and rising unemployment rates. In April 2012, funding conditions for Spanish institutions deteriorated once again. In May 2012, systemic risk materialised in the form of an application for recapitalisation of the BFA–Bankia group. In response to the bank's problems, a “flight to quality” began, which worsened the situation of the Spanish economy. The risk premium increased while stock prices fell sharply. In June 2012, Spain requested financial assistance from the EU institutions. The granting of financial support and the implementation of a series of reforms helped to gradually restore its access to foreign markets and attract external capital. In the same year, the Financial and Budgetary Stability Law was adopted, which limited the level of public deficit and debt. In 2012, the central government deficit reached 6.8% of GDP; excluding external financial support, it amounted to 3.7% of GDP. Public debt rose to 86% of GDP in the same year. A labour market reform was also implemented in 2012 to make the labour market more flexible and thus increase employment. As part of this reform, the decentralisation of wage negotiations was introduced to enhance the flexibility of companies in hiring and dismissing employees and issues related to temporary and permanent contracts were also addressed. Additionally, legislation was amended to liberalise the activity in selected sectors of the economy and to strengthen competitiveness. To provide financing for indebted Autonomous Regions (CCAA), the Autonomous Liquidity Fund (FLA) (*Fondo de Liquidez Autonómica*) was created (BdE, 2017c).

In 2012–2013, the authorities implemented new policies to strengthen the resilience of the financial system. In February and May 2012, Real Decrees were adopted that increased provisions of banks for operations financing the real estate market. In addition, on 20 July 2012, the European Commission signed a Memorandum of Understanding and public assistance was provided to the financial sector. The EU and Spanish authorities agreed on external financial support amounting to €10 billion, which was preceded by an assessment of the quality of banking assets.

Reforms of the savings banks also continued. During 2012–2013, the special role of SAREB (*Spanish Sociedad de Gestión de Activos Procedentes de la Reestructuración Bancaria*) in cleaning up toxic assets from balance sheets should be emphasised. During this period, €324 billion of such assets were removed. The toxic assets mainly related to loans that had been granted to companies in the real estate and construction sectors. In 2013, the highest level of non-performing loans was reported. The NPL ratio for both banks and savings banks was approximately 14% in 2013 (BdE, 2017c).

During the second stage of the crisis in Spain, government bonds that were being held by financial institutions were used as collateral in the liquidity operations that were conducted by the ECB in August 2012. The ratio of government bonds to assets was higher in the case of savings banks than commercial banks. For savings banks, the ratio amounted to 11.6% in 2013 and 7.2% in 2011. For banks, it was 5.5% in 2011 and 6.5% in 2013. During the second recession in the EU, the decrease in ROE reached –21%, while ROA fell to –1.2%. Paradoxically, in the period from 2007 to 2011, both banks and savings banks maintained a solid capital base. Nonetheless, negative financial results gradually eroded the capital of the entire financial system. The decreases in Tier 1 capital mainly concerned savings banks. Risk-weighted assets also decreased in 2012. The largest decrease occurred in savings banks (11.8%). Banks reduced risk-weighted assets by 1.6% in 2012, while savings banks reduced them by almost 30%. This was also linked to the balance sheet cleaning strategies of Sareb. In 2012, for the group of deposit institutions, capital ratios fell to 11.4%, while the Tier 1 capital ratio decreased to 9.8%. However, there was significant heterogeneity in the capital being held by institutions. The average ratio of capital to risk-weighted assets and Tier 1 capital to risk-weighted assets for banks was 11.8% and 10.7%, respectively, whereas for savings banks the average values were 10.6% and 7.6% (BdE, 2017c).

In 2013, the capital of the entire sector of depository institutions increased by 3.5% and Tier 1 capital doubled to 8.2%. This improvement was mainly driven by an increase in capital in the savings banks sector. In 2013, due to the growth in capital volume alongside a simultaneous decrease in risk-weighted assets, the capital ratio rose to 13.2% in December 2013, while the Tier 1 capital ratio increased to 11.8%. The improvement was particularly pronounced in the case of savings banks (BdE, 2017c).

It is worth emphasising that before requesting EU assistance for the banking sector, Spain commissioned stress tests from two independent consulting firms, Roland Berger and Oliver Wyman. The evaluation covered 14 banking groups whose assets represented 90% of the Spanish banking system. According to estimates published on 21 July 2012, about €16–€26 billion were missing in the baseline scenario and €51–€62 billion in the stress scenario. In addition, a bottom-up analysis of individual banks was conducted. In the second evaluation of the banking sector, the need to recapitalise €55.9 billion was identified (Oliver Wyman, 2012; Roland Berger Cons., 2014; BdE, 2017c).

After identifying the recapitalisation needs of banking institutions, the authorities made decisions concerning four groups of entities. For the first group, on 28 November 2012, it was decided to recapitalise BFA-Bankia, NCG Banco, Catalunya Banco and Banco de Valencia using FROB funds. The recapitalisation was conducted on 26 December 2012 for a total amount of €36.9 billion. On 31 December 2012, the toxic assets were transferred to Sareb. Based on the Real Decree-Law 2/2012, €802 million were allocated to the recapitalisation of BFA, €2 257 million to cover provisions and €872 million to recapitalise Bankia. In addition, these institutions were required to implement internal reforms of their management systems, whose effectiveness during the crisis had been questioned. Regarding the second group, on 20 December 2012, a decision was made to restructure Banco Mare Nostrum, Caja3 and Liberbank through recapitalisation with public funds. For the third group, Banco CEISS, the orderly liquidation procedure was initiated. In the final group, Banco Popular and Ibercaja were able to cover their deficits without public assistance (BdE, 2017c).

In May 2010, Caixa d'Estalvis de Catalunya, Caixa d'Estalvis de Tarragona and Caixa d'Estalvis de Manresa merged with the operation being supported by FROB. However, in 2011 restructuring was required once again and Catalunya Banc was created, which subsequently obtained FROB funding. In 2014, a small part of Catalunya Banc's portfolio was sold to Blackstone, while the remainder (98.4%) was acquired by BBVA (BdE, 2017c). Similar to Catalunya Banc, in June 2010, Caja de Ahorros de Galicia and Caixa de Aforros de Vigo, Ourense e Pontevedra merged forming NovaCaixaGalicia, which received FROB support amounting to €1.16 billion. In 2011, an additional pool of public assistance amounting to €2.5 billion (FROB II) was approved alongside the restructuring of the group through NCG Banco. Despite the public assistance, in 2012, the bank was once again included in the allocation of EU funds. In 2014, this institution was sold to Banco Etcheverría SA/Grupo Banesco (BdE, 2017c).

The assessment of Banco de Valencia in 2012 revealed undercapitalisation of €3.4 billion. In November 2012, the resolution procedure for Banco de Valencia was initiated based on the Bank of Valencia Liquidation Plan (*Plan de Resolución del Banco de Valencia*).

In 2014, a positive economic growth rate was recorded in Spain (1.4%). The most difficult situation persisted in the labour market where the unemployment rate remained at 23.7% of the active population in the last quarter of 2014 (BdE, 2017c). Cooperation within the euro area to counteract the effects of the crisis reduced uncertainty. Stress tests that were conducted in 2014 confirmed the stability of the Spanish financial sector and contributed to a decrease in financing costs. The improvement in the economic and financial situation also supported an increase in credit supply and a partial easing of credit conditions for small and medium-sized enterprises. The central government deficit was reduced to 6% of GDP, while public debt rose to 100.4% of GDP. The economy was also positively affected by falling oil prices on the global markets. Both consumption and investment increased in 2014, by 8% and 1.6%, respectively, compared to the previous year. Moreover, for the first time since the crisis, investment in real estate increased. Household and corporate indebtedness

Table 3.2 Additional funds for institutions from FROB and FGDEC.

December 2013	FROB	FGDEC
NCG Banco	62.7%	25.6% (a)
Catalunya Banc	66.0%	32.4% (a)
Bankia	68.4%	–
BMN	65.0%	–

Source: BdE (2017c).

fell by 24 percentage points of GDP from the peak level that had been reached in 2010. Nevertheless, real estate investment remained below the historical average. Given the very high level of financial leverage, deleveraging continued in 2014. The sharpest contraction in lending was recorded in the construction and real estate sectors. Compared to December 2007, the stock of loans granted in December 2014 had decreased by 22.9%. The largest decrease concerned loans to non-financial corporations (–36.8%), followed by households (–13%). Within the corporate sector, the steepest decrease was observed in real estate and construction (–56.1%). Non-performing loans decreased compared with the peak level recorded in 2013 (BdE, 2017c).

The improvement in the economic situation translated into higher profitability for financial institutions. The ROE ratio rose to 6.6% in 2014, although this was still well below pre-crisis levels. Capital ratios and Tier 1 capital ratios improved in 2015 as a result of capital growth and the stabilisation of risk-weighted assets. During 2014–2015, the Spanish financial system continued its restructuring. For four institutions, support from FROB and FGDEC was required, see Table 3.2. The solvency and profitability of financial institutions improved compared to the period of greatest uncertainty in 2011–2012 owing to the recapitalisation of banks, the restructuring of the banking sector and the orderly liquidation of selected institutions.

In 2014, FROB and FGDEC sold their shares in NCG Banco and in 2015 in Catalunya Banc. On 15 March 2017, FROB announced plans to merge Bankia with BMN. From 2012 to the end of 2014, the cooperative sector was also restructured. In particular, in 2012, Cajamar and RuralCaja merged creating the SIP Grupo Cajas Rurales Unidas, which was composed of 19 cooperatives. Since 2014, the SIP has been headed by Banco de Crédito Cooperativo (BdE, 2017c).

After a long period of restructuring in the EU banking system, the next stress tests were conducted in November 2014. Using 2013 data, these tests covered 130 institutions from 19 countries including 15 Spanish banks that represented 90% of the Spanish banking system's assets. The evaluation was conducted in two stages. In the first stage, an Asset Quality Review was undertaken. In the second stage, stress tests were conducted according to the methodology that had been developed by the EBA. The tests required each institution to maintain minimum capital levels of sufficient quality. Specifically, each bank had to meet a CET1 requirement of 8% in the first stage and 5.5% in the adverse scenario of the second stage. According to the results, all 130 institutions across Europe were deemed to be insufficiently capitalised. The effects of capital-raising measures that had been introduced at the beginning of 2014 were not yet reflected in the tests. For Spanish banks, however, the results were satisfactory. Only one institution was required to supplement its capital, which was done before the stress test results were published. These positive outcomes reflected the impact of the measures that had been implemented to restructure the banking system.

3.1.2 Greece

3.1.2.1 Prior to the Accession to the EMU

In the 1980s, Greece's undercapitalised banking sector was sustained through injections of public funds. Between 1994 and 1999, a series of reforms initiated the deregulation of the financial system

and consumer credit, while capital movements were liberalised. These reforms included the establishment of a secondary bond market and the phasing out of financing provided by the Bank of Greece under Regulation 3604/93 (BoG, 2014). After the changes in the banking sector during the 1990s, by 1998, 70% of the banking system remained in public ownership. During this period, the banking system was stable and resistant to external shocks; however, the problem of moral hazard was largely underestimated.

Between 1998 and 2000, a series of privatisations and restructuring measures were implemented in the banking sector. As a result, four major banks emerged that controlled more than 65% of the market: the National Bank of Greece, Alpha Bank, Eurobank and Piraeus Bank. The first of these remained under indirect government control. At the same time, a policy of promoting stock market investment was pursued. In 2000, the stock market bubble burst, which led to a decrease in the wealth of households, investment and pension funds and companies. Between 2000 and 2001, private sector debt increased. The rising indebtedness in the private sector fuelled economic growth in Greece as was the case in Spain and Ireland.

In the years leading up to Greece's accession to the eurozone, the fiscal deficit was reported to have decreased from 13.6% of GDP in 1993 to 2.0% in 1999, although the reliability of these figures was later questioned. Over the same period, GDP growth accelerated from 2% in 1994 to 3.4% in 1999, while the inflation rate fell to 2.1%, supported by a steady decrease in interest rates (BoG, 2014). According to economic theory, accession to the single currency area should accelerate growth by reducing uncertainty, foreign exchange risk and financing costs, while anchoring inflation. Consistent with this, inflation rate fell from double-digit levels in the 1970s to an annual average of 3.3% between 2001 and 2007 (BoG, 2014).

3.1.2.2 Building Up of Vulnerabilities in the Expansion Phase of the Cycles (2000–2007)

Following its entry into the economic monetary union (EMU), Greece experienced a period of rapid development with an average annual growth rate of 4.2% between 2001 and 2007. This expansion was largely driven by private consumption, which increased at the same pace as GDP over that period. Rising incomes fuelled an expansion of credit and housing investment, much as it did in Spain. Yet, as in the Spanish case, the growth model that underpinned this performance proved to be unsustainable in the medium to long term (BoG, 2014).

Owing to an inflation rate averaging 3.3% per annum – significantly higher than that of the euro area as a whole – the Greek economy gradually lost competitiveness, a pattern that was also observed in Spain. At the same time, the growth of domestic demand proved to be insufficient for sustaining the country's broader needs. Between 2000 and 2007, the current account deficit widened to 8.5% of GDP, while exports remained the lowest among the peripheral euro area economies, amounting to 23.8% of GDP in 2007, compared to 26.9% in Spain, 32.2% in Portugal and 28.9% in Italy (BoG, 2014).

In the years following Greece's accession to the EMU, the structural problems of the peripheral countries, particularly Greece, remained unresolved. Moreover, between 2001 and 2004 its fiscal policy was excessively expansionary. After the adoption of an Excessive Deficit Procedure, fiscal policy became somewhat more restrictive but not sufficient enough to offset the imbalances that had already accumulated in the early 2000s (BoG, 2014). In contrast to the Spanish economy, the state of Greece's public accounts was much weaker. The government deficit amounted to 7.4% of GDP in 2004, only a few years before the financial crisis. According to the provisions of the Stability and Growth Pact and in line with the requirements of the Excessive Deficit Procedure that had been established by the ECOFIN decision of 2 February 2005, Greece was required to reduce its deficit to 3% of GDP. Nonetheless, the Greek authorities did not make sufficient efforts to improve public finances and no institutional framework was established to monitor and control the budget deficit and debt. The Greek economy also failed to take advantage of the favourable conditions of the 2000s to consolidate its public accounts when growth was strong and interest rates remained low. Revenues

from the privatisations that had been undertaken in the 2000s were used ineffectively. In addition, Greece's credibility was damaged when inaccuracies in the public accounts were revealed in the mid-2000s. The imbalances that had accumulated during the 2000s left the economy more exposed to the crisis. In 2008, Greece entered a recession although the European Commission forecasts at the time remained optimistic about its severity.

3.1.2.3 The Contraction Phases of the Cycles and the Crisis in Greece (2009–2013)

Although the crisis originated in the United States, confidence in the Greek economy had already been undermined. In 2009, GDP contracted by 3.2%, the fiscal deficit climbed to 15.7% of GDP with figures initially being misreported and only revised in April 2010 and public debt rose to 129.7% of GDP. The cumulative loss of international competitiveness amounted to 16.9% (BoG, 2014). A key factor in the propagation of the crisis was the role of uncertainty and expectations regarding the economy's current state and future outlook. The first symptoms were visible in the interbank market after Greece's credit rating was downgraded from A to A– and later they were present in all financial markets. The spread between Greek and German bonds widened significantly. Moreover, following the elections of 4 October 2009, the new government's decision to increase public spending further heightened uncertainty over the country's future.

During the crisis, the Bank of Greece closely monitored developments and proposed policies and reforms. As early as 2008, it highlighted factors that mitigated the immediate impact of the crisis on the Greek economy, notably the decrease in oil prices and labour mobility. At the same time, the Bank emphasised the urgent need to consolidate public finances in Greece and called for a more expansionary monetary policy in the euro area. In reports published in April and October 2008 and in February, April and October 2009, the Bank of Greece assessed the scale of economic imbalances and the problems facing the Greek financial sector. It also noted that rising uncertainty in the markets combined with fiscal weaknesses posed serious risks. The Bank stressed that a shift in the fiscal stance was necessary to reduce the public deficit, debt and current account imbalance. It further warned that the increase in the spread between Greek and German government bonds would place a greater burden on taxpayers in the future (BoG, 2014). At the outbreak of the financial crisis, the long-standing structural problems of the financial sector from the 2000s materialised.

The impact of the global crisis became visible in Greece in 2009, when a decrease in credit and a slowdown in economic growth were observed. From that year onwards, the demand of Greek banks for liquidity from the Eurosystem also increased. In Greece, problems that had originated in the public sector soon spread to the banking sector. In June 2009, the Bank of Greece emphasised the resilience of the Greek banking sector and published the results of stress tests that were based on scenarios prepared by the IMF. The 2009 results were positive and no immediate threat to financial stability in Greece was identified. Between 2008 and 2009, additional measures were introduced to provide liquidity to the banking sector and to strengthen, at least partially, its resilience to shocks. Nevertheless, by 2009, it became clear that banks could not maintain sufficient liquidity without external assistance.

During this period, the microprudential supervision of credit institutions was reinforced under Banking Law 3601/2007 and through the implementation of the Committee of European Banking Supervisors (CEBS) guidelines. According to the Bank of Greece, new elements were introduced into the supervisory framework in 2008. These included amendments to capital provisions for credit institutions and the introduction of a new risk-based methodology for calculating capital requirements. Owing to the large exposure to U.S. securities and the spread of the U.S. crisis, new methods were adopted for calculating the capital requirements for securitisation-related exposures. As in other countries, provisions were also introduced to control the risks associated with large exposures. By the end of 2008, discussions had begun on the introduction of macroprudential supervision and instruments. In an effort to mitigate systemic risk, attention was focused on monitoring payment, clearing and settlement systems to ensure their efficiency and reliability. In particular, Act 3723/2008

included provisions that were aimed at strengthening the capital base and fulfilling liquidity requirements, thereby limiting the risk of a credit crunch and mitigating the crisis's impact on the economy. However, following the reform, banks were reluctant to seek support owing to fears of stigma. As a result, the impact of the reform was limited (BoG, 2014).

In 2010, the financial crisis in the euro area evolved into a sovereign debt crisis. Among the eurozone countries, Greece proved to be the weakest link as it faced the largest imbalances in its current and fiscal accounts alongside deep structural problems. From May 2010 onwards, the crisis became more difficult to manage than previously anticipated. The question of reforming the EMU and addressing the imbalances between the core and peripheral EU countries was also raised. At the European level, institutional reforms were introduced to mitigate systemic risk and limit the severity of the crisis. In Greece, meanwhile, measures were adopted to improve competitiveness and strengthen public finances. The main objectives of the Greek authorities were to meet the requirements of support programmes and to work towards a new growth model. On 11 February 2010, EU support for the Greek government, which was subject to a series of conditions, including, in particular, a decrease in the fiscal deficit to 4% of GDP in 2010 was announced. The primary aim was to stabilise Greece's economy and financial system as well as the eurozone as a whole. Based on this decision, in May 2010, Greece received the first tranche of funds from the European Commission, the European Central Bank and the International Monetary Fund. Greece was the first to receive such assistance followed by Ireland a few months later. The aim of the aid package was to reduce financing costs for both the private and public sectors and to limit the spread of systemic risk, first among the EU's peripheral countries and subsequently across the wider Union.

As was noted earlier in the case of Spain, the European Financial Stability Facility (EFSF) was established in May 2010. It was used not only by Spain but also by Greece. In addition, the expansionary monetary policy of 2010 sought to boost market liquidity, improve financing conditions and support credit flows to the real economy. In response to the crisis not only conventional but also unconventional measures such as interventions in the secondary market through the purchase of government bonds issued by certain countries were implemented. The provision of assistance and the favourable results of banking sector stress tests in 2010 temporarily boosted confidence in the financial system though only for a short period (BoG, 2014). In May 2010, a new EU strategy, the "European Semester", was proposed to strengthen cooperation among Member States and ensure compliance with the principles of the Stability and Growth Pact. The cooperation framework was further defined in September 2010 through the so-called "Six-pack". Its main provisions concerned fiscal discipline and sanctions for non-compliance, the introduction of the reverse qualified majority voting rule and the creation of a set of economic indicators to monitor macroeconomic imbalances and systemic risk. In 2010, the European Systemic Risk Board (ESRB) was also established. The Greek crisis, to a large extent, highlighted the need for enhanced cooperation in macroprudential oversight across the EU and for the development of EWS. Although Greece received public assistance in 2010 and undertook measures to reduce structural imbalances and improve public finances, risks linked to rising imbalances and doubts about the future of the eurozone intensified from 2011. In April 2011, Portugal became the third country to receive financial aid from the Troika with the economic adjustment programme being adopted by the Eurogroup on 17 May 2011. However, growing social opposition to the conditionality that had been attached to the support programmes fuelled negative expectations regarding Greece's future (BoG, 2014). In 2011, it was also decided to allow interventions in the primary market for government bonds. In addition, the maturity of bilateral loans to Greece was extended to 7.5 years and interest rates on these loans were reduced. "Due to the interconnectedness of the global economy, most countries expressed concern that Greece could declare insolvency, which could lead to the deepest recession in recent years" (BoG, 2014). Rising uncertainty over the future of the euro also posed a threat of a systemic event. In July 2012, Greece received a second support package. However, this did not prevent a rise in interest rates on government bonds in the larger euro area countries.

3.1.2.4 Alternative Look at the Causes and Course of the Crisis in Greece

After joining the eurozone, the cost of living in Greece increased. During this period, banks sought foreign sources of financing, which they obtained mainly from banks in the EU's core member states, especially Germany. The rise in household consumption was largely financed through loans and advances. Between 2001 and 2008, the number of loans that had been granted to households increased five-fold. As in Spain, the expansion of credit was particularly marked in the mortgage sector. However, the difference between Spain and Greece was that while in Spain the increase in mortgage lending was driven primarily by the private sector, in Greece, the public administration played an active role. Moreover, liquidity and maturity mismatches were greater in Greece than in Spain. By 2005, most banks were highly profitable. Alongside the increase in bank profitability, foreign investor interest also grew. In March 2004, 50.2% of the General Bank of Greece's shares were acquired by Société Générale and Beniki Bank was created. In August 2004, Crédit Agricole SA purchased shares in Emporiki Bank SA. In 2005, policies supporting investment in the real estate sector were introduced along with mortgage and investment loans for this sector. As in Spain, a housing bubble developed, which was accompanied by a rapid increase in lending to the private sector.

The crisis in Greece began in 2009. Its course was exceptionally rapid and cannot be explained solely in terms of cyclical fluctuations or changes in the phases of the financial cycle. The main reasons were, above all, the high level of indebtedness, structural weaknesses of the economy that limited competitiveness, the crisis of the banking sector and the subsequent loss of investor confidence in the state of the economy and the solvency of the country. The dynamic increase in debt was also linked to high debt-servicing costs and high wages in the inefficient public sector. Institutional and structural factors as well as problems related to mismatches in the structure of assets and liabilities were also significant.

The direct trigger of the confidence crisis and the surge in market uncertainty, however, was the publication of false data on the economy and the financial sector after Greece's accession to the eurozone in 2002. In 2009, the practice of falsifying statistics – particularly those relating to the public deficit – was disclosed by Yorgos Papandreou during the election campaign. In contrast to Spain, Greece's budget deficit was exceptionally high at 12.7% of GDP even before the global economic slowdown began. Official sources, however, had submitted false data to the EU institutions, reporting a deficit of only 3.7% of GDP. Unlike in Spain, in Greece there was also a link to the large-scale use of U.S. derivatives and a regulatory gap in the euro area. Because there was no requirement to report exposures to foreign currency derivatives, Greece used such instruments to conceal its true level of indebtedness. After the 2009 elections, the deficit stood at 12.7% of GDP and public debt at 113.4% of GDP. The banking system faced difficulties not only because of the high share of government bonds in the portfolios of banks but also because market concerns escalated sharply after the publication of the real deficit and debt figures. The lack of trust in the Greek government, the publication of unreliable statistics on the economy and financial system and uncertainty over Greece's future in the eurozone all contributed to capital flight. From 2009 onwards, the spread between Greek and German bonds widened sharply. In the face of rising uncertainty, stock market prices fell and investor losses triggered further capital outflows from the country.

In the face of mounting problems and uncertainty about the future of the euro area, the European Commission instructed Greece to reduce its deficit and debt and to implement structural reforms including wage cuts, which triggered a wave of protests. In March 2010, a consolidation plan to save €4.8 billion was approved, primarily through higher taxes and sharp expenditure decreases, particularly in social spending. In March 2010, a decision was also taken to launch the first EU financial support programme for the Greek economy. The publication of data that confirmed a recession in 2008 worsened the outlook for debt reduction, which led to a downgrade of Greece's credit rating and an increase in uncertainty. Amid falling investor confidence, on 21 April 2010, talks were held between the Greek government, the European Commission, the European Central Bank

and the International Monetary Fund. On 2 May 2010, a loan of €110 billion was approved, which was conditional on the implementation of structural and privatisation reforms and above all, budget cuts and debt reduction plans. These requirements provoked strong protests in Greece.

As the Greek economy deteriorated further, a second financial support programme, which was primarily aimed at recapitalising the undercapitalised banking sector (€88 billion), was approved on 21 July 2011. The programme entered into force in 2012. In total, the financial support that was granted between 2010 and 2014 amounted to €240 billion. The adoption of the assistance programmes led to repeated waves of protest. In addition to the original state aid, Greece was also granted IMF loans totalling €8.2 billion for the period of January 2015 to March 2016.

In 2014, for the first time, the economy showed signs of recovery and Greece's debt decreased thanks to the generation of a primary budget surplus. However, after this period of relative improvement, Greece fell back into recession beginning in the fourth quarter of 2014. Amid growing social discontent, in 2014, the political party SYRIZA came to power. SYRIZA rejected the repayment of loans and demanded a loosening of state aid conditions. Following unsuccessful negotiations, the International Monetary Fund, the European Commission and the European Central Bank decided to withdraw financial assistance to Greece, which triggered a liquidity crisis and sharp decreases on its stock market. After the next election, the terms of the agreements were renegotiated and the next tranche of international aid for Greece's economy and banking sector was granted. Negotiations, however, were repeatedly interrupted due to persistent social unrest.

In July 2015, Greece submitted an application for further international assistance and presented proposals for tax reform and expenditure reduction. A series of additional reforms was also planned, which provoked protests, particularly from the trade unions. The approval of reforms on 22 July 2015 enabled negotiations on obtaining international assistance. These negotiations concluded with the signing of a financial support agreement on 11 August 2015.

3.1.2.5 Reforms in Greece During the Crisis

Among the most important reforms was a 10% decrease in the remuneration for public officials and an increase in the retirement age from 61 to 63 years. As in Spain, a decision was also taken to increase VAT on selected products. In addition, in April 2011, a series of privatisations was undertaken.

The most controversial reforms and those that provoked the greatest social resistance, were wage cuts (including a 22% decrease in the minimum wage), pension decreases and steep tax increases, which further burdened the economy and constrained growth. Moreover, macroprudential policy measures were introduced under Act 4261/2014, which transposed the CRD IV/CRR provisions.²

3.1.3 Ireland

Between 1994 and 2007, the Irish economy grew very dynamically, driven by both external and internal factors. Growth was supported by the ECB's low interest rate policy, which, however, contributed to the emergence of a housing bubble and a partial loss of competitiveness. During this period, a number of policies and reforms were adopted to promote investment in the real estate and construction sectors including tax incentives for companies operating in these areas. At the same time, the economy appeared to be highly stable, particularly due to the banking rules that had been introduced in the 2000s under the Basel Accords. Nevertheless, weaknesses in public finance management and numerous cases of corruption highlighted persistent problems in the public sector. Moreover, banks that seemed stable were in fact heavily indebted abroad due to refinancing real estate projects through foreign borrowing. In 2007, the real estate and construction sector slowed for the first time, thus signalling the end of the Irish growth model, which was similar to that of Spain that was discussed earlier. Rising uncertainty in financial markets also made it more difficult to refinance projects on international markets. When difficulties in the real estate market emerged, the mismatches between assets and liabilities became apparent. Banks reported liquidity needs as much

of the property that had been repossessed due to business insolvencies could not be sold during the crisis. This feature was not only characteristic of Ireland but also of Spain, Greece and the United States.

By 2007, the first symptoms of a crisis and signs of public debt problems had appeared. Although Ireland had recorded a budget surplus before the crisis (1.2% in 2007), after 2008 public finances deteriorated. Economic growth decreased with GDP falling by 8.5% in the first quarter of 2009 compared to the previous quarter and the unemployment rate rose sharply from 8.75% to 11.4%. In 2009, the unemployment rate continued to climb and reached 14.6%. As in Spain, Irish banks were highly exposed to the real estate sector with the largest exposure held by Anglo Irish Bank. The outbreak of a scandal over concealed losses from mortgage loans led to a collapse of the bank's valuation and panic on the stock market.

The Irish government officially confirmed the recession in September 2009 but emphasised that it was the result of the global economic slowdown. Negotiations on the draft budget were particularly difficult during the crisis. The new budget focused mainly on raising taxes and changing the patterns of public spending. Proposed changes to healthcare and the possible reintroduction of payments for schools and university studies sparked protests, particularly among students and pensioners. Social discontent deepened in 2009 after the suspension of payments at Waterford Wedgwood followed by a wave of redundancies at Waterford Crystal. In addition, pension reforms were introduced in February 2009. To calm public sentiment, trade unions organised meetings with government representatives, which led to the signing of the Croke Park Agreement under which the government committed to halting further cuts in remuneration.

As for banking support measures, on 19 September 2008, the government introduced an unlimited guarantee for the six main banks in the system. This measure was initially approved by the European Commission. However, in the subsequent period, these guarantees proved to be insufficient. In April 2009, the National Asset Management Agency (NAMA) was established to provide large loans to banks in order to safeguard their liquidity. The first NAMA assessment was conducted in September 2009 prior to the issuance of the second series of guarantees for the banking system. The costs of NAMA's activities combined with state aid to banks and the budget deficit contributed to a sharp increase in public debt in Ireland. In April 2010, the Public Debt Agency published a note stating that no support was required to raise funds on foreign markets to refinance debt. However, by September of the same year, banks had begun to experience difficulties in obtaining financing. Consequently, the authorities decided to renew bank guarantees for a third year. This decision was not positively received by the markets and the spread between Irish and German bonds widened significantly.

Rising costs of bank assistance forced the government to begin negotiations for external public support. A formal application for financial assistance was submitted on 21 November 2010. International aid was granted under the EFSM–IMF–EFSF–NPRF support programme, which combined contributions from the European Financial Stabilisation Mechanism (EFSM), the International Monetary Fund (IMF), the European Financial Stability Facility (EFSF) and Ireland's National Pensions Reserve Fund (NPRF). The programme included €20 billion for bank recapitalisation, €25 billion to cover banking sector losses and €50 billion for budget financing.

In April 2011, Moody's downgraded Irish sovereign bonds to the lowest investment grade. Amid heightened uncertainty, discussions began on a second tranche of aid for Ireland. In 2012, a referendum was held to amend the constitution and incorporate the provisions of the Treaty on Financial Stability into Article 29 of the Constitution. In 2013, a series of further reforms was implemented and measures were adopted to reduce market uncertainty and increase support to the banking sector. In February 2013, IBRC Bank was liquidated. Officially, Ireland exited the crisis in December 2013. In addition to the implementation of ad hoc measures to counter the negative effects of the crisis, macroprudential policies were also introduced in Ireland. A comprehensive analysis of macroprudential measures is presented in the subsequent chapters of this book.

3.2 Systemic Risk in the Scandinavian, Baltic and Central and Eastern European Countries

It is difficult to describe the mechanisms and effects of the crisis without considering the impact of the Icelandic crisis on the EU economy and banking system. Nonetheless, our analysis focuses on EU Member States. The mechanisms and consequences of the Icelandic crisis for the EU were examined by Mishkin and Herbertsson (2011), Wade and Sigurgeirsdóttir (2011) and Ólafsson and Kristjánsson (2013). With the exception of Iceland, the Nordic countries to be proved more resilient to the crisis owing to their experience with severe banking crises in the 1990s (Anderson, 2009). The Nordic crisis of the 1990s had its roots in the deregulation processes of the 1980s, which altered the incentives of lenders and borrowers. Developments in the financial sector fuelled a boom and had a direct impact on the real economy (Jonung, 2011). It should be noted, however, that other countries, including Spain, had also been affected by cyclical banking crises in the past. Yet only in the Nordic countries did the policies and regulations that had been introduced during the crisis lead, in the medium term, to improved competitiveness and greater resilience to external shocks of the banking sector. Following Lin et al. (2014) and similar to the cases of Spain and Greece, we analyse the period preceding the crisis – the expansionary phase of the cycle – in Denmark, Finland and Sweden. We then examine the course and effects of the crisis in these countries.

3.2.1 *The Banking Crisis of the 1990s in Scandinavian Countries*

In reference to the analysis of major historical crises by Reinhart and Rogoff (2008) and Honkapohja (2009) argued that the crises in Norway, Sweden and Finland, which began in the late 1980s and extended into the early 1990s, were among the five most severe in modern history. The recession in these countries lasted for three years from 1990 to 1993. During this period, the average loss provisions on bank lending were between 1.5% in Finland and Norway and 2.1% in Denmark. The highest loss provisions were recorded at 1.9% in Denmark, 3.4% in Finland, 2.7% in Norway and 4.8% in Sweden. In all of the Scandinavian countries, the banking sector required bailouts in the 1990s. The most notable example of crisis management was Finland. Economic growth there had been particularly strong in the 1980s. Nonetheless, the Finnish growth model was not sustainable and at the beginning of the 1990s, the country experienced the most severe crisis in its history. Similar to the peripheral countries that also faced crises at the start of the 1990s, Finland managed to recover by the end of the decade and entered a new expansionary phase in the 2000s. These developments were not confined to Finland alone but formed part of a broader regional pattern. The business cycles of Sweden, Finland and Denmark were relatively synchronised. However, Sweden's economic growth in the 1980s was lower than Finland's. Both Sweden and Finland ran high external deficits in the second half of the 1980s. In the same period, both countries abandoned their fixed exchange rate regimes. Unemployment rose sharply but gradually decreased once the crisis ended (Honkapohja, 2009). This experience was not unique to Scandinavia and reflected the macro-financial dynamics that were observed in other European economies during the same period. In some sense, the crisis of the 1990s was not very different from that in Spain during the same decade, nor was the cyclical behaviour of the Spanish and Scandinavian economies. The business and financial cycles were relatively synchronised across most EU countries. Property and share prices rose sharply during booms and decreased significantly during banking crises in the same decades in many European economies. Lending increased during the booms of the 1980s in most EU countries but decreased during the bust of the 1990s. In the Scandinavian countries, this effect was most pronounced in Finland and Sweden where lending growth turned negative (Honkapohja, 2009).

The main difference between the periphery countries and the Scandinavian countries was that in Sweden and Finland, the restructuring of the banking system was undertaken at the beginning of the 1990s, whereas in the periphery countries, the banking sector reforms were delayed until after the 2009–2014 crisis. The causes of the Scandinavian crises in the 1990s were also similar to those of the more recent crisis in the periphery. First, during the boom of the 1980s, inflation rates

were higher than in most other European countries, which led to a gradual loss of competitiveness. Second, deregulation processes began in the 1980s. In this context of increasing deregulation, lending increased significantly, which made the banking sector relatively more fragile. At the same time, capital inflows rose sharply due to interest rate differentials and the adoption of fixed exchange rates. As a result, Scandinavian countries began to experience external balance problems. Finally, as Honkapohja (2009) pointed out, towards the end of the 1980s, rising prices of forest products also contributed to the overheating of the Scandinavian economies.

At the beginning of the 1990s, a crisis emerged in the Scandinavian countries. In just two years, GDP growth fell from 5.4% in 1989 to -6.5% in 1991. In November 1991, a decision was taken to devalue the currency. Almost a year later, Finland moved to a floating exchange rate. In both Sweden and Finland, German reunification and the high German interest rates had a negative impact on their economies. In addition, Finland historically traded with the Soviet Union, which created further problems for its economy. In the medium to longer term, however, political changes compelled Finland to seek new economic partners and to modernise its industries and export sector, whereas Sweden did not undergo the same transformation. In 1991, the banking crises in Sweden and Finland began. Compared to these two economies, Denmark performed much better. Thanks to the adoption of prudential measures and the earlier start of deregulation processes, Denmark was able to counter the consequences of the slowdown more effectively. Although the crisis affected all three banking systems, public interventions were mainly required in Finland and Sweden, whereas in Denmark sectoral restructuring and raising additional funds on equity markets proved to be sufficient. The crisis began with the bailout of Skopbank in Finland in 1991. From 1993 onwards, a series of government interventions was undertaken. As in the more recent crises in the periphery countries, in the 1990s, deposit guarantees were raised and banks were recapitalised. The banking sector received public funds not only during the crisis of 1991–1993 but also in subsequent years, particularly in 1994. Three years later, the banks that had undergone interventions began to generate profits.

Banking sector restructuring during the Scandinavian crisis was also similar to the measures that were later adopted during the 2009 crisis in the peripheral countries. The main objective was to increase efficiency by reducing the number of branches and cutting employment in the sector. As part of this process, a large number of savings banks were merged into a single institution, the Saving Bank of Finland (SBF), in a way that was reminiscent of the SIP structure in Spain. In the following years, many of these savings banks were absorbed by more prosperous institutions in the market. In addition, Finland created a so-called bad bank, Arsenal, which was designed to take over non-performing loans and other distressed assets from the banking sector so that the healthier institutions could continue their activities. Its role was broadly comparable to that of Sareb in Spain.

Honkapohja (2009) also described examples of mergers in the market such as between STS-Bank and KOP and later with SYP, which eventually created Merita Bank; or between Post-Office Bank and Vientiluotto, which led to the creation of Leonia Bank. Merita and Nordbanken later merged to form the well-known Nordea, while Leonia Bank and Sampo Insurance Corporation formed the Sampo conglomerate, which was later sold to Danske Bank. Unlike in Spain, in Sweden and Finland these mergers not only contributed to greater internationalisation of banks but also resulted in a larger share of the banking system coming under foreign ownership.

The crisis began with liquidity and then solvency problems at one of the key savings banks in the market, Första Sparbanken. Later, Nordbanken had to be bailed out. The third bank to request financial support was Gota Bank, which was eventually merged with Nordbanken. To manage the crisis, a crisis resolution agency, Bankstödsnämnden (BSN), was created. At the beginning of the crisis, the difficulties of individual savings banks did not appear to be systemic. However, within a relatively short period of time, due to the high level of interconnectedness and increased uncertainty regarding the solvency of the banking system, the crisis became systemic.

3.2.2 *Lessons from the 1990s and the Crisis of 2009 in the Scandinavian Countries*

From the experience of the 1990s crisis in the Scandinavian countries – here understood to be the Nordic EU members – we can draw important lessons on how to manage crises and why these countries proved to be more resilient during the 2009 downturn. Following the 1991–1993 crisis in Sweden and Finland, stability-oriented macroeconomic policies were adopted to mitigate systemic risk and prevent the overheating of the economy. At the same time, efforts were directed towards safeguarding confidence in the banking system, particularly to avoid costly bank runs. The Nordic model, however, was not without weaknesses, as it increased moral hazard by offering excessively high guarantees (Honkapohja, 2009). In both Sweden and Finland, crisis resolution agencies were kept separate from the central banks in order to prevent conflicts of interest.

Lin et al. (2014) reported that Denmark, Finland and Sweden all experienced negative real GDP growth in 2008–2009. The impact of the financial crisis in these three countries was less severe than in Iceland. Sweden's recovery in 2010 was the most rapid among the Scandinavian countries. In contrast to the situation in the periphery countries, none of the three substantially increased their debt and deficit levels. All met the requirements of the Stability and Growth Pact. In particular, their debt levels did not exceed 60% of GDP. Only Iceland reported an increase in public spending after providing funds to its financial system.

Nevertheless, after the 2008 crisis, unemployment increased across all of the the Scandinavian countries with the exception of Norway, which is included in the analysis here only for the most important comparisons. The impact on inflation, however, was limited as the CPI levels remained close to those that had been observed before the crisis. Following the Nordic crisis of the 1990s, Sweden introduced more stringent prudential regulatory rules. It was also among the first EU countries to activate a countercyclical buffer and to set it at a positive value of risk-weighted assets, thus reflecting its longer tradition of applying prudential policies – a topic discussed in more detail in the following chapter. Despite their relative resilience to the financial crisis, Sweden, Denmark and Finland all introduced stimulus packages amounting to between 0.7% and 2.7% of GDP (Lin et al., 2014).

3.2.3 *The Crisis in the Baltic States*

In contrast to the developments in the Scandinavian countries, the Baltic states were hit particularly hard by the crisis with GDP contracting by as much as 15–20%. Mačys (2012) analysed the causes, course and consequences of the crisis in Estonia, Latvia and Lithuania between 2005 and 2011. He found that while Estonia, due to its stronger initial position, passed through the downturn with comparatively limited losses, Latvia and Lithuania experienced far heavier damage. His study also examined the synchronisation of business cycles across the three economies. Lithuania, which still recorded modest positive growth of 2.9% in 2009 while Latvia (–3.3%) and Estonia (–3.7%) were already in recession, entered the contractionary phase more than a year later. Yet, because of the high degree of interdependence between the Baltic economies, once one began to contract the others were quickly and severely affected. In all three Baltic states, consumption, investment, public expenditure and bank lending fell sharply. Mačys (2012) also emphasised the importance of expectations in shaping the downturn noting that deteriorating consumer confidence further depressed domestic demand across.

Despite the severity of the recession, the Baltic states recovered relatively quickly. By 2010, GDP growth had returned to positive territory in Lithuania (1.4%) and Estonia (2.3%), while Latvia's recovery was slower with output contracting only marginally at –0.3%. A key factor behind this rebound was the structural reform that had been undertaken in response to the crisis. Rather than using public funds to bail out the financial system, governments channelled them into supporting the economy through investment in new technologies and infrastructure. In this way, government contracts complemented, rather than substituted for, private investment. At the same time, foreign

direct investment increased owing to their EU accession and structural funds. In some respects, the Baltic countries benefited from similar processes to those experienced by Spain in the 1980s. Since the Baltic banking systems were closely interconnected with the relatively resilient Scandinavian banking system, Estonia, Latvia and Lithuania suffered less from the consequences of the European banking crisis.

The crises in the Scandinavian and Baltic countries had a more limited social impact than in the peripheral states. In the Baltic region, unemployment rose during the downturn but then gradually decreased. By contrast, in countries such as Spain, Greece and Portugal, the crisis not only pushed unemployment to unprecedented levels but also deepened the structural weaknesses in the dual labour markets where younger and temporary workers were particularly exposed. Mačys (2012) also presented data on the national at-risk-of-poverty rate (RPR), which showed that in the Baltic states, it remained broadly stable between 2005 and 2010.

These relatively favourable outcomes reflected what might be called a distinct Baltic model of crisis management that was built around fiscal restraint and structural reform. Estonia exemplified this approach with its determined efforts to contain its deficit and a firm commitment to balanced budgets, which reinforced confidence in the economy and ultimately paved the way for its accession to the euro area in 2011. This contrasted sharply with the experience of many peripheral countries where heavy spending, delayed reforms and weaker institutional credibility amplified both the social and economic costs of the crisis.

3.2.4 The Crisis in the Central and Eastern European Countries

In the Central and Eastern European (CEE) countries, the crisis was marked by a sharp contraction in GDP, falling exports, collapsing industrial production and a significant outflow of capital from the region as was highlighted in the ECB (2010) report. The ECB also stressed that CEE countries outside the euro area were among the most severely affected by the global financial turmoil. Even so, economic and financial indicators varied widely across the region. Poland, for instance, managed to sustain positive economic growth, whereas in other countries the downturn was particularly severe. Scholars and policymakers have linked this heterogeneity both to the extent of internal vulnerabilities that had built up before the crisis and to the stage of the business and financial cycle at which each economy was caught. Structural characteristics and the design of national policy responses also played an important role in shaping outcomes.

In 2008–2009, risk aversion towards Central and Eastern Europe rose sharply and the region's earlier reputation as being relatively safe changed dramatically. Most countries experienced capital outflows and decreasing foreign demand. The banking sector was also hit by a rise in non-performing loans and by problems stemming from the high degree of interconnectedness among banks. Latvia, Hungary and Romania even requested financial assistance from the EU. As in the periphery countries and in the Scandinavian and Baltic states, the CEE countries displayed a strong synchronisation of economic cycles, albeit with some lags. According to the ECB (2010), output growth in Bulgaria, the Czech Republic and Romania remained robust in the final quarter of 2008 but turned negative in the first quarter of 2009. Unemployment also rose sharply in the aftermath of the crisis. In 2009, when the impact was most severe, GDP contracted by around 5% in both the Czech Republic and Slovakia and by between 7% and 9% in Hungary, Romania and Bulgaria, according to estimates by Pradelle (2012).

The factors behind the 2009 crisis in the CEE countries differed across cases but most arose from imbalances that had built up during the expansionary phase of the cycle. Two elements were particularly significant: the massive inflows of capital and the lending policies that had been pursued by banks. Although a range of macroprudential measures was introduced in an attempt to restrain credit growth and capital inflows, their effectiveness remains contested. Capital outflows – particularly from Croatia – provide a striking example of the vulnerabilities that emerged during the transition from expansion to contraction in business and financial cycles.

As elsewhere in the EU, asset prices rose steeply, especially in the property market. Wealth effects added to demand pressures, thus fuelling inflation, currency appreciation and a loss of competitiveness. Expansionary fiscal policy also played a negative role that further undermined stability. These weaknesses were not unique to the CEE countries; the Baltic states faced similar challenges and are sometimes grouped together in this context.

One of the main factors differentiating countries within this group was the share of foreign-currency loans to the private sector and the extent to which regulations were (or were not) introduced to mitigate the systemic risks that were generated by this high exposure.

With the exception of Poland and the Czech Republic, all of the countries in this group experienced a contraction of domestic demand. In the Baltic States and Romania, private consumption decreased particularly sharply. ECB experts explained the differences in the contraction of consumption by differences in labour market responses to the crisis.

The CEE countries also experienced “an unwinding of external imbalances. This can be traced back to a substantial decrease in domestic demand pressures that led to a sharp fall in imports, which more than offset the foreign demand-related contraction in exports” (ECB, 2010).

There is no single explanation for the differences in the impact of the crisis on the CEE countries. Most experts emphasise the role of divergent macroeconomic policies and, in some cases, the macroprudential measures that had been adopted in these countries – an issue to which we return later in this book.

3.3 Systemic Risk in the EU Core Countries

In contrast to the countries that were analysed at the beginning of this study, mainly the peripheral economies, Germany was one country that managed to overcome the negative effects of the crisis within a relatively short period of time. Experts often highlight Germany as a success story within the EU and above all within the euro area. Germany not only had an effective crisis management strategy but it is also a highly competitive and innovative economy with a flexible labour market.

Germany entered a recession in the first quarter of 2008. The immediate cause of the GDP decrease was a sharp drop in exports. It took approximately three years for Germany to return to its pre-crisis growth level – a much shorter recovery than in countries such as France, the Benelux states and especially the EU periphery countries. Labour market adjustments in Germany also differed from those in the other countries. The unemployment rate rose only slightly during the crisis and subsequently returned to its pre-crisis level.

Storm and Naastepad (2015) noted that the persistence of the crisis posed a threat to the stability of lender–borrower relationships within the euro area and even the EU as a whole. Observing how the conditions for granting international assistance to Greece, Ireland, Portugal or Spain were determined lends some credibility to this argument. From a macroeconomic perspective, the development of such relationships reinforced the current account imbalances across EU countries, which were not corrected in line with the expectations of the founders and theorists of the euro area (Adamus et al., 2015). Despite the undeniable success of the German economy, many experts call for a rebalancing of the EU by addressing current account imbalances.

Germany’s strong economic position is striking when set against the historical context of its post-reunification difficulties. As Storm and Naastepad (2015) noted, after reunification around five million people were unemployed. Eastern Germany was much poorer and most sectors of its economy were inefficient, which resembled the situation in other countries of the former socialist bloc. In the 1990s, however, a series of reforms was undertaken to increase competitiveness. Rather than competing on prices and wages, Germany emphasised product and service quality, which required a stronger focus on innovation. In addition, labour market reforms – the Hartz reforms – were introduced, which restructured job-placement services, expanded support for job seekers, tightened unemployment-benefit rules and promoted flexible and part-time work arrangements.

In contrast to the peripheral countries, German policy was characterised by fiscal restraint, limited wage growth and labour market deregulation. Unlike Spain, however, these reforms did not result in the creation of a dual labour market where workers are divided into two tiers: a core group with stable contracts and protections and a secondary group that is reliant on temporary or precarious jobs with few rights. Instead, Germany's strategy of promoting innovation and implementing structural, sectoral policies fostered the development of non-price competitive advantages that continue to underpin the strength of its economy today.

It is true that during the crisis the main sectors of the German economy were deeply affected by the recession, particularly the auto mobile and pharmaceutical industries. After the outbreak, uncertainty rose and foreign trade contracted. Key sectors struggled to import the inputs needed for the production of final goods, while demand for these goods also fell sharply. As a result, moderate decreases in employment followed. Yet, due to the flexibility of the labour market and the adaptability of workers to frequent job changes, Germany avoided the dramatic rise in unemployment that was seen in the peripheral countries. Because income fluctuations were smaller than in other EU countries, changes in aggregate consumption were also relatively less pronounced. Nonetheless, the German banking system suffered from the negative consequences of the crisis. Owing to the problems faced by leading sectors of the economy, non-performing loans in the corporate sector rose sharply. In 2008, the German government provided assistance to WestLB and BayernLB. In October 2008, the government passed the Financial Market Stabilisation Fund (*Finanzmarktstabilisierungsfonds*) worth €400 billion to stabilise the financial sector. In addition, efforts were made to strengthen the German economy through the implementation of stimulus packages (*Konjunkturpaket I and II*).

The impact of the crisis in Germany is often compared to its effects in other “core” EU countries such as Austria and the Benelux states. In Austria, the share of investment in stocks and mutual funds within total wealth was relatively small compared with other developed economies. As a result, the wealth and distributional effects of the U.S. crisis on Austrian society were relatively limited, especially when contrasted with the experience of the countries in Central, Eastern and Southeastern Europe (CESEE).

Although the immediate impact of the U.S. crisis on Austria's financial sector and economy was limited, Austrian banks held substantial exposures to the CESEE region and were closely interconnected with financial institutions there. As the economic conditions for companies and households in CESEE deteriorated, the strain first appeared in local banking systems and then spread to the Austrian banking sector through contagion mechanisms.

Although the Austrian financial system and economy were only partially affected by the U.S. crisis, the transmission channels were not linked to securitisation. Structured credit products made up just 1.5% of total system assets and the largest banks had only moderate exposures. Of the twenty-five main banks analysed, only six reported exposures amounting to €14.6 billion, all of which were highly rated (Schürz et al., 2009). According to experts from the Oesterreichische Nationalbank, the Austrian financial and real sectors were hit primarily through contagion in the interbank market and through exposures to the CESEE banks. Following the introduction of liquidity-provision measures and the establishment of USD/EUR swap lines by the ECB in cooperation with the Federal Reserve, the interbank market partially stabilised and conditions in Austria improved.

On Austria's part, Oesterreichische Clearing-Bank AG was established and, from November 2008, took part in interbank operations. These measures indicate that Austrian banks were affected primarily through their activities in other regions – most notably in CESEE – rather than by liquidity shortages in the domestic interbank market (Schürz et al., 2009). Assistance from the International Monetary Fund and the European Commission contributed to a partial stabilisation in the peripheral and CESEE countries, which in turn reinforced the position of German and Austrian banks. Both banking systems were highly interconnected with institutions in these regions and frequently financed business operations there.

In Austria itself, the average capital ratio decreased from 11.8% in 2004 to 10.5% in the third quarter of 2008, while the post-tax return on assets of banks fell to just 0.09% in 2008. To address these pressures, a bank recapitalisation programme was introduced in 2008–2009.

As the crisis unfolded, the creditworthiness criteria in Austria became more stringent, which led to a contraction in lending and a fall in bank profitability. By 2009, average margins had been increased to offset part of the losses. Loan conditions for companies were tightened most severely for large firms, which in turn weighed on economic growth, while household lending was mainly influenced by demand-side factors.

Perceptions of risk and uncertainty also played a major role in shaping the course of the crisis in Austria (Schürz et al., 2009). Financial institutions reached markedly different assessments of the health of the economy, the behaviour of market participants and the value of collateral, which further complicated lending decisions and amplified financial stress.

In response to the financial crisis, Austria also moved to strengthen macroprudential supervision and to implement the provisions of CRDIV/CRR.

The experiences of Germany and Austria are often considered alongside those of other highly developed EU economies, notably the Netherlands, Belgium, Luxembourg and France. As Masselink and van den Noord (2009) observed, prior to the crisis, the Dutch economy was marked by low unemployment, current account and budget surpluses and a comparatively modest level of indebtedness. At the outbreak of the financial turmoil in 2008, the Netherlands therefore appeared to be relatively stable and resilient. Yet by the end of that year, the first signs of strain had emerged and in 2009 the economy entered recession with GDP contracting by 4.5%, a rate worse than the euro area average.

Masselink and van den Noord (2009) emphasised that, somewhat paradoxically, two features often cited as strengths of the Dutch economy before the crisis – a strong external position and a reformed social insurance system – actually amplified external shocks and generated negative wealth effects. Dutch households did not lose much directly from falling asset prices but they were nonetheless affected indirectly through a decrease in the value of the assets that were held by pension funds. This mechanism was similar to that observed earlier in the case of the United States.

The outbreak of the crisis had a negative impact not only on exports but also on investment and consumption. The Dutch economy was hit primarily by the fall in global demand including that of its main trading partners but also – though to a lesser degree – through pressures on bank balance sheets. Exports account for roughly one-eighth of Dutch GDP, so it is unsurprising that turmoil in world markets pushed the economy into a deep recession in 2009. Unlike Germany and Austria, however, BIS data show that Dutch banks had the largest exposure in the EU to U.S. banks, amounting to around 66% of GDP. Similarly high exposures to the U.S. financial system were also observed in the United Kingdom, Belgium and Luxembourg. Nevertheless, despite the high level of exposure of Dutch banks, the direct contribution of the financial system to GDP was relatively modest – no more than 6%. As a result, the overall impact of the global crisis on the Dutch economy through this channel was moderate (Masselink and van den Noord, 2009). The authors argue that the role of the external shock was therefore less significant than might have been expected. Instead, they highlight contagion within the domestic economy along with internal amplification and feedback mechanisms as the main drivers of systemic effects.

Within the group of core EU countries, Luxembourg suffered relatively the most as a result of the crisis, given its reliance on the financial sector and related services. In addition, in 2008 the financial crisis in Luxembourg was compounded by a constitutional crisis. During this period, the country's two most important banks – Dexia-BIL and Fortis (formerly Banque Générale du Luxembourg) – came close to bankruptcy and required public intervention as well as additional funds from investors for recapitalisation. The problems stemmed largely from the losses of their Belgian and French parent institutions. Paradoxically, however, the “Dexia-BIL and Fortis crisis” became a “real problem” only after these difficulties were revealed in the media. This case clearly illustrates the role of risk perception in amplifying the crisis and propagating contagion.

At the beginning of 2008, Fortis Bank experienced liquidity problems and its share price fell sharply. However, it was the media coverage that triggered the bank's most severe difficulties. Following the revelations, deposit withdrawals rose significantly. On 28 September 2008, Fortis had to be nationalised in cooperation with the Belgian, Dutch and Luxembourg governments. The Fortis Group was divided into two institutions: the Dutch shares were transferred to the Dutch government, while the Belgian shares were taken over by the French bank BNP Paribas. The Dutch government purchased the Fortis insurance division – including Fortis Bank Nederland, Fortis Verzekeringen Nederland, Fortis Corporate Insurance and ABN Amro – for €16.8 billion. BNP Paribas acquired the majority stake in Fortis Bank, while the Belgian and Luxembourg governments retained minority holdings. Toxic assets were placed in Royal Park Investments, which was subsequently sold in 2013 to the American investment company Lone Star.

Similar problems arose in the case of the Dexia Group, which was ultimately dissolved. Only Dexia Bank Belgium was nationalised after which its name was changed. As with Fortis, in September 2008 the Belgian, French and Luxembourg governments intervened jointly to rescue Dexia. Its difficulties stemmed largely from its U.S. subsidiary FSA, which had heavy exposure to the American market and later suffered additional losses during the Icelandic and Greek crises as well as from loans that it had extended to Depfa in Germany. In 2011, Dexia Bank Belgium was purchased by the Belgian government for €4 billion and renamed Belfius. Toxic assets were transferred to Dexia Holding, which became the largest toxic-asset bank operating under a state guarantee and receiving public capital injections. In 2012, Dexia Holding continued to generate losses and required further public support amounting to €5.5 billion.

After the cases of Fortis and Dexia, KBC Bank encountered difficulties in October 2008. As with Austrian banks, the main problem was linked to exposure in the CESEE region. The bank's market value fell by more than half on the stock exchange. KBC applied for public assistance of up to €3.5 billion to cover potential losses in the CESEE. In January 2009, it received a second tranche of public aid amounting to €1.5 billion. However, unlike in the case of the peripheral countries' banks, most of these funds were repaid out of profits that were generated in 2012.

In response to the banking sector problems, the Belgian government provided institutions with capital and guarantees and increased deposit insurance – initially to €20,000 and later to €100,000 for all solvent banks. Moreover, protection for Belgian depositors in Icelandic banks, mainly Kaupthing Bank in Iceland (through Kaupthing Bank Luxembourg), was negotiated by the government. In 2011, the Belgian government promoted the purchase of *staatsbon*, a government bond that offered a higher interest rate than savings accounts. In this way, the state borrowed €5.68 billion from the private sector.

As in Luxembourg, the financial and economic crisis in Belgium coincided with a political crisis, which was marked by the N-VA election breakthrough. In the 1990s, Belgium had been one of the most indebted countries in Europe with public debt peaking at 137.8% of GDP in 1993. In the run-up to euro area accession, however, the government implemented consolidation measures that reduced debt to around 100% of GDP by 1999. Following accession, a prudent fiscal policy was maintained, which brought the ratio down further to 84%.

However, the fiscal imbalances associated with Belgium's federal system together with inflation that was higher than the euro area average resulted in a loss of competitiveness. Although the deficit level was not alarming, public debt remained relatively high by historical standards. In line with the IMF's 2008 recommendations, it was deemed necessary to adopt a medium-term budgetary framework to guide the annual budget process and to strengthen the role of the High Finance Council (HFC).

Wage indexation was one of the main drivers of rising inflation. In Belgium's case, the decrease in non-price competitiveness contributed to a deterioration of the current account. The country recorded a current account deficit for the first time following the outbreak of the crisis. Between the onset of the crisis and 2012, public debt once again rose to 99.6% of GDP, mainly due to government

interventions and increasing public expenditure. The crisis in Belgium was therefore shaped not only by global developments but also by underlying structural weaknesses in the economy.

3.4 Systemic Risk in Great Britain

On 8 October 2008, the UK government announced an international assistance request in response to the liquidity problems that had emerged in September 2008 following the outbreak of the U.S. financial crisis. In early September, stock prices dropped significantly and doubts arose about the stability of British banks. The aim of the government's plan was to restore confidence in the stability of the banking system, stabilise financial markets and above all, provide short-term loans to ease tensions in the interbank market. After the outbreak of the global crisis, the Bank of England undertook coordinated action with other central banks to reduce interest rates. The policy rate was lowered to 0.5%, which was in line with measures that had been taken by the ECB, the Federal Reserve and the central banks of China, Sweden, Canada and Switzerland. Rate cuts helped stabilise global stock exchanges. In addition, the United Kingdom adopted an asset purchase programme, which was often compared to the U.S. Troubled Asset Relief Program (TARP). While the U.S. government purchased real-estate-related securities that could no longer be sold on the market, the UK programme involved direct asset purchases.

The stabilisation package in the United Kingdom included the recapitalisation of the banking sector, liquidity provision and loan guarantees. Bank recapitalisation was secured through the Bank Recapitalisation Fund with an initial tranche of €25 billion. A further €25 billion was reserved for emergencies and the government declared loan guarantees of up to €250 billion. Moreover, for all of the banks that applied for public support, dividend payments and profit distributions were suspended. According to the plan, the government expected to recover at least part of the invested funds once the institutions stabilised. Assistance was tailored to the needs of specific institutions. Other banks and groups, including HSBC and Standard Chartered, also participated in the plan to support other institutions. Some banks, such as Barclays pursued their own strategies to secure private funds and limited dividend payouts. The institutions initially selected for public aid were Abbey, the Royal Bank of Scotland (RBS), the Nationwide Building Society, Lloyds TSB, HBOS, HSBC and Standard Chartered. Ultimately, however, the main recipients of state support were Lloyds and RBS.

On 19 January 2009, a second financial aid package was introduced in response to the global financial crisis. This programme was primarily aimed at increasing the funds that were available to enterprises and households in the form of loans and credit. The first component, worth £50 billion, was intended mainly to provide loans to large companies. The second component, the size of which was not disclosed, was channelled to banks that had recorded heavy losses in 2008–2009. In February 2009, Lloyds TSB merged with HBOS. However, the merger proved to be unfavourable as Lloyds reported a loss of £22 billion in the same year.

3.5 Assessing the Relative Role of Systemic Risk in Explaining the Crisis in the European Union Countries

In the last chapter, we verified the hypothesis that the relative role of systemic risk in explaining the origin, course and effects of the crisis was greater with regard to its course and consequences than its causes in the case of the United States. In this chapter, we tested this hypothesis in the context of the EU.

While systemic risk in the United States was predominantly associated with too-big-to-fail institutions and the problem of moral hazard, in Europe such explanations are less persuasive. Acharya and Steffen (2012) analysed systemic risk in the banking sector during two major eurozone crises, focusing in particular on the sovereign debt crisis and employed the systemic expected shortfall

(SES) as a measure of individual institutions' contributions to the overall capital shortfall of the financial system. They found that markets demanded more capital from banks with high exposures to peripheral countries in Europe; in other words, the sovereign debt holdings of banks were a major source of systemic risk. Although their analysis is valuable, it overlooks key aspects of systemic risk in Europe. The role of SIFIs was less prominent than in the United States owing to differences in regulation. For instance, the Bank of Spain conducted regular cyclical audits of the main market players such as Santander and BBVA. However, the supervision of savings banks was weak and sporadic during the expansionary phase prior to the 2009 crisis. Acharya and Steffen used SES not to identify systemic institutions but rather to highlight the countries in which most SIFIs were located and where systemic threats emerged. Ultimately, however, the main systemic threat in Europe did not stem from the presence of large, systemically important institutions but rather from the interconnectedness of institutions and markets.

Acharya and Steffen (2012) explained the crisis in Europe in terms similar to the U.S. crisis, largely perceiving the mechanisms of the 2007 and 2011 crises as analogous. In reality, however, both the causes and the mechanisms of crisis development were fundamentally different. The impact of the U.S. financial crisis was evident in all of the analysed EU countries though it spread through different channels. The main factors behind the crisis in the EU were structural (a "spatial component") and accumulated over time (a "temporal or cyclical component"). A detailed analysis of Spain and Greece and their comparison with Ireland showed that at the core of the crisis lay structural vulnerabilities such as the sectoral concentration of activities of banks, high indebtedness of economic agents and the high degree of interconnectedness within the financial system. By contrast, the experience of the Scandinavian, Baltic and CEE countries – and the way they adjusted after both earlier and more recent crises – suggests that policies and regulations matter.

The analysis of internal vulnerabilities and the mechanisms of risk transmission within the system led to the conclusion that the role of systemic risk in explaining the origin, course and effects of the crisis in the EU was greater with regard to its course and consequences than its causes. While the vulnerabilities that had enabled the crisis certainly existed beforehand, it was above all in 2011 that risk became systemic in the peripheral countries, thus leading to a second recession in the EU through contagion mechanisms. Because the vulnerabilities of the U.S. and EU economies differ, the regulatory and policy responses adopted after the financial crisis should also have differed. In the next chapter, we discuss the regulatory and macroprudential measures that were implemented in the EU in order to compare them with the framework that had been established by the Dodd–Frank Act in the United States.

Final remarks

This chapter has examined the role of systemic risk in shaping the course of the crisis within the EU. We have shown that the origins and trajectory of the crisis diverged markedly from those in the United States where the downturn was closely tied to the collapse of securitisation markets and the failure of systemically important financial institutions. In Europe, by contrast, the vulnerabilities were more closely connected to the sovereign-bank nexus, cross-border exposures and institutional shortcomings within the euro area. At the same time, significant heterogeneity emerged among EU member states themselves, thus reflecting differences in their financial structures, fiscal positions and institutional resilience.

Our analysis concentrated on the peripheral economies in order to highlight a crucial contrast: whereas the financial crisis in the United States had largely run its course by 2009, the EU endured two distinct recessions. The first occurred in 2008–2009 and reflected the global financial shock; the second unfolded during the sovereign debt crisis when doubts about fiscal sustainability and the stability of the euro area resurfaced. In the latter episode, the principal amplification mechanisms were linked not only to concerns about the solvency of financial institutions and the fiscal position of

governments but also to deeper uncertainty regarding the institutional architecture and long-term credibility of the euro project itself.

The European experience thus demonstrates that systemic risk is not a uniform phenomenon. It manifests differently depending on national conditions, institutional frameworks and the interactions between the financial and sovereign sectors. For this reason, the crisis in Europe cannot be understood solely as a spillover from the United States but must also be viewed as the outcome of endogenous fragilities that had accumulated over time.

These conclusions set the stage for the following discussion, which turns from diagnosis to response. In the next chapter, we consider how European policymakers attempted to contain and mitigate systemic risk through regulatory reform and the creation of new institutional arrangements. The effectiveness of these measures – and their implications for the design of macroprudential policy – will be assessed in detail.

Notes

1. The FAAF was terminated in June 2012.
2. For more details on CRD IV/CRR in the EU, *see*: [Chapter 4](#).

Part II

Macroprudential Policies After the Global Financial Crisis (GFC)



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4 Systemic Risk Mitigation Through Regulation and Macroprudential Policies

This book began by setting out the theoretical foundations of systemic risk and uncertainty. The discussion clarified how the distinction between exogenous and endogenous sources of systemic risk shapes the approaches to measurement and modelling in both mainstream and heterodox economics. The analysis then turned to the global financial crisis considering how systemic risk featured in its origins, development and consequences. By examining the experience of the United States alongside that of the European Union (EU), the argument highlighted both commonalities and important regional differences.

Building on these insights, the focus shifted to the mitigation of systemic risk through macroprudential regulation and policy. Particular attention was paid to the regulatory and institutional reforms adopted in the EU after the crisis. Theoretical perspectives on macroprudential policy were then explored, followed by the ESRB's framework and the experiences of EU Member States in deploying specific instruments. This discussion culminated in an assessment of their effectiveness.

The final part of the book moves from the question of effectiveness to that of optimality. Here, macroprudential policies are analysed using agent-based modelling (ABM) with the results contrasted against those derived from the dynamic stochastic general equilibrium (DSGE) approaches. This comparison offers a deeper insight into how alternative modelling frameworks can guide the design of policies that not only meet their stated objectives but also strengthen the resilience of a financial system while supporting the broader welfare of a society.

4.1 Post-Crisis Institutional and Regulatory Changes

The developments in global financial markets following the collapse of Lehman Brothers highlighted the need for enhanced cooperation between international institutions to mitigate the adverse effects of a crisis and to safeguard the stability of the financial system in the future.

Among the most important meetings of world leaders after the outbreak of the financial crisis was the G20 Summit in Washington, DC, in 2008 (White House Archive, 2008). The media sometimes referred to it as Bretton Woods II given the recognition of the need for monetary and financial reform and for strengthening the role of the International Monetary Fund (IMF). Since then, some countries have advocated for increased IMF funding to support bailouts of countries that are facing currency runs or distressed financial institutions. The White House reported that the summit achieved five main goals: establishing a common understanding of the root causes of the global crisis, reviewing national actions that had been taken or were planned to address the immediate crisis and strengthen growth,

agreeing on common principles for financial market reform, launching an action plan to implement those principles and mandating ministers to prepare further recommendations for subsequent summits and reaffirming the commitment to free market principles. A more detailed discussion of the outcomes and longer-term implications of the summit is provided by Lo Duca and Stracca (2014) and Luckhurst (2016).

Equally significant were the G20 Summits in London (G20, 2009b) and Pittsburgh in 2009 (G20, 2009a). In line with the conclusions of the Washington, DC Summit, countries pledged to reform the financial system by strengthening the supervision and regulation of financial markets. At the EU level, action was taken to implement the G20 commitments and to establish a new institutional framework within the Union.

Among the most important measures taken at the EU level following the outbreak of the financial crisis was the establishment of an expert group chaired by J. de Larosière. As a result of the group's work, in February 2009, the *Report of the High-Level Group on Financial Supervision in the EU* was published, in which the authors outlined the desired changes in policy and regulation as well as EU and global surveillance (Larosière Report, 2009).

At the time of the publication of the de Larosière Report, the EU was still suffering from the effects of the financial crisis. It was necessary not only to take action as indicated in the Report but also to undertake international cooperation with the International Monetary Fund, the Financial Stability Forum,¹ the Basel Committee and other G20 Member States. First and foremost, it was necessary to implement and enforce new standards and to ensure the integration of financial market regulation and financial supervision. The de Larosière Report presented proposals for changes in the new regulatory framework, the establishment of stronger coordinated supervision and the implementation of effective crisis management procedures.

4.1.1 Provisions of the de Larosière Report

According to the de Larosière Report (2009), it was deemed necessary to introduce far-reaching changes not only in policy and regulation but also in the oversight. In the report, regulation was defined as the set of rules and standards governing financial institutions, which were designed above all to safeguard financial stability and protect users of financial services, while supervision was understood as the process of ensuring that those rules and standards are effectively applied (Larosière Report, 2009, p. 13). The proposals of the report have been widely discussed in the literature with critical assessments offered by Acharya (2009), Lannoo (2009) and Onado (2010).

The Report recommended that regulation should place greater emphasis on addressing financial bubbles, improving oversight of poorly regulated institutions and adjusting the regulatory and accounting practices that had intensified procyclicality. It also stressed the need to foster incentives for sound governance and transparency, to ensure greater consistency of standards and rules at the international level and to strengthen coordination between regulators and supervisors (Larosière Report, 2009, pp. 13–14). Since the publication of the de Larosière Report, most of these recommendations have been implemented in the form of EU regulations and directives.

The experts of the de Larosière Group explained excessive risk-taking and the development of bubbles primarily by the persistence of a low interest rate environment. They shared the view that the creation of bubbles is inevitable and that monetary authorities should not attempt to “lean against the wind”. Instead, the role of monetary authorities should be to communicate concerns related to asset prices and to assess systemic risks. Regulatory agencies, in turn, should implement counter-cyclical measures such as dynamic provisioning, counter-cyclical reserves or more restrictive loan-to-value ratios and should also adjust tax rules that excessively stimulate demand for assets.

According to the de Larosière Report, one of the most urgent post-crisis regulatory changes was the revision of Basel II,² primarily in order to reduce the procyclicality of its provisions. In particular, it was pointed out that the assumption that securitisation shifts risk away from banks is erroneous and that banks should by no means be allowed to lower capital requirements when securitisation is

used. Other shortcomings of Basel II included the limited treatment of liquidity issues and maturity mismatches, problems with internal risk models, over-reliance on external ratings in investment activities and the overall procyclicality of capital requirements.

First and foremost, attention was drawn to the need to take the business cycle into account in the risk assessments of banks. It was also suggested that dynamic reserve arrangements, analogous to those that had been introduced by the Bank of Spain, could be implemented alongside the creation of countercyclical buffers during periods of growth, which could be drawn upon in times of recession. Equally important in the Group's assessment were the determination of optimal liquidity levels and the monitoring of asset structure, complexity, quality and maturity; the establishment of rules for off-balance-sheet vehicles; and the presentation of a more rigorous definition of regulatory capital (Larosi re Report, 2009, pp. 15–19). Further recommendations from the de Larosi re Group concerned changes to the regulation of credit rating agencies, a review of their economic model and the elimination of conflicts of interest (Larosi re Report, 2009, pp. 19–20).

The experts also proposed strengthening the role of the International Accounting Standards Board (IASB) in fostering a consensus on when the mark-to-market principle should be applied and when it should not, given the procyclical effects it might produce under certain market conditions (Larosi re Report, 2009, pp. 20–22).

Although the financial crisis in the EU was primarily linked to the banking sector, the stability of the insurance sector also required protection. This contrasted with the United States, where public intervention focused on the insurance sector owing largely to its involvement in CDO–CDS activities. In response, the Group recommended the introduction of the Solvency II Directive, which was designed to establish a balanced support framework with adequate safeguards for host Member States, a binding mediation mechanism between supervisors and harmonised insurance guarantee schemes (Larosi re Report, 2009, p. 23).

The Group also highlighted the need to standardise sanctions for financial crimes and infringements of competition law as well as to strengthen the detection of financial offences. Sanctioning regimes in the Member States differed and needed to be enforced more effectively (Larosi re Report, 2009, p. 23).

In addition to regulatory reforms, attention was also drawn to the activities that are commonly referred to as shadow banking – that is, credit intermediation that was conducted outside the traditional banking system, often by hedge funds, investment banks, off-balance-sheet vehicles or mortgage brokers. Although not banks in the strict sense, these entities performed bank-like functions and could generate systemic risks, while remaining largely outside the existing supervisory framework. The Group stressed that the regulatory perimeter should therefore be broadened to cover such institutions and activities. Among the recommendations were the mandatory registration of hedge funds with the disclosure of their strategies, methods and leverage at both national and international levels and the imposition of capital requirements on banks owning or operating hedge funds or engaging in significant proprietary trading. Enhanced supervisory scrutiny of such activities was also considered to be essential (Larosi re Report, 2009, pp. 23–25).

One of the greatest threats to the stability of a financial system is the complexity of financial instruments and the lack of transparency in the market for securitised products and derivatives. The main objectives of future regulation were to simplify and standardise OTC derivatives, develop risk mitigation techniques and increase market transparency. In addition, the experts pointed to the need to set up a highly capitalised clearing house and to require issuers to maintain an amount corresponding to the unsecured risk.

Another area that attracted the attention of the Group was the activity of investment funds including money market funds. It was essential to standardise the definition and identify the assets in which investors were allowed to invest (Larosi re Report, 2009, p. 26).

Apart from these areas, further efforts to reduce regulatory inconsistencies between EU countries and to enhance harmonisation were needed. Differences in the set of rules could lead to regulatory arbitrage, less efficient risk management and capital allocation and failures in the proper management

of crises in the case of cross-border institutions. This problem should be addressed at both the global and at the European level. In the first case, the EU should present a common stance when participating in international arrangements. In the second case, the Commission and the Level 3 Committees should identify inconsistencies and set standards, while Member States should adopt appropriate national regulatory measures that comply with these standards (Larosière Report, 2009, pp. 26–29).

One of the most serious problems that emerged during the crisis was that of corporate governance. In particular, the strategies of financial institutions did not take into account the long-term interests of stakeholders. Short-term remuneration schemes encouraged excessive risk-taking. At the same time, accounting policies and risk management were highly biased towards short-term performance. According to the Report (2009, pp. 29–31), it was important to ensure that compensation incentives also reflected long-term, firm-wide profitability and that bonus payments were spread over the cycle. The same principles should also apply to proprietary traders and asset managers.

In addition, the Group addressed the issue of crisis management and resolution. In this context, it was essential to systematise crisis prevention and crisis resolution tools within a single and consistent regulatory framework.

First and foremost, attention was paid to the problem of moral hazard, the priority of private sector solutions (e.g. restructuring) as well as national supervision in the management of a problematic institution provided that it was not a cross-border institution. Crisis management should also be kept at the national level, according to the experts (Larosière Report, 2009, pp. 31–34).

In addition, the Group emphasised the importance of ensuring that deposit guarantee schemes in the Member States were reliable and well-functioning. It did not, however, propose the creation of a single EU-wide fund. Instead, it was recommended that national schemes be financed *ex ante* by the private sector with public funds to be made available only in exceptional circumstances (Larosière Report, 2009, pp. 34–35).

Beyond regulatory reforms in financial services, the Group also considered supervisory practices at both the micro- and macroprudential levels. Particular attention was devoted to the role of the European Central Bank (ECB). Debate centred on whether the ECB should assume direct supervisory responsibility for cross-border banks within the EU or the euro area and if so, whether this responsibility should cover all banks or only those deemed systemically important. Ultimately, while the Group endorsed an enhanced role for the ECB in macroprudential supervision, it rejected proposals to extend its authority into microprudential supervision. The reasoning was that the ECB's mandate was primarily geared towards ensuring monetary and macroeconomic stability and that it lacked experience in supervising the insurance sector – making the case for granting it broader supervisory powers less convincing (Larosière Report, 2009, p. 43).

The purpose of microprudential supervision is to oversee the activities of individual financial institutions and to protect their clients. The objective of macroprudential oversight is to ensure the stability of the financial sector as a whole, to eliminate disruptions and to reduce systemic risk. The main problems highlighted during the crisis were the lack of adequate macroprudential supervision, the failure of early warning mechanisms, competence issues, the lack of cross-border supervisory practices and the lack of cooperation between supervisors (Larosière Report, 2009, pp. 35–41).

As a solution, it was proposed that a European system of supervision and crisis management be created. The Group also supported the idea of replacing the Banking Supervision Committee (BSC) of the European Central Bank (ECB) with the European Systemic Risk Council (ESRC), which was to be set up under the auspices and with the logistical support of the ECB. The ESRC would be composed of the President of the ECB; the Vice-President of the ECB; the governors of the national central banks; the chairpersons of Committee of European Banking Supervisors (CEBS), Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS) and Committee of European Securities Regulators (CESR); and one representative from the European Commission. The ESRC would be chaired by the President of the ECB and a secretariat would also be provided by

the ECB. According to the recommendations of the Group, the flow of information between national authorities and the ESRC should be mandatory.

Attention was also paid to the need to establish an early warning system under the auspices of the ESRC and the Economic and Financial Committee (EFC). According to the proposal, the ESRC should be able to issue macroprudential risk warnings, which would then be assessed by the relevant competent authorities in the EU. The Chairman of the EFC should be informed about the nature of the risks. The EFC and the Commission would then prepare a strategy to address the problem. In the case of risks that endanger the stability of the global monetary and financial system, cooperation between the ESRC, the IMF, the FSF – Financial Stability Forum³ and the Bank for International Settlements (BIS) should be ensured. The ESRC should also be entitled to evaluate whether the actions undertaken by national supervisors were sufficient to resolve the problem (Larosi re Report, 2009, pp. 44–46).

From the perspective of microprudential supervision, the Group recommended the establishment of a decentralised network of European financial supervisors, building on the existing level-3 committees, to form what became the European System of Financial Supervision (ESFS). Ongoing supervision would remain the responsibility of national supervisory authorities but closer cooperation was envisaged with the colleges of supervisors that had been introduced under the revised Capital Requirements Directive (CRD) and the Solvency II framework (Larosi re Report, 2009, p. 47).

In place of Committee of European Banking Supervisors (CEBS), Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS) and Committee of European Securities Regulators (CESR), three new European Supervisory Authorities were to be established to coordinate the application of supervisory standards and to ensure close cooperation between the national supervisors. For all larger cross-border institutions, colleges of supervisors should be created (Larosi re Report, 2009, p. 48).

The European System of Financial Supervision (ESFS) was to be created in two stages. In 2009–2010, legislative changes were to transform the level 3 committees into European Authorities: a European Banking Authority, a European Insurance Authority and a European Securities Authority. In the same period, a more harmonised set of financial regulations, supervisory powers, norms and sanctioning regimes was to be developed. According to the Report, supervisory colleges for all of the major cross-border financial firms were to be established by the end of 2009.

The second stage of establishing the ESFS consisted of legally transforming the level 3 committees into the three aforementioned Authorities in 2011–2012. It is worth emphasising that the Authorities would not be responsible for the day-to-day supervision of domestic and cross-border institutions. However, they would have the power to make binding decisions, adopt binding supervisory standards and play a mediating role in case of disputes. The Authorities should also supervise certain EU-wide institutions such as credit rating agencies (CRA) and post-trading infrastructures (Larosi re Report, 2009, pp. 48–53).

It is important to consider the cooperation between the newly proposed Authorities and the body that the Report referred to as the European Systemic Risk Council (ESRC) – later formally established as the European Systemic Risk Board (ESRB) – in order to ensure the effectiveness of macroprudential supervision. According to the Report, this cooperation was to be governed by binding procedures for information sharing and the Authorities were expected to lead groups of national supervisors to resolve any problems that affected more than one Member State (Larosi re Report, 2009, p. 54). The Report also presented a diagram illustrating how macroprudential and microprudential supervision would interact within the new European Framework for Safeguarding Financial Stability (Larosi re Report, 2009, p. 57). Furthermore, no later than three years after the establishment of these arrangements and the creation of the European System of Financial Supervision (ESFS), an evaluation of their effectiveness was to be undertaken (Larosi re Report, 2009, p. 58).

Although the Report primarily presented recommendations for the institutional and legal framework in the EU, reforms could not be introduced without taking into account international standards,

regulations and initiatives. To guarantee the stability of the global financial system, the highest possible degree of consistency between international standards was deemed necessary. Discussions on this issue took place at the G20 meetings. The experts of the de Larosière Group considered the debates on reforming the FSF and enhancing its cooperation with the IMF and the Basel Committee as steps in the right direction. According to the Report, the IMF should safeguard the highest standards within the framework of Article IV Reviews. In addition to ensure the consistency of the rules and standards, it was crucial to strengthen cooperation between supervisors. Based on the lessons of the financial crisis, it was recommended that the colleges of supervisors for large, complex, cross-border financial groups focus on internal risk management (Larosière Report, 2009, pp. 58–63).

Taking into account the experience in setting standards in banking, the coherence of banking regulation should be safeguarded by the Basel Committee. The IMF should concentrate on assessing the macroprudential risks and vulnerabilities as well as on developing EWS and procedures such as the “Early Warning Exercise” (EWE). Within the framework of the Article IV consultation process, the IMF/World Bank Financial Sector Assessment Programmes (FSAP) should also be included. The BIS, the IMF and the national central banks should cooperate to establish an international credit register with the data to be used to prepare a global financial risk map. Furthermore, cooperation between international institutions should extend to crisis management and resolution in order to limit negative spillovers, distortions to competition and regulatory arbitrage. Particular emphasis should be placed to strengthening the IMF’s capacity to support countries facing balance of payments problems during crises (Larosière Report, 2009, pp. 63–67).

4.1.2 Institutional and Regulatory Changes After the de Larosière Report

The European System of Financial Supervision

Following the recommendations of the de Larosière Report, in September 2009, proposals were presented for the creation of the European Systemic Risk Board (ESRB) and the establishment of the European Supervisory Authorities (ESAs). Collectively, the ESRB and ESAs form the European System of Financial Supervision (ESFS).⁴ The ESAs comprise the European Banking Authority (EBA), the European Securities and Markets Authority (ESMA) and the European Insurance and Occupational Pensions Authority (EIOPA).⁵ Both the ESRB and the ESAs commenced operations in January 2011. In 2011, the EU introduced the Omnibus II directive in order to better define the responsibilities of the newly established regulatory bodies, especially those overseeing the insurance industry.

The ESRB is responsible for monitoring and assessing potential risks to financial stability and thus functions as a macroprudential supervisor. It analyses early-warning indicators and issues recommendations to mitigate threats to the stability of the financial system. The three ESAs cooperate with national supervisors to ensure the financial soundness of individual institutions and the protection of consumers of financial services. The role of the ESAs is essentially microprudential. Cooperation between the individual ESAs is achieved through the establishment of Joint Committees (Weismann, 2016).

In September 2012, the European Commission put forward a proposal to create the Single Supervisory Mechanism (SSM),⁶ the first pillar of the EU Banking Union. The SSM became operational in November 2014. Under the SSM, the ECB acts as the central prudential supervisor of financial institutions in the euro area and in any other EU Member States that choose to participate. The ECB directly oversees the activities of the largest banks, while national supervisors retain responsibility for supervising the remaining institutions. The ECB and national supervisors cooperate closely in supervising and in addressing problems in the banking sector.

Single Resolution Mechanism (SRM)

On 19 August 2014, the Single Resolution Mechanism (SRM) entered into force (Reg. 806, 2014). It is the second pillar of the EU Banking Union. The SRM applies to the banks that are

supervised under the Single Supervisory Mechanism (SSM) as well as other cross-border groups and its purpose is to ensure that failing institutions can be resolved in an orderly manner and at minimal cost to the public. At its core lies the Single Resolution Board (SRB), an independent EU agency that prepares resolution schemes and manages the Single Resolution Fund (SRF), which is financed by contributions from banks rather than by taxpayers (see EC SRM (2025)).

Although the SRM regulation remains in force, it has been subject to subsequent amendments (EP Legislative Train Schedule, 2025), most notably to strengthen the Minimum Requirement for own funds and Eligible Liabilities (MREL) under the Bank Recovery and Resolution Directive (BRRD) (Dir. 1174, 2024; Dir. 879, 2019). By 2023, the SRF had reached its target level of 1% of covered deposits, thereby bolstering its credibility as a backstop. Further reforms are currently under discussion within the framework of the Crisis Management and Deposit Insurance (CMDI) package, which seeks to harmonise the resolution tools and improve consistency across Member States.⁷

From the perspective of systemic risk and uncertainty, the SRM plays a central role in containing crises by breaking the feedback loop between banks and sovereigns, which had been one of the key amplification mechanisms during the euro area crisis. By shifting the burden of resolution away from taxpayers and establishing pre-defined resolution tools, it reduces uncertainty for market participants and strengthens confidence in the stability of the financial system. In this way, the SRM not only limits the contagion effects but also mitigates the build-up of systemic vulnerabilities over the longer term.

Credit Ratings Agencies (CRAs)

Following the publication of the de Larosière Report, steps were taken to address the issues it identified and to implement appropriate solutions. A key area of concern, which was also highlighted by the G20 Summit, was the reform of credit rating agencies (CRAs). The activities of CRAs had long been criticised for their lack of transparency, conflicts of interest and high degree of market concentration (Bahena, 2010; Gupta et al., 2010; White, 2010). The market was dominated by three agencies – Standard & Poor's, Moody's and Fitch – which together accounted for more than 95% of total activity. This level of concentration was seen as symptomatic of deeper imperfections in the system and raised questions about whether fundamental reform of the CRA sector was required (see, for a normative discussion, Goodhart, 2008). In response, regulatory initiatives were undertaken including the development of a list of authorised rating agencies maintained by the European Securities and Markets Authority (ESMA) in order to improve transparency and oversight of the sector.

Since November 2008, regulatory reforms of CRA activity have been launched⁸ in the EU. In December 2010, the EU Regulation on Credit Rating Agencies (CRA I) entered into force. In May 2011, the amendment to CRA I was adopted – the so-called CRA II. Under the second Credit Rating Agencies Regulation (CRA II), the European Securities and Markets Authority (ESMA) was established and a formal procedure for registering credit rating agencies was introduced. ESMA, which began operations on 1 January 2011, was tasked with assessing risks to investors, markets and financial stability; completing a single rulebook for EU financial markets; promoting supervisory convergence; and supervising financial entities. Since July 2011, all rating agencies operating in the EU have been required to register with the ESMA. Agencies established outside the EU may also be recognised through ESMA certification either under the equivalence regime or by endorsement. The main shortcoming of CRA II was the limited regulation of how ratings were used by financial institutions. Furthermore, the regulation was adopted without a comprehensive analysis of the impact of ratings on financial markets. These deficiencies were later addressed through CRA III (Dir. 14, 2013) and the Capital Requirements Directive IV (CRD IV, 2013).

The new regulatory framework for credit rating agencies, known as CRA III, came into force on 20 June 2013. It represented a significant step forward in addressing the weaknesses that had been left unresolved by earlier reforms. According to its provisions, reliance on external ratings was to be reduced with greater emphasis placed on the use of internal models and assessments of

creditworthiness. The European Central Bank (ECB) welcomed the new framework, while some scholars have examined its broader implications for financial regulation and market practices (see e.g. Moloney, 2014).

In 2013 the Directive also amended earlier legislative acts governing the operation and supervision of key financial institutions and funds, including institutions for occupational retirement provision (IORPs), undertakings for collective investment in transferable securities (UCITS) and the Alternative Investment Fund Managers Directive (AIFMD). The common objective was to curtail excessive dependence on external ratings when evaluating the quality of assets (Dir. 14, 2013).

In line with these requirements, credit rating agencies are now required to disclose the dates of the publication of sovereign debt ratings across the EU Member States. All such ratings must be published through the European Securities and Markets Authority (ESMA) on the European Rating Platform. This initiative not only facilitates comparability across rating outcomes but also enhances the visibility of smaller agencies, thereby helping to counterbalance the dominance of the three largest CRAs in the market.

Alternative Investment Fund Managers Directive (AIFMD)

In June 2011, the Directive on Alternative Investment Fund Managers (AIFMD)⁹ was adopted and entered into force the following month. Its purpose was to establish a harmonised regulatory and supervisory framework for managers of alternative investment funds across the EU. Implementation, however, proved uneven; by 2014, only twelve of Member States had transposed its provisions into national law (KPMG, 2013). The AIFMD Directive covers investment activities that are not regulated by the UCITS Directive,¹⁰ including the business activities of hedge funds, private equity funds and real estate funds. During the crisis, the contribution of AIFMs to leverage was substantial. In line with G20 recommendations, it was necessary to regulate the activities of AIFMs in the EU. The implementation of the Directive was intended to increase transparency of AIFMs vis-à-vis investors and supervisors, to give ESMA and the ESRB powers to monitor and reduce risks to the stability of the financial system, to protect investors in the funds and to strengthen the single market.

The Directive regulates the issuance of single-market AIFMD passports as well as third-country passports, thereby enabling alternative investment fund managers (AIFMs) to conduct investment activities across the EU. In this context, the European Securities and Markets Authority (ESMA) provided advice to the European Parliament, the Council and the Commission on the extension of AIFMD passports to non-EU AIFMs and funds (ESMA, 2015). The Directive also designates competent institutions that are responsible for monitoring and, where necessary, reducing leverage. To enhance investor protection, it further introduced the requirement that funds must be held with depositories.

Deposit Guarantee Schemes (DGS)

In July 2010, the regulations regarding Deposit Guarantee Schemes (DGS) were adopted. The guarantee fund is fully covered by the funds of other banks, not by taxpayers. The first regulations on DGS were introduced at EU level in 1994 but full harmonisation between national Deposit Guarantee Funds was not ensured, which was particularly acute during the 2007–2008 financial crisis. The 2009 amendment introduced a requirement to protect deposits at a minimum of €50 000 in 2009 and then €100 000 in 2010. In 2014, a new Directive¹¹ was adopted, which introduced the requirement to establish at least one DGS in each EU Member State as well as changes to harmonise the protection of depositors. The Directive also sets out the types of deposits that will be protected. DGSs established and officially recognised in one of the EU Member States cover deposits in branches that operate in other Member States. DGS funds can be used for resolution purposes. DGSs should be able to pay out funds in the event of a default of a small or medium-sized bank. The contributions of individual banks to the DGS fund depend on the risks that these banks face. The resolution of large banks is regulated by the Bank Recovery and Resolution Directive (BRRD).¹²

Financial Conglomerates Directive (FICOD)

Financial conglomerates are financial groups that conduct banking and insurance activities in one or more countries. Due to the size and complexity of their activities, they are often considered to be systemically important. The major problems associated with conglomerates are the higher risk of the group and the multiple use of the same capital by the various institutions that are involved in the conglomerate. One of the main goals of the new regulations, notably the Financial Conglomerates Directive (FICOD)¹³ introduced changes to the previous Directives,¹⁴ was to ensure that capital is not used repeatedly for the same purpose.

European Market Infrastructure Regulation (EMIR)

In 2012, the European Market Infrastructure Regulation (EMIR) was adopted (Reg. 648, 2012). Its main objectives were to increase transparency in the over-the-counter (OTC) derivatives market and to mitigate credit and operational risks in this segment. EMIR is widely regarded as one of the most important regulatory measures that were designed to prevent a recurrence of the events that triggered the global financial crisis.

Under EMIR, all information on derivative contracts must be reported to trade repositories (TRs), which then transmit the data to supervisory authorities. TRs are also required to publish aggregated positions for individual classes of derivatives on the OTC market (Abad et al., 2016; D’Errico and Roukny, 2017). Their activities are overseen by the European Securities and Markets Authority (ESMA), which grants – and may withdraw – accreditation.

Another central provision of EMIR is the requirement that all transactions involving standardised derivatives that are traded on the OTC market must be cleared through central counterparties (CCPs). These CCPs must comply with detailed prudential, organisational and market-specific requirements. EMIR also establishes rules for the recognition of the CCPs and TRs operating outside the EU.

The regulation applies to all financial institutions and to certain non-financial institutions that hold significant positions in the OTC derivatives market, which are therefore subject to the central clearing obligation. By contrast, non-financial firms with positions below the regulatory threshold, institutions engaged in the management of public debt, pension funds and intra-group transactions are exempt from this obligation.

Mortgage Credit Directive

The effects of a real estate bubble burst in even one country are often also seen in other countries as a result of the contagion effect. The financial crisis forced cooperation on mortgage credit, consumer protection at EU level and the provision of common quality standards. The first step in this direction was the Mortgage Credit Directive (Dir. 17, 2014), which entered into force in March 2014. The rules started to be applied in March 2016. This Directive applies to loans that are granted to consumers and businesses for the purpose of buying residential property.

The Directive introduces an obligation to provide consumers with detailed information on the loan, the requirement to assess the consumer’s creditworthiness in line with EU standards, common standards and business conduct principles for all EU countries, the consumer’s right to early repayment of the loan before the date specified in the contract and the EU passport that permits credit intermediaries authorised in one country to operate in other EU countries.

Framework for Securities Market & Market Abuse Prevention

The first Markets in Financial Instruments Directive¹⁵ (MiFID) came into force in November 2007 and it was the main document regulating financial markets in the EU, particularly the provision of investment services in financial instruments by banks and investment firms, as well as the operation of traditional stock exchanges and alternative trading venues.

In October 2011, the *Enhanced framework for securities markets* (MiFID/R’) and the *Enhanced framework to prevent market abuse* (MAD/R’) were discussed. At the same time, simplifications

in accounting rules were introduced in the document *Simplification of accounting* together with provisions on transparency in the *Enhanced transparency rules* and audit in the *Enhanced framework for the audit sector*.

In June 2014, the European Commission adopted a new MiFID framework, consisting of the MiFID II Directive and the MiFIR Regulation.¹⁶ MiFID II specifies rules for the securities market including ensuring that organised trading is conducted on regulated platforms. It also regulates algorithmic and high-frequency trading; aims to increase market transparency, particularly in commodities derivatives markets; and to strengthen investor protection.

MiFIR regulates the publication of trading activity data, reporting obligations for supervisors and the requirement for derivatives trading on organised venues, while also ensuring competition between providers of clearing services. The entry into force of MiFID II and MiFIR was originally scheduled for 3 January 2017 but was postponed until 3 January 2018. Both frameworks remain the cornerstone of EU financial market regulation, although a review process has led to amendments that entered into force on 28 March 2024.

Similarly, the Market Abuse Regulation (MAR)¹⁷ entered into force in July 2016, replacing the earlier Market Abuse Directive. MAR remains in force today and continues to provide the legal foundation for preventing insider dealing, unlawful disclosure of inside information and market manipulation across EU financial markets.

Benchmark Rates

In response to the LIBOR scandal that was revealed in 2012 when several global banks were found to have manipulated benchmark interest rates for profit, discussions began on the lack of regulation of benchmarks in the EU. In June 2014, the EU enacted new rules against market abuse that replaced the 2003 Market Abuse Directive. The earlier directive had failed to keep pace with changes in financial markets and infrastructure, including the rise of new trading platforms, OTC trading and technologies such as high-frequency trading. Market Abuse Regulation explicitly prohibits benchmark manipulation including LIBOR (Reg. 596, 2014). It also requires Member States to introduce a common definition of criminal offences related to insider dealing and market manipulation. Benchmark manipulation is closely linked to systemic risk as it undermines trust in financial markets and weakens confidence in the institutions that rely on these benchmarks.

To strengthen the framework further, the EU Benchmarks Regulation was adopted in 2016 (UK Benchmarks Reg., 2020). This measure introduced common rules for the authorisation and supervision of benchmarks, enhanced transparency in their calculation and placed additional oversight on key benchmarks such as Euribor and LIBOR (Reg. 1011, 2016). Both Market Abuse Regulation (MAR) and the Benchmarks Regulation (BMR) remain in force today, although the use of LIBOR itself has been phased out; most settings were discontinued by the end of 2021 with limited synthetic versions temporarily retained for legacy contracts until 2023. These reforms are therefore still relevant but in practice their application has shifted towards the supervision of other critical benchmarks, most notably Euribor and newer risk-free reference rates such as €STR.

A parallel process occurred in the United Kingdom where LIBOR had been administered. Following Brexit, the EU's Benchmarks Regulation was transposed into UK law as the UK Benchmarks Regulation (UK Benchmarks Reg., 2020) and was overseen by the Financial Conduct Authority (FCA). The FCA also took direct responsibility for the orderly wind-down of LIBOR and the introduction of synthetic LIBOR settings for certain contracts. Both jurisdictions therefore adopted broadly similar frameworks though implementation has diverged in the details since Brexit with the EU and the United Kingdom focusing on ensuring continuity for market participants while facilitating the transition towards risk-free reference rates.

PRIIPS Regulation and UCITS Amendment

In July 2012, the EU adopted the PRIIPS Regulation on key information documents for packaged retail and insurance-based investment products¹⁸ and the UCITS V Directive¹⁹ on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities as regards depositary functions, remuneration policies and sanctions. The former requires producers or sellers of complex financial products to provide investors with a short key information document (KID) and is aimed at increasing transparency and limiting mis-selling. The latter amended previous Directive (Dir. 65, 2009b) by strengthening rules on depositaries, introducing stricter liability for asset losses, harmonising sanction regimes and aligning remuneration with prudent risk-taking.

More recently, the UCITS rules have been updated. In March 2024, the EU adopted a new Directive,²⁰ which further aligned UCITS with the Alternative Investment Fund Managers Directive (AIFMD), which refined the rules on delegation, liquidity risk management, supervisory reporting, depositary services and loan origination by alternative investment funds. In parallel, ESMA issued technical advice in 2025 on revising the UCITS Eligible Assets Directive (EAD) and clarified the rules on eligible assets, derivatives and liquidity criteria (ESMA, 2025).

The closer alignment between UCITS and AIFMD reflects a broader systemic risk agenda; both frameworks are now subject to stricter requirements on liquidity, leverage and risk management, thus ensuring that vulnerabilities in either retail or alternative investment funds cannot spill over into the wider financial system. By reducing opacity, limiting contagion from excessive risk-taking and improving supervisory convergence, these reforms aim to strengthen investor protection while also enhancing the resilience of the EU financial markets in the face of uncertainty.

Shadow Banking Regulations

Concerns that regulated banking activities were shifting into less transparent parts of the financial system after the crisis led the European Commission to issue a Green Paper on Shadow Banking in 2012 (EC Com., 2012) and a Communication in 2013 (EC Com., 2013). Particular attention was paid to securities financing transactions (SFTs) – repos, securities lending and similar operations in which securities serve as collateral for cash because they can obscure leverage and interconnectedness. To address these risks, the EU adopted the Securities Financing Transactions Regulation (SFTR) (Reg. 2365, 2015), which introduced the mandatory reporting of SFTs to trade repositories and stricter rules on collateral reuse. The SFTR, which is still in force in an amended form, is complemented by ongoing initiatives such as the FSB’s framework on minimum haircut floors and the EBA’s 2025 proposals requiring banks to disclose their aggregate exposures to shadow banking entities. These measures are directly linked to systemic risk and uncertainty. By reducing opacity in non-bank financial intermediation, they help to contain hidden leverage, mitigate contagion channels and strengthen the resilience of the EU financial system.

CRD Reforms

In July 2011, the European Commission presented the key components of its envisioned Single Rule Book – covering capital, liquidity, leverage, remuneration rules and transparency – which eventually led to the CRD IV/CRR package. In 2013, these proposals became law.²¹ These reforms responded directly to the lessons of the crisis, strengthening capital quality, addressing maturity mismatches, formalising reporting and transparency obligations and tightening the links between remuneration and prudent risk management. Supervisors were empowered to impose additional capital buffers or sanctions when remuneration policies proved misaligned with risk tolerance.

In 2019, the CRD IV/CRR regime was substantially revised as part of the *Risk Reduction Measures Package*.²² The reforms sought to embed the remaining Basel III standards into EU law, bolster the resilience of banks and align prudential requirements with the goals of the Banking Union. Among the most significant innovations were the introduction of a binding leverage ratio – a simple,

non-risk-based backstop that limited the build-up of excessive debt, a net stable funding ratio (NSFR) – to ensure that banks hold sufficient stable, long-term funding relative to their assets, stricter rules on large exposures and enhanced disclosure requirements. CRD V enhanced supervisory powers, refined capital buffer frameworks and improved rules for third-country banks operating in the Union. Together with the Single Resolution Mechanism Regulation II (SRMR II) and the Bank Recovery and Resolution Directive II (BRRD II) (Reg. 877, 2019; Reg. 879, 2019), these measures reinforced resolution frameworks and aimed at a more coherent regulatory treatment of cross-border banking groups.

These CRD/CRR reforms are critical for systemic risk management because they expand the toolkit for resilience and shock absorption. By mandating higher-quality capital buffers (including new structural and macroprudential buffers), controlling leverage through both risk-based and non-risk-based requirements and enforcing stricter liquidity norms, the reforms reduce excessive risk-taking and strengthen the capacity of banks to absorb shocks. In periods of heightened uncertainty, these safeguards limit the risk of contagion across the financial system and provide greater predictability for banks, supervisors and markets. As a result, both systemic risk and systemic uncertainty are contained more effectively than under the pre-crisis regulatory regime.

4.1.3 A Closer Look at the Implementation of Basel III and IV in the EU Through the CRR/CRD Frameworks

Systemic risk and uncertainty lie at the core of post-crisis regulatory reforms. The financial crisis of 2007–2009 revealed how fragile capital structures, excessive leverage, maturity mismatches and interconnectedness amplified shocks and undermined confidence in the stability of the banking system. To address these vulnerabilities, international standards were tightened under the Basel III agenda (often referred to in its later refinements as Basel IV) and the EU translated these requirements into binding law through the CRR/CRD frameworks.

As Olszak (2015) notes, several priorities were identified: improving the quality of bank capital and ensuring international consistency in prudential norms; broadening the definitions of risk and loss-absorbing capital; introducing a leverage ratio alongside traditional risk-based measures; mitigating procyclicality through countercyclical tools; and addressing the risks arising from the interconnectedness of financial institutions and the presence of systemically important banks.

The CRD IV package (Reg. 575, 2013a; CRD IV, 2013), together with subsequent revisions under CRR II/CRD V (Reg. 876, 2019; Dir. 878, 2019), represent a decisive regulatory response to systemic vulnerabilities. Its provisions explicitly sought to reduce uncertainty by ensuring that banks are able to absorb shocks, limit contagion effects and maintain confidence in both national financial systems and the wider European banking union.

From this foundation, the following subsections consider the specific mechanisms that were introduced under the CRR/CRD framework: changes in the quality of capital, the role of Common Equity Tier 1 (CET1) and Tier II, the capital conservation and countercyclical buffers, systemic risk buffers for SIFIs, the leverage ratio and liquidity standards such as the LCR and NSFR. Each of these instruments illustrates how post-crisis prudential reforms were shaped not merely to meet regulatory benchmarks but to mitigate systemic risk and reduce the uncertainty that magnifies financial crises.

The Quality of Capital Within the CRD IV Framework

The reforms that were introduced under Basel III and subsequently incorporated into the CRD IV package brought significant changes to the definition and quality of regulatory capital (Olszak, 2015).²³ These reforms were aimed not only at strengthening the resilience of banks but also at reducing systemic risk and uncertainty by ensuring that the capital base was genuinely loss-absorbing and less prone to regulatory arbitrage.²⁴

Under the Basel regulatory framework, bank capital is structured into tiers that reflect its capacity to absorb losses. Common Equity Tier 1 (CET1) represents the highest-quality capital, consisting

primarily of paid-up common shares and retained earnings and serves as the core buffer against unexpected losses. Additional Tier 1 and Tier 2 capital instruments offer supplementary loss-absorbing capacity, but are less robust due to their subordinated nature and contingent loss-absorption mechanisms. Regulatory capital ratios are measured relative to risk-weighted assets (RWA), which adjust a bank's exposures to credit, market and operational risks. This ensures that capital requirements reflect not only the size but also the risk profile of a bank's balance sheet.

In CRR/CRD IV, firstly, Tier III capital was removed from the regulatory framework as it had proven to be inadequate in absorbing losses during periods of stress. Secondly, the role of Common Equity Tier 1 (CET1) capital was reinforced. In the case of joint-stock banks, CET1 consists mainly of paid-up share capital and retained earnings. Its minimum ratio to risk-weighted assets (RWA) was raised to 4.5% compared to the Basel II threshold of just 2%. Thirdly, the importance of Tier II capital was reduced, thus reflecting its weaker ability to absorb losses compared to CET1. Fourthly, the minimum Tier 1 capital ratio was increased to 6% up from 4% under Basel II. Finally, more stringent rules for capital valuation adjustments were introduced, particularly for Tier 1 instruments.²⁵ These changes substantially improved both the quantity and the quality of regulatory capital. By prioritising CET1 and tightening the capital definitions, the CRD IV framework sought to mitigate systemic vulnerabilities, strengthen the ability of banks to absorb shocks and reduce the uncertainty surrounding their solvency in times of financial stress.

Under CRD IV, banks must hold at least 4.5% of risk-weighted assets in CET1 capital. In addition, banks are required to hold 1.5% in Additional Tier 1 instruments and 2% in Tier 2 capital but left the overall minimum capital requirement unchanged at 8%. However, compared with the earlier CRR/CRD frameworks, the quality of the capital has been significantly improved with CET1 placed at the core of the system to ensure greater loss-absorbing capacity. National authorities cannot increase these minimum requirements except where justified under supervisory review, systemic risk concerns or macroprudential considerations (including systemic risk, global systemically important institutions (G-SIIs) and other systemically important institutions (O-SIIs) buffers as well as Pillar 2 requirements.

In addition to these minimum requirements, the framework introduced a capital conservation buffer of 2.5% of RWA, which was applied under Pillar 1. This buffer is intended to enhance the resilience of banks by ensuring that capital is preserved in good times, thereby creating additional capacity to absorb losses during periods of stress. The introduction of the buffer has important implications for systemic risk and uncertainty. In the long run, by obliging banks to maintain higher levels of capital, it is expected that the procyclicality of capital regulation will be dampened and the amplification of financial cycles to be reduced. In the short term, however, compliance with the new requirements may constrain lending activity, particularly in higher-risk segments of the market, as banks adjust their balance sheets to the stricter standards (Olszak, 2015). This reflects the inherent trade-off between stability and credit supply.²⁶

Countercyclical Buffer

The countercyclical capital buffer (CCB) was introduced to address the temporal dimension of systemic risk by mitigating the build-up of vulnerabilities during credit booms. Its primary function is to limit the excessive risk-taking of banks in periods of rapid credit expansion, thereby reducing the likelihood and severity of systemic stress during downturns (Olszak, 2015). When activated, the buffer is set by the competent authority in response to evidence of unsustainable credit growth and a corresponding rise in systemic risk. The CCB can be raised to up to 2.5% of risk-weighted assets (BCBS, 2010). Institutions that fall short of the required capital are required to retain earnings, face restrictions on dividend distribution and must adjust their risk-taking accordingly.

The instrument is particularly significant for systemic risk and uncertainty as it seeks to smooth the financial cycle and reduce the procyclicality of bank capital regulation. By increasing capital requirements during expansions, the buffer builds resilience that can be drawn upon in times of

crisis, thereby dampening contagion effects across the financial system. Its design was inspired by the Spanish practice of dynamic provisioning, which had been used prior to the global financial crisis. Nevertheless, several challenges limit the buffer's effectiveness. These include methodological difficulties in measuring any deviations of credit growth from its long-term trend, the calibration of appropriate buffer rates and the inherently discretionary nature of activation decisions. Such issues introduce a degree of uncertainty into its practical application and highlight the importance of transparent communication and cross-border coordination (Kowalik, 2011; Repullo and Suarez, 2013; Drehmann et al., 2011).

Systemic Risk, O-SII and G-SII Buffers

Systemically important financial institutions (SIFIs) are considered too-big-to-fail, which makes them especially prone to moral hazard and a key source of systemic risk. To address these vulnerabilities, the CRD IV/CRR framework introduced additional capital buffers that are intended to strengthen the resilience of both individual institutions and the system as a whole (Olszak, 2015).

The systemic risk buffer is an optional tool that is designed to cover structural risks under Pillar 1. From 2014, national authorities were authorised to set the buffer between 0% and 3% subject to notification to the European Commission, the European Banking Authority (EBA) and the European Systemic Risk Board (ESRB). From 2015 onward, the buffer could be increased to 3–5% and rates above 5% require prior approval from the European Commission. Its flexibility makes it particularly relevant in addressing the uncertainty that is associated with long-term, non-cyclical risks such as excessive concentration in certain markets or structural imbalances in national banking systems.

In addition, the framework introduced specific buffers for Other Systemically Important Institutions (O-SIIs) and Globally Systemically Important Institutions (G-SIIs). The former is optional, whereas the latter is mandatory. The O-SII buffer, which has been applicable since 2016, can be set up to 2% of risk-weighted assets (RWAs) with notification to the EU and national authorities. It can apply to either the entire financial system or to a subset of intermediaries and can be imposed at both the national and international level. The G-SII buffer, by contrast, applies to global institutions on a consolidated basis and is set within a range of 0–3.5% of RWAs. Where more than one buffer is relevant, the highest rate applies though the systemic risk buffer can be combined with O-SII or G-SII requirements if it relates specifically to exposures in one Member State.

From the perspective of systemic risk, these buffers are intended to internalise the externalities that are created by large and highly interconnected institutions, thereby reducing both the likelihood of their failure and the contagion effects such a failure would generate. By strengthening the resilience of SIFIs, the buffers also reduce uncertainty in the financial system as markets can be more confident in the ability of core institutions to withstand shocks.

Leverage Ratio

The leverage ratio was introduced in the EU as a binding prudential requirement in 2018 under the CRR/CRD IV framework. It is defined as the ratio of Tier 1 capital to the measure of total exposure, which is calculated on a non-risk-weighted basis. In order to limit excessive balance sheet expansion and the build-up of systemic vulnerabilities, the ratio must not fall below 3%. The measure of total exposure includes the book value of on-balance-sheet assets, derivative exposures, securities financing transactions (SFTs) and certain off-balance-sheet items.²⁷

Unlike risk-weighted capital requirements, which are sensitive to the quality of assets, the leverage ratio is deliberately simple and transparent and acts as a backstop to prevent banks from taking on excessive leverage during periods of optimism. This makes it particularly relevant in addressing systemic risk and uncertainty as it ensures a minimum level of resilience even when risk weights might underestimate the true scale of exposures such as during asset price booms or when model-based approaches underestimate credit risk.

The importance of the leverage ratio was further reinforced under the 2019 reforms (CRR II/CRD V), which made the 3% requirement permanently binding from June 2021. In addition, global systemically important institutions (G-SIIs) are now required to maintain an additional leverage ratio buffer equal to 50% of their risk-based G-SII capital buffer. This strengthens the framework for institutions whose size and interconnectedness amplify systemic vulnerabilities, thus further reducing the uncertainty that is associated with their stability.

Looking ahead, the EU has committed to implementing the final Basel III reforms (often referred to as Basel IV) from 2025, which will further refine the leverage ratio framework. These reforms are designed to ensure greater comparability of the risk exposures of banks and to close any gaps that were revealed during the financial crisis, especially regarding model-based risk measurement. For the EU, the integration of these rules into the CRR III/CRD VI package will extend the leverage ratio's role as a safeguard against systemic risk, thereby ensuring that it continues to operate alongside capital buffers and liquidity requirements as part of a comprehensive framework to reduce procyclicality, contain contagion and mitigate uncertainty in the banking sector.

Liquidity Measures: LCR and NSFR

One of the key lessons of the global financial crisis was that many banks, although meeting capital requirements, faced severe liquidity shortages that quickly translated into systemic instability. To address this vulnerability, the CRR/CRD IV framework introduced two liquidity standards that were inspired by Basel III: the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR). Both measures are designed to mitigate maturity mismatches and ensure that banks maintain a resilient funding structure.

The LCR requires institutions to hold sufficient high-quality liquid assets (HQLA) to withstand a severe liquidity stress scenario for at least 30 days. This is calculated as the ratio of HQLA to net cash outflows over the next 30 days with net outflows being defined as the difference between the expected outflows and inflows or 75% of the total outflows, whichever is lower (Olszak, 2015). To avoid over-reliance on lower-quality assets, the framework distinguishes between Level 1 and Level 2 assets with Level 2 assets being capped at 40% of the total buffer. The NSFR complements the short-term LCR by addressing longer-term funding stability. It requires that the amount of available stable funding (ASF) be at least equal to the required stable funding (RSF), thus ensuring that illiquid, long-maturity assets are not funded excessively through short-term wholesale markets. The NSFR ratio must not fall below 100%.

Both the LCR and NSFR directly address systemic risk by limiting the potential for liquidity-driven contagion and sudden funding crises. By requiring banks to maintain liquidity buffers and stable funding structures, these instruments reduce uncertainty in periods of stress and curb the amplification mechanisms that triggered much of the 2008–2009 crisis. However, scholars note that they may have procyclical effects; during downturns, banks might reduce lending in order to meet liquidity thresholds, which could exacerbate the contraction of credit supply (Olszak, 2015; Giordana and Schumacher, 2017).

The EU has fully phased in both the LCR (from 2018) and the NSFR (from 2021 under CRR II), thereby aligning with international Basel III commitments. These measures, together with capital and leverage requirements, form an integrated macroprudential framework that is designed to enhance resilience against shocks, reduce uncertainty and safeguard financial stability in the long run.

Spain's pre-crisis experience illustrates the necessity of such liquidity requirements. Despite apparently robust capital positions, Spanish banks and savings banks became highly vulnerable when wholesale funding markets froze in 2008. Their over-reliance on short-term external financing left them exposed to sudden liquidity shocks, which amplified the downturn in the real estate sector and deepened systemic stress. By imposing harmonised liquidity standards, the LCR and NSFR are intended to prevent similar dynamics in the future and to strengthen the credibility of the funding models of banks across the EU.

4.2 Macroprudential Policies

The preceding discussion of capital, leverage, liquidity standards and buffers highlighted how post-crisis reforms in the EU sought to contain the vulnerabilities that had amplified systemic risk. These reforms, while crucial, form only one component of a broader framework: the design and implementation of macroprudential policy. Moving from the technical requirements of the CRR/CRD packages to the theoretical underpinnings of macroprudential regulation allows us to situate those reforms within a wider conceptual debate on how financial stability can be best safeguarded in the long term.

Macroprudential policy seeks, on the one hand, to develop and apply instruments that reduce and withstand systemic risks that arise over the credit cycle (the time dimension) and, on the other, to deploy tools with a cross-sectional dimension, thereby addressing the risks that are associated with the size, complexity and interconnectedness of institutions (the structural or spatial dimension) (Mencía and Saurina, 2016).

Macroprudential policies are often contrasted with microprudential policies. Yet the two differ fundamentally in their objectives; while microprudential tools are that are designed to safeguard the resilience of individual institutions, macroprudential measures aim to preserve the stability of the financial system as a whole. In this sense, macroprudential policies are particularly concerned with systemic properties such as procyclicality, interconnectedness and common exposures to shocks (Galati and Moessner, 2014).

Although the distinction between the two perspectives is frequently emphasised, the boundary is not always clear-cut. A number of tools that had originally been developed for microprudential purposes – such as loan-to-value (LTV), loan-to-income (LTI) and debt-to-income (DTI) ratios as well as capital controls and certain forms of taxation – are now recognised as having macroprudential functions (BIS, 2010; Morgan et al., 2015; Gadanez and Jayaram, 2015). The IMF therefore distinguishes between instruments that have been explicitly designed to mitigate systemic risk and those that have been adapted from other domains but that are applied with systemic concerns in mind (Lim et al., 2011; IMF, 2021).

It is also important to note that measures aimed at strengthening crisis management and resolution frameworks, while closely related, are not themselves macroprudential in a strict sense. They are reactive in nature and seek to address crises once they occur, whereas macroprudential policies are pre-emptive and are designed to reduce the probability and severity of crises by containing risk at its source (Nier et al., 2011). At the same time, some scholars stress that macroprudential policies can sometimes play an active role in crisis management rather than being purely preventive in orientation (Szpunar, 2012).

Macroprudential policies can thus be analysed across temporal and spatial dimensions (Schoemaker and Wierst, 2011). Within each dimension, intermediate objectives can be defined and linked to specific tools – for example, limiting excessive leverage and credit growth in the temporal dimension or addressing vulnerabilities in market structures and contagion channels in the spatial dimension. The evolving taxonomies of macroprudential instruments have been examined in detail by Nier and Zicchino (2008), Bruno et al. (2017), Nier and Forte (2016), Galati and Moessner (2014), Bańbula (2013), Rosati (2014) and Dobrzańska (2014), thus offering a useful framework for evaluating both their theoretical justification and practical application.

4.2.1 *The Theory of Macroprudential Policies*

The rationale for macroprudential policies has been examined using a variety of modelling approaches, including banking and finance models, three-period general equilibrium models, dynamic stochastic general equilibrium (DSGE) models with financial frictions and infinite-horizon general equilibrium macro models (Galati and Moessner, 2014).

The first strand of the literature adopted a partial equilibrium perspective, which lends itself to the analysis of the spatial (cross-sectional) dimension of macroprudential policy but largely neglects its temporal dimension. Classic contributions include Diamond and Dybvig (1983), Diamond and Rajan (2001) and Perotti and Suarez (2011). These models emphasise the interactions between lenders and borrowers, while abstracting from broader general equilibrium effects. Assets and contracts are typically state-dependent and sensitive to market imperfections such as information asymmetries, externalities or moral hazard. In this framework, the justification for macroprudential intervention often arises from the presence of externalities with instruments being conceptualised in the form of Pigouvian taxes.

A second strand focuses on three-period general equilibrium models, which allow for a richer analysis of interactions between asset prices and financial distress in both the financial and corporate sectors (e.g. Kashyap et al., 2014). Here too, the rationale for macroprudential policies is linked to market failures (Lorenzoni, 2007; Tsomocos, 2003; Goodhart et al., 2012; Gersbach and Rochet, 2012). Externalities emerge because individual agents fail to internalise the general equilibrium effects of their actions. As Galati and Moessner (2014) noted, these models analyse the risk-taking behaviour of heterogeneous agents in economies that have been exposed to systemic risk and potential default. In practice, however, such heterogeneity is often simplified or omitted.

The third strand includes infinite-horizon macroeconomic models with financial frictions, typically DSGE models that are based on the financial accelerator mechanism (Bernanke et al., 1999). In central banking practice, DSGE models with stylised macroprudential instruments – such as those developed by Clerc et al. (2015a,b) and now used by the ESRB and the ECB – are among the most common. These models have been criticised for several limitations. As Galati and Moessner (2014) emphasise, infinite-horizon DSGEs, which are solved by linearisation, are poorly suited for capturing state-contingent dynamics and systemic crises and until recently, they assumed complete markets and largely ignored defaults (though exceptions exist, e.g. Benigno et al. (2013)). Moreover, as Geanakoplos (2011) argues, endogenous leverage was frequently omitted.

Finally, more recent contributions adopted a continuous-time setting with financial frictions, which better capture the dynamic build-up of vulnerabilities and systemic events (He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014).

Despite these shortcomings, general equilibrium approaches remain highly influential in the theoretical justification of macroprudential policy. Within this framework, the central rationale is usually associated with pecuniary externalities – that is situations in which individual decisions affect relative prices and thereby the borrowing constraints faced by other agents (Caballero and Krishnamurthy, 2001; Lorenzoni, 2007; Bianchi, 2011; Jeanne and Korinek, 2010; Bianchi, 2011; Korinek, 2011). These externalities are typically analysed by introducing incomplete markets into the Arrow–Debreu framework (Stiglitz, 1982; Geanakoplos and Polemarchakis, 1986; Geanakoplos et al., 1990) or by incorporating borrowing constraints that are sensitive to asset prices. Importantly, as Greenwald and Stiglitz (1986) showed, private information is not strictly required for such externalities to arise.

An alternative approach that was developed by Farhi and Werning (2016) highlights aggregate demand externalities within models that feature complete markets, nominal rigidities and monetary policy constraints (see [Appendix B](#)). The authors also propose a joint model that incorporates both pecuniary and demand externalities. Their framework is particularly valuable because it embeds macroprudential policy alongside monetary and exchange rate policies and explicitly considers how wealth distribution affects demand and output within a social planner framework. This allows welfare effects to be analysed more directly, thus offering a benchmark that differs from the agent-based approach that will be explored in the next chapter.

In this setting, macroprudential tools can be conceptualised as Pigouvian taxes or as quantitative restrictions on borrowing and portfolio choices. Optimal taxes provide incentives for agents with high marginal propensities to spend on goods that are relatively depressed in some states to shift wealth towards those states, thereby increasing aggregate demand and improving efficiency. As Korinek

(2011) stresses, because output is demand-driven, the distribution of wealth across agents plays a central role. In principle, unemployment can be reduced by reallocating wealth towards agents with high propensities to consume. According to Farhi and Werning (2016), this can be achieved either *ex ante* through macroprudential policies or *ex post*, through redistribution.

Their analysis illustrates four applications. Firstly, they show how debt deleveraging by households might trigger a liquidity trap in the presence of nominal rigidities, which extends the insights of Eggertsson and Krugman (2012) and Guerrieri and Lorenzoni (2017). In this context, macroprudential restrictions on credit expansion during booms (e.g. LTV or DTI caps) can reduce the severity of downturns. Secondly, they apply the framework to Mundell's trilemma and show that under fixed exchange rate regimes or currency unions, capital flow management tools are necessary complements to macroeconomic stability. Thirdly, they analyse sudden stops in capital inflows highlighting the role of pre-emptive taxes on risky capital flows. Fourthly, they consider the case of incomplete markets with local- and foreign-currency debt and recommend higher taxes on foreign-currency borrowing due to its poor risk-sharing properties.

Taken together, these mainstream theoretical perspectives demonstrate that macroprudential policies are justified as corrective tools to address systemic externalities, mitigate procyclicality and reduce uncertainty in both the financial system and the wider economy.

Beyond the mainstream, heterodox approaches, such as post-Keynesian and institutionalist frameworks offer a complementary rationale. Rather than modelling systemic risk primarily through externalities in stylised equilibrium models, these perspectives emphasise the inherent instability of financial markets (in the Minskyan tradition), the procyclicality of credit creation by banks and the structural role of inequality in amplifying systemic fragility. Macroprudential policies are thus interpreted less as Pigouvian corrections and more as instruments of structural reform that are designed to contain speculative dynamics, constrain leverage cycles and support long-term financial stability through counter-cyclical buffers and credit guidance. While less formalised, these approaches underline the uncertainty that characterises financial systems and highlight the importance of robust institutional design over narrow optimisation exercises. In this sense, both mainstream and heterodox theories converge on a key insight: macroprudential policies are not merely technical adjustments but institutional responses to systemic risk and uncertainty with profound implications for the resilience of financial systems and their interactions with the real economy.

4.2.2 *The ESRB's Objectives and Macroprudential Instruments in the EU*

Having outlined the theoretical underpinnings of macroprudential policy, we now turn to its operationalisation in the EU. The ESRB's Handbook on Operationalising Macroprudential Policy in the Banking Sector (2015; 2018) remains the key reference for the EU framework. It stresses that the instruments that are introduced under CRR/CRD IV are not meant to be applied in isolation but rather linked to well-defined intermediate objectives. This connection between tools and objectives is essential; it ensures that macroprudential policy does not drift into a vague supervisory practice but instead operates with a clear sense of purpose that is grounded in the logic of systemic risk.

The ultimate aim, as the ESRB formulates it, is safeguarding financial stability as a whole. To make that ambition concrete, the Handbook identifies four intermediate goals. The first is to limit excessive credit growth and leverage, which are the classic sources of boom-bust cycles in finance. Instruments aligned with this goal include the countercyclical capital buffer, borrower-based measures such as loan-to-value and loan-to-income limits, sectoral capital requirements and the leverage ratio.

The second goal is to contain excessive maturity mismatch and market illiquidity. These vulnerabilities are less visible in normal times but can amplify shocks once uncertainty spikes. To address them, the ESRB points to liquidity regulation – most prominently the liquidity coverage ratio (LCR), the net stable funding ratio (NSFR) and complementary measures such as loan-to-deposit limits or liquidity charges.

The third intermediate objective is to reduce direct and indirect exposure concentrations. Systemic risk in the spatial dimension often arises not from the sheer level of credit in the system but from the clustering of exposures to the same sector, instrument or counterparty. Sectoral requirements, the systemic risk buffer, large-exposure limits and the capital conservation buffer are designed with precisely this in mind.

Finally, the ESRB highlights the need to curb misaligned incentives and moral hazard, particularly in systemically important institutions. Here, the toolkit overlaps with structural measures: capital buffers for global or other systemically important institutions (G-SIIs and O-SIIs), the systemic risk buffer, the conservation buffer and, where necessary, additional liquidity requirements. These instruments are justified not because they smooth the cycle but because they reduce the likelihood that the failure of a large or complex bank will trigger a cascade through the system.

Seen together, the four objectives reflect the two dimensions of systemic risk that were already discussed in the theoretical section: the temporal build-up of imbalances and the structural vulnerabilities arising from size, complexity and interconnectedness. The ESRB's framework translates these abstract dimensions into an operational map of tools. In the following subsections, we examine how EU countries, particularly those most affected by the financial crisis, have applied this toolkit in practice and how the use of instruments has evolved since the adoption of CRR/CRD IV.

4.2.3 Experience with Macroprudential Policies in the EU Countries

The practical application of macroprudential policy in Europe has largely taken shape only since the entry into force of the CRR/CRD IV framework in 2014, which provided a common regulatory foundation for the use of systemic risk buffers, capital-based instruments and borrower-based tools across Member States. Yet the European story of macroprudential thinking does not begin in 2014. Long before the codification of macroprudential instruments in EU law, national authorities had experimented with credit controls, provisioning rules and liquidity requirements that were aimed at taming procyclicality and preventing contagion. For instance, the United Kingdom relied on direct credit ceilings in the 1970s, the Netherlands used similar restrictions through the 1980s and Sweden experimented with domestic credit controls as early as the 1950s. Comparable measures were popular not only in advanced economies but also in emerging markets where policymakers often turned to credit rationing, reserve requirements or loan-to-value limits as early forms of systemic safeguards.

After the wave of financial liberalisation in the 1980s and 1990s, many of these tools were dismantled only to re-emerge – this time under the label of “macroprudential policy” – in the aftermath of the 2008 global financial crisis. The crisis underscored the urgent need to address systemic risk both in its temporal dimension by leaning against credit booms and the build-up of leverage and in its spatial or structural dimension by containing the vulnerabilities of large, complex and interconnected institutions. Since then, EU countries have gradually converged on a shared framework under the ESRB's guidance, while still tailoring instruments to their domestic financial structures and vulnerabilities.

In what follows, we turn to the experience of selected EU countries to illustrate how macroprudential policies have been applied in practice. These case studies highlight both the diversity of national approaches and the common challenge of containing systemic risk in a monetary union that is marked by strong cross-border spillovers and heightened uncertainty.

4.2.3.1 The Macroprudential Policies in PIIGS Countries

The Spanish experience with macroprudential policy is particularly instructive as Spain was one of the first European countries to experiment with explicitly countercyclical tools. Well before the global financial crisis and long before the formalisation of macroprudential frameworks under CRR/CRD IV, Spanish regulators recognised the dangers of excessive credit growth and procyclicality. At the centre of these early efforts stood dynamic provisioning, a rule that was designed to require banks to

build up reserves in good times so that they could be released during downturns. In this way, Spain attempted to address the temporal dimension of systemic risk, smoothing the financial cycle and limiting the amplification of shocks.

This pioneering approach was rooted in the country's earlier economic trajectory. From the 1970s onwards, Spain experienced repeated credit booms and busts, which were often amplified by government policies such as low interest rates, tax incentives for real estate and land market deregulation. These measures fuelled household indebtedness, speculative demand for housing and strong procyclical dynamics. By the late 1990s, Spain combined one of the lowest levels of loan-loss provisions in the OECD with one of the highest correlations between provisioning and GDP growth, a clear sign of excessive cyclicality. Coupled with rapid immigration-led population growth in the 2000s, which further boosted credit demand and real estate prices, the vulnerabilities of the system became increasingly visible. Against this background, the authorities introduced dynamic provisioning in 2000 as a forward-looking countercyclical buffer.

Discussions on the introduction of dynamic provisioning began in 1998. The idea was to require banks to accumulate funds during the expansive phase of the cycle so that they could later be drawn down in periods of contraction. The reserves were to be explicitly forward-looking, while remaining neutral to the business activities of foreign branches. At the same time, Spanish experts also considered how to regulate off-balance sheet securitisation, which was gaining importance. Dynamic provisioning was formally approved in December 1999 and came into force in June 2000. At first, these reserves were referred to as anti-cyclical provisions but the terminology soon shifted to statistical provisions to better reflect their character. The mechanics of dynamic provisioning were designed to capture the so-called latent loss in loan portfolios. In practice, this meant that during upswings, when realised defaults were unusually low, banks were required to charge additional statistical provisions to their profit and loss accounts, thereby building up a fund to be used once losses inevitably rose above their long-term average (Saurina, 2009a,b).

Because loan portfolios differ widely in their risk structure, the regulation allowed for two methods of calculating latent losses: a standardised approach with parameters fixed by the Bank of Spain for each class of loan and an internal approach that was subject to supervisory review. Importantly, the accumulated statistical fund counted as Tier-2 capital but its growth was subject to an explicit cap in order to avoid unrealistically high coverage ratios. This meant that the burden of provisioning was not imposed uniformly across banks but varied according to the specific risk composition of each institution's loan book.

In Spain, accounting rules and macroprudential regulation have always been closely intertwined, particularly in the area of provisioning. Between 2000 and 2017, four major revisions to dynamic provisioning were introduced, the most important in 2004 when the framework was aligned with IFRS. From then on, provisions were divided into only two categories – general and specific – while the general provisions themselves had two components: α , capturing latent losses and β , reflecting the average level of specific provisions over a full credit cycle.

The mechanism was simple in spirit; during credit booms, the β component turned positive forcing banks to build statistical reserves; in downturns, when losses materialised, the same component became negative releasing part of the buffer. This limited, though did not entirely eliminate, the procyclicality of reserves. Moreover, caps were imposed to prevent coverage ratios from reaching unrealistic levels. Importantly, statistical provisions up to 1.25% of risk-weighted assets could also be counted as Tier-2 capital.

The first revision to dynamic provisioning was introduced in 2005 during the expansionary phase followed by further changes in late 2008 and 2009 as the financial crisis unfolded and additional ad hoc increases in 2012. In practice, dynamic provisioning worked as a countercyclical buffer; it accumulated during the boom years of 2000–2007 and was drawn down once the crisis erupted in 2008.

Yet under stress, the mechanism quickly weakened. The Bank of Spain reduced provisioning requirements from 33% in 2008 to 10% and then to zero in 2009 leaving reserves at only 1.25% of

total credit (Jiménez et al., 2017a). This sparked criticism that the framework risked eroding the competitiveness of Spanish banks relative to their peers abroad.

Despite these shortcomings, research suggests that dynamic provisioning generated real effects. Using firm-level data, Jiménez et al. (2017b) found that a one-basis-point increase in buffers translated into a nine-basis-point rise in business credit, a six-basis-point increase in employment and a modest improvement in firm survival rates. Although these results are difficult to validate due to data restrictions, complementary studies such as Balla and McKenna (2009) confirmed that dynamic provisioning has the potential to smooth the credit cycle and mitigate systemic risks.

The Spanish experience with dynamic provisioning, later echoed in several Latin American countries, fed directly into the Basel Committee debates that shaped Basel III. One of the most notable innovations of Basel III compared to Basel II was the countercyclical capital buffer, which was designed to prevent the accumulation of systemic risk during booms and to provide usable reserves in downturns. While the theoretical rationale for such time-varying buffers is clear, their actual effects on credit supply, the real economy and the smoothing of business cycles remain only partially tested. Still, the Spanish case strongly influenced international discussions with scholars and policymakers such as Alegre (2008), Saurina (2009b,a) and Fernández-Ordóñez (2011) explicitly supporting the inclusion of countercyclical tools in Basel III (see also Enguádanos, 2012).

Parallel to this, Spain grappled with aligning its provisioning framework to international accounting standards. The expected loss model was debated as early as 2009 but was not adopted at that time (EFRAG-EFF Joint Working Group, 2009). Subsequent reforms, including Circular No. 2/2012 (BdE, 2012) and Royal Decree No. 2/2012 (BOE, 2012), revealed tensions between national rules and International Financial Reporting Standards (IFRS), particularly IAS 39. A major step came in 2016 with Circular No. 4/2016 (BdE, 2016b), which amended the previous framework and paved the way for a shift from incurred-loss to expected-loss provisioning in line with IFRS 9, which was effective from January 2018. Notably, while Basel III placed strong emphasis on the countercyclical buffer, Basel IV makes relatively little reference to this instrument, thus signalling a shift in the international debate.

Alongside loan provisioning, Spain's regulatory stance on securitisation played a crucial role in shaping the resilience of its banking system. The first framework for covered bonds was introduced in 1981 and, for many years, these remained the only securitised instruments permitted on the balance sheets of banks. A significant shift came in 1998 when asset securitisation funds were authorised to issue securities backed not only by mortgages but also by other assets (BBVA Research, 2014). Between 1998 and 2004, issuance was dominated by off-balance-sheet securitised paper. In 2004, the Bank of Spain tightened regulation anticipating both Basel II and International Financial Reporting Standards by requiring banks with significant exposure to asset-backed securities to consolidate these holdings. This step reflected a regulatory awareness of the systemic risks posed by opaque, off-balance-sheet instruments. However, in 2007, rules were again relaxed; securitisation became more flexible, although stricter over-collateralisation requirements were introduced. The outcome was a hybrid system. On the one hand, Spain limited the expansion of complex off-balance-sheet vehicles compared to other countries; on the other, securitisation remained a significant funding channel, though concentrated in relatively simple "plain-vanilla" products, which were largely purchased by non-residents. By 2007, off-balance-sheet securitisation accounted for only 6–7% of the Spanish total, which showed both the relative caution of regulators and the ongoing vulnerabilities connected with real estate lending.

While securitisation rules shaped the way Spanish banks managed risks on their balance sheets, the introduction of the countercyclical capital buffer (CCB) marked a shift towards explicitly cyclical tools that were designed to dampen credit booms and strengthen resilience during downturns. The purpose of the CCB was to mitigate risks associated with excessive growth of aggregate credit during the expansive phase of the cycle. It is designed to create capital reserves in good times that can be released in downturns, thus limiting the build-up of systemic vulnerabilities and smoothing the cycle. The Bank of Spain is required to set a quarterly CCB rate for domestic exposures taking into account

the credit-to-GDP gap, complementary indicators and ESRB recommendations (BoE, 2015; ESRB, 2015).

In December 2015, the Bank of Spain announced that the buffer would be set at 0% from January 2016, which reflected the highly negative credit-to-GDP gap (−58%) compared to the 2% activation threshold that had been suggested by the Basel Committee on Banking Supervision (BdE, 2015; BCBS, 2010). The gap remained deeply negative throughout 2016–2017 (around −60 pp) and other cyclical indicators such as credit intensity, real estate dynamics and private sector indebtedness confirmed the absence of overheating (BdE, 2017c). This cautious stance was maintained for several years. Between 2016 and 2023, the CCB in Spain remained at 0% as credit growth was subdued and bank deleveraging persisted in the aftermath of the crisis. The Spanish approach was broadly in line with the ESRB's recommendation to avoid activating buffers mechanically when the credit-to-GDP gap is negative or distorted by structural changes (ESRB, 2015).

A turning point came in 2024, when the Bank of Spain signalled a new strategy: the progressive build-up of a positive CCB as a structural buffer. Following the example of several euro area countries, the Bank of Spain announced its intention to establish a “neutral” buffer of 1% in the medium term. The transition began with a 0.5% CCB that will be applicable from the fourth quarter of 2025 with an increase to 1% scheduled for the end of 2026 (BdE, 2024). This decision reflects the growing consensus in both policy and academic debates that time-varying capital requirements can play a stabilising role in the presence of financial cycles even if the empirical evidence on their effectiveness is still developing (Claessens et al., 2012; Jiménez et al., 2017b; Galati and Moessner, 2014).

If the countercyclical buffer was meant to address the risks building up across the cycle, the introduction of the G-SII and O-SII buffers targeted risks of a different nature – those stemming from the size, interconnectedness and potential moral hazard of systemically important institutions.

In December 2015, the Bank of Spain announced the introduction of capital buffers for systemic institutions from January 2016, which was justified by the need to mitigate externalities and moral hazards associated with the failure of large institutions (BdE, 2015). Initially, both Santander and BBVA were classified as global systemically important institutions (G-SIIs) with Santander's designation automatic under the Basel methodology, while BBVA's classification was made at the discretion of the BdE despite its score falling just below the formal threshold (FSB, 2014). According to the transitional provisions of Law 10/2014 (BdE, 2016a), only 25% of the final G-SII buffer was applied in 2016 resulting in modest requirements.²⁸ At the same time, the Bank of Spain identified other systemically important institutions (O-SIIs), including Santander, BBVA, CaixaBank, Bankia, Popular and Sabadell. The buffer for O-SIIs was phased in gradually, with the final levels ranging from 0.25% to 1% depending on systemic importance (BdE, 2017a). In practice, combined buffer requirements were applied whenever an institution was designated as both a G-SII and O-SII with the higher requirement prevailing in line with CRD IV. By 2017, Santander remained the only G-SII, while BBVA lost its global designation but continued to be classified as an O-SII.

From 2019 onwards, the methodology for identifying O-SIIs was refined in accordance with EBA guidelines (EBA, 2016, 2020) establishing a clear scoring system based on size, interconnectedness, substitutability and complexity. Since then, the list of Spanish O-SIIs has remained relatively stable and consistently includes Santander, BBVA, CaixaBank and Sabadell. The Bank of Spain has adopted a “bucketing” approach in which buffers are calibrated automatically to the systemic importance score of each institution. This has increased the transparency and predictability of the framework (BdE, 2025). Santander has remained the only Spanish G-SII maintaining a buffer of around 1–1.25% of total risk exposure. BBVA, while no longer a G-SII, has retained a high O-SII buffer. In 2025, however, the BdE reduced BBVA's buffer from 1% to 0.75%, which reflected a decrease in its systemic risk indicators, particularly complexity and cross-border interconnectedness. CaixaBank and Sabadell have continued to carry lower but still non-negligible, requirements that are consistent with their role in the domestic financial system (BdE, 2025).

Overall, the evolution of the O-SII and G-SII buffer framework in Spain illustrates the gradual consolidation of the macroprudential toolkit after CRD IV. Unlike the more experimental dynamic

provisioning of the early 2000s (Saurina, 2009a,b), these buffers are firmly embedded in the European regulatory architecture. As the BdE emphasises in its Financial Stability Reports (BdE, 2017b, 2020), the function of these capital buffers is not only to absorb shocks but also to act as a preventive measure against the build-up of systemic risk over time. Their stability and limited recalibration demonstrate a preference for credibility and forward-looking prudence over frequent discretionary adjustments.

The Portuguese case offers an instructive contrast with Spain. While Spain pioneered forward-looking measures such as dynamic provisioning well before the global financial crisis, Portugal only began to build its macroprudential toolkit in earnest after the introduction of the CRR/CRD IV framework. The designated authority for macroprudential policy is the Banco de Portugal, which since the mid-2010s has gradually assembled a combination of capital-based and borrower-based measures (BdP, 2015).

The capital conservation buffer was phased in between 2016 and 2019 and reached the 2.5% target at the start of 2019 (BdP, 2016). Portugal has not designated any global systemically important institutions (G-SIIs) but since 2018 it has identified a set of domestic systemically important institutions (O-SIIs) such as Banco Comercial Português, S.A., Caixa Geral de Depósitos, S.A., Santander Totta, SGPS, S.A., LSF Nani Investments S.à.r.l. (only from 2019), Novo Banco (only in 2018 and 2025), Banco BPI, SA, Caixa Económica Montepio Geral, Caixa Económica Bancária, S.A., Caixa Central – Caixa Central de Crédito Agrícola Mútuo (only since 2023) (BdP, 2025c). For these banks, O-SII buffers were introduced on a phased basis from 2018 onwards and reached levels between 0.25% and 1% of risk-weighted assets depending on their systemic importance. The countercyclical capital buffer (CCB) was kept at 0% for much of the period as the credit-to-GDP gap remained strongly negative after the crisis. However, in line with ESRB guidance, the *Bank of Portugal* announced in 2025 that the CCB would rise to 0.75% of the total exposure risk amount in January 2026 (BdP, 2025a) marking a new stage in the cyclical use of capital requirements.

One distinctive feature of Portugal's macroprudential framework is the early and active use of borrower-based instruments. In 2018, the Banco de Portugal issued a macroprudential Recommendation setting binding limits on loan-to-value (LTV) and debt-service-to-income (DSTI) ratios as well as maximum maturities for new mortgage and consumer loans (BdP, 2018). The measure was directly aimed at the temporal dimension of systemic risk by containing riskier lending practices during periods of low interest rates and strong credit demand. In 2022, the Recommendation was refined by linking maximum loan maturities to the age of the borrower (Banco de Portugal, 2022), thereby steering the average maturity of mortgage loans towards 30 years. In 2023, in response to rising interest rates, the stress assumptions applied in DSTI calculations were tightened to ensure the resilience of borrowers to rate shocks (BdP, 2023). Monitoring reports show that compliance has been high; by 2024, the weighted average LTV of new mortgage loans was around 69% and over 90% of loans were originated with DSTI ratios below 50% (BdP, 2025b). Empirical studies confirm the effectiveness of these measures; Abreu et al. (2024) found that the LTV cap reduced household leverage with constrained households borrowing less, taking smaller loans relative to income and facing slightly higher borrowing costs.

The contrast with Spain is clear. Spain's regulatory innovation was concentrated in capital-based measures, especially dynamic provisioning, which anticipated Basel III's countercyclical buffer. Structural buffers for G-SIIs and O-SIIs also played a prominent role. By contrast, borrower-based measures played only a limited role in the Spanish framework. Portugal followed a different path; it did not innovate in capital tools but it adopted borrower-based measures early and adapted them repeatedly to changing conditions. Both approaches reflect attempts to address systemic risk in its temporal and structural dimensions: Spain through capital buffers and provisioning rules that targeted procyclicality in the balance sheets of banks, Portugal through direct constraints on household borrowing. The two cases thus illustrate complementary paths within the broader European macroprudential framework.

The Italian case reflects a more cautious and conservative approach to macroprudential policy compared to Spain's early experimentation and Portugal's more recent embrace of borrower-based instruments. Supervisory powers are concentrated in the Bank of Italy, which operates under the Consolidated Law on Banking. (ESRB, 2019b). Unlike Spain, which introduced dynamic provisioning well before Basel III or Portugal, which advanced the use of borrower-based measures after 2017, Italy's macroprudential framework has been more conventional, relying primarily on the gradual phasing-in of capital buffers.

Its countercyclical capital buffer (CCB) provides an illustrative example. Between 2015 and 2017, the Bank of Italy consistently maintained the CCB at 0%. This decision was guided by persistent negative credit-to-GDP gaps (around -7 to -10 percentage points) and declining credit-to-GDP ratios. The authorities considered that the subdued credit dynamics did not justify activating a cyclical buffer. This conservative stance contrasts with Spain's more ambitious countercyclical innovations, such as dynamic provisioning but resembles Portugal's long period of a zero CCB rate, which was justified by post-crisis deleveraging. This position has remained unchanged in subsequent years and as of 2024 the CCB was still set at zero with the estimated credit gap around -12 percentage points (BdI, 2024a). While other jurisdictions have occasionally activated the CCB, Italy has so far refrained from doing so, preferring to leave it as a dormant instrument.

By contrast, greater weight has been placed on structural buffers. UniCredit was designated a global systemically important institution (G-SII) in 2015 with a phased buffer requirement that reached 1% of risk-weighted assets by 2019. Intesa Sanpaolo and Monte dei Paschi di Siena were identified as other systemically important institutions (O-SIIs) with gradually rising buffers being applied between 2018 and 2021 (BdI, 2018). In 2023, the Bank of Italy once again designated UniCredit, Intesa Sanpaolo, Banco BPM and Monte dei Paschi di Siena as other systemically important institutions (O-SIIs), requiring them, from 1 January 2023, to maintain capital buffers of 1.00%, 0.75%, 0.25% and 0.25% of their risk-weighted assets, respectively (BdI, 2022). The capital conservation buffer was also phased in and reached the full 2.5% in 2019 (BdI, 2019). These measures reflect Italy's focus on the structural systemic risk that arises from the concentration and interconnectedness of its largest banks. The approach is broadly comparable to Spain's reliance on structural buffers for Santander and BBVA though Italy did not face the same intensity of cross-border systemic risk.

A more significant innovation came in 2024 when Banca d'Italia announced the introduction of a systemic risk buffer (SyRB). Unlike the CCB, which is linked to cyclical conditions, the SyRB is designed to address structural vulnerabilities that are not covered by other instruments. The new buffer was set at 1.0% on credit and counterparty risk-weighted exposures to Italian residents and was phased in over 2024 and 2025 (BdI, 2024b). The stated objective was to strengthen resilience against shocks including those unrelated to the credit cycle and to build additional macroprudential space for the future.

Italy adhered closely to the harmonised European framework without significant national innovations. Its reciprocity decisions also illustrate this cautious stance; in 2016, the Bank of Italy explicitly chose not to reciprocate the macroprudential measures that had been applied in Belgium and Estonia, thereby signalling a reluctance to impose additional requirements on domestic banks in the absence of direct systemic concerns (BdI, 2016a,b).

Summarising, in a comparative perspective, Italy's approach differs markedly from that of Spain and Portugal. Spain relied heavily on dynamic provisioning and later on capital buffers that directly addressed procyclicality, while Portugal developed a highly active framework of borrower-based measures such as loan-to-value and debt-service-to-income caps that targeted the temporal dimension of systemic risk in household lending. Italy has neither pioneered dynamic provisioning nor embraced borrower-based limits. Instead, its emphasis has been on structural buffers – G-SII, O-SII, conservation and most recently the SyRB – while leaving the CCB at zero. This pattern reflects a cautious strategy in which systemic resilience is built through capital overlays on large institutions rather than through cyclical adjustments or borrower-level restrictions.

Ireland's experience with macroprudential policy reflects both the severity of the boom–bust cycle in its housing and credit markets and the determination of regulators to avoid repeating the mistakes that culminated in the 2008 crisis. Macroprudential supervision is conducted by the Macroprudential Measures Committee (MMC) of the Central Bank of Ireland, which brings together the Governor, both Deputy Governors and the senior officials that are responsible for financial stability, supervision and economics.

In Ireland, the countercyclical capital buffer (CCB) was first introduced in January 2016 and was initially set at 0%. This decision reflected the persistent deleveraging of the Irish private sector after the crisis: the credit-to-GDP gap remained deeply negative with values of –60 percentage points in late 2015 and –65 points in April 2016. Regular quarterly assessments in 2016 and 2017 confirmed the maintenance of a 0% CCB as the recovery of credit activity lagged well behind output growth. Only in 2019, once the cycle had normalised, did the Central Bank of Ireland begin to activate the CCB, first at 1% and later raising it further in response to cyclical pressures (CBI, 2019). In March 2020, however, the rate was cut back to 0% as part of the emergency response to the COVID-19 shock, thus freeing capital for banks to absorb losses and sustain lending (CBI, 2020). More recently, the buffer has been rebuilt: by 2023 the CCB once again stood at 1.5% and in 2024 the Bank announced an increase to 2% from mid-2025, signalling its intent to actively use the CCB as a stabilisation tool in line with ESRB guidance (CBI, 2024a).

Systemic risk buffers also play a role in Ireland. No bank has been designated a global systemically important institution (G-SII) but several have been identified as domestic systemically important institutions (O-SIIs). These include the Bank of Ireland Group plc (BoI), Allied Irish Banks Group (AIB), Permanent TSB Group Holdings plc, Ulster Bank (before its wind-down), Citibank Europe and since 2022 also Barclays Bank Ireland plc. Phased-in O-SII buffers have been applied since 2019 and reached between 0.5% and 1.5% of risk-weighted assets depending on systemic importance. For the largest two institutions, BoI and AIB, the requirement now stands at 1.5% (CBI, 2024b).

Where Ireland's macroprudential policy has been most distinctive, however, is in the use of borrower-based measures. In the aftermath of the property crash, the Central Bank moved early to restrain mortgage lending by introducing binding limits on loan-to-value (LTV) and loan-to-income (LTI) ratios. Since 2015, first-time buyers have faced a maximum LTV of 90%, while second and subsequent buyers are capped at 80% and buy-to-let borrowers at 70%. An LTI cap of 3.5 times gross income applies to most new lending (CBI, 2017). Limited allowances permit banks to lend above the caps for a small share of loans, which creates some flexibility while keeping systemic risks contained. These measures directly targeted the temporal dimension of systemic risk by curbing excessive credit growth in a low-interest environment. They have been adjusted over time; in 2017 the allowance for first-time buyers was eased, while in 2022 the framework was recalibrated in order to simplify the rules and ensure that they remained effective as housing market pressures re-emerged (CBI, 2022).

In 2021–22, the Central Bank of Ireland conducted a comprehensive Mortgage Measures Framework review to assess whether the LTV and LTI caps remained appropriate. The review confirmed the effectiveness of the dual-instrument approach but recommended targeted calibration changes to rebalance financial stability and credit access. From 1 January 2023, three key changes were implemented: (i) the LTI cap for first-time buyers (FTBs) was raised from 3.5 to 4 times income; (ii) the LTV limit for second and subsequent buyers (SSBs) was increased from 80% to 90%, while the FTB limit remained at 90%; and (iii) lender allowances were recalibrated per borrower type with up to 15% of FTB and SSB lending and 10% of buy-to-let lending allowed above the caps (CBI, 2022).

Complementing these borrower-based tools, Ireland also adopted stricter risk-weight requirements. In 2014, a 100% risk weight was imposed on commercial real estate exposures (rather than the Basel standard of 50%) and the criteria for applying the preferential 35% risk weight on residential mortgages were tightened; only loans with an LTV below 75% and where the borrower occupied the property qualified (CBI, 2014). This structural measure addressed the cross-sectional dimension of systemic risk by strengthening the resilience of banks to concentrated property market exposures. The changes particularly benefited previously constrained lower-income households by improving

access to credit while keeping risk constraints in place. From a stability perspective, Central Bank of Ireland argued that supply constraints had made the earlier framework excessively binding, thus creating the risk of long-term exclusion from homeownership. The recalibration therefore illustrates a balanced macroprudential philosophy: easing rules where justified, while preserving guardrails.

Overall, Ireland's framework illustrates a distinct balance compared to Spain, Portugal or Italy. While those countries relied heavily on capital buffers and provisioning rules, Ireland combined capital-based measures with an ambitious and proactive use of borrower-based instruments. In effect, Ireland addressed systemic risk in both dimensions by building capital buffers against structural vulnerabilities in its concentrated banking system and by directly constraining mortgage credit flows to smooth the credit cycle and reduce uncertainty in the housing market. The Irish case has often been cited in European and international debates as an example of how borrower-based policies can complement the Basel-inspired capital framework to enhance resilience in a small, open economy that is highly exposed to property cycles.

The Greek experience with macroprudential policy is heavily shaped by the legacy of its sovereign debt and banking crises. The Bank of Greece holds the mandate for financial stability and macroprudential supervision. This mandate was formally consolidated in 2015 through Executive Committee Act No. 53, which set out the institutional framework for applying the instruments that were introduced by European legislation, notably the CRR/CRD IV package (BoG, 2017). With the transposition of the EU legislation into national law (Law 426, 2014), Greece gained access to the full European macroprudential toolkit, including the countercyclical capital buffer (CCB), systemic risk buffer (SyRB) and capital buffers for global (G-SIIs) and other systemically important institutions (O-SIIs).

Yet the actual use of these instruments reflects the country's fragile post-crisis environment. The CCB, first set in January 2016, has remained at 0% ever since. Quarterly assessments by the Bank of Greece in coordination with the Hellenic Capital Market Commission consistently pointed to weak credit growth and a deeply negative credit-to-GDP gap, which provided no justification for activating a positive buffer. Even during the post-pandemic recovery, the CCB was left unchanged, thus underscoring how ongoing deleveraging in the banking system constrained the use of cyclical tools. Greece does, however, automatically recognise the countercyclical buffer rates that have been set by other EU Member States up to the standard 2.5% ceiling (BoG, 2025).

Structural measures have played a comparatively larger role. No institutions in Greece qualify as G-SIIs but four banks – Alpha Bank, National Bank of Greece, Eurobank and Piraeus Bank – have consistently been designated as O-SIIs since 2015. Initially, these banks were assigned a 0% O-SII buffer, reflecting both their systemic importance and the urgent need to support balance sheet repair and recapitalisation. Only from 2019 onwards did the Bank of Greece begin to phase in positive requirements, gradually increasing O-SII buffers towards 0.25–1% by the early 2020s (BoG, 2024). This measured approach sought to strengthen resilience without undermining efforts to reduce the still-elevated stock of non-performing loans.

In contrast to other crisis-hit EU countries such as Ireland or Portugal, Greece has not relied on borrower-based instruments like loan-to-value (LTV) or debt-service-to-income (DSTI) limits. Instead, the emphasis has remained on supervisory guidance, bank-specific capital measures and the close monitoring of real estate exposures. The systemic risk buffer has so far not been activated though the Bank of Greece has acknowledged its potential role once the system stabilises further.

Taken together, the Greek macroprudential framework highlights the limits of countercyclical policy in a context of weak credit dynamics and crisis recovery. Whereas Spain experimented with forward-looking dynamic provisioning and Ireland introduced binding mortgage caps, Greece has leaned more heavily on structural capital buffers and supervisory oversight. The focus has been less on containing new credit booms than on gradually rebuilding resilience in a banking system still scarred by the crisis.

Although not part of the PIIGS group, both Malta and Cyprus offer relevant case studies for understanding the macroprudential landscape of smaller EU Member States, particularly given their

close financial and institutional ties to Greece. Their experiences illustrate how small, open economies with concentrated banking systems have adapted the European macroprudential framework to their domestic conditions.

In Malta, responsibility for macroprudential oversight lies with the Central Bank of Malta (CBM), which cooperates closely with the Malta Financial Services Authority (MFSA). The framework was formalised through Directive No. 11 (CBM, 2013). CBM firstly introduced the countercyclical capital buffer (CCB) in 2016. However, like in Greece and other crisis-affected economies, the CCB has consistently remained at 0%, thus reflecting subdued credit dynamics and a strongly negative credit-to-GDP gap (CBM, 2025). By contrast, structural buffers have played a greater role. Three institutions have been designated as other systemically important institutions (O-SIIs): the Bank of Valletta, HSBC Malta and Mediterranean Bank. Their O-SII buffers, which range from 0.5% to 2%, reflect the high concentration of the Maltese banking system where just a handful of banks dominate the domestic market (ESRB, 2024). In line with ESRB recommendations, Malta has also committed to reciprocating foreign macroprudential measures, such as Estonia's systemic risk buffer, thereby reinforcing cross-border consistency in prudential rules (CBM, 2016).

Cyprus presents a somewhat different picture. The Central Bank of Cyprus (CBC) became the designated macroprudential authority in 2016 following the adoption of the Macroprudential Oversight of Institutions Law 6(I). The countercyclical capital buffer (CCB) was introduced at the same time but as in Malta, it has remained fixed at 0% due to the strongly negative credit-to-GDP gap. Even as the Cypriot economy recovered from its post-2013 banking crisis, the legacy of excessive private sector indebtedness limited the scope for activating the time-varying capital tools (ESRB, 2017). Instead, the authorities have relied on structural buffers applying them not only to banks but also partially to investment firms – a rare case in Europe (CBC, 2017b). In 2017, several Cyprus-based investment companies including SIB (Cyprus) Ltd and Renaissance Securities were designated as O-SIIs with buffer rates of 1–1.5% (CBC, 2017a). The main domestic banks, such as Bank of Cyprus, Hellenic Bank and RCB Bank have been subject to gradually increasing O-SII requirements and reached levels between 0.5% and 2% by 2022 (CBC, 2021) and projected higher (ESRB, 2023). This reflects both their systemic importance and the continued need to rebuild resilience in a financial sector that is still exposed to external shocks.

In a comparative perspective, Malta and Cyprus differ from Spain or Ireland where dynamic provisioning and borrower-based instruments, respectively, played pioneering roles. Instead, their macroprudential regimes have remained cautious and highly reliant on capital-based measures. Both countries illustrate the constraints faced by small peripheral economies: the limited scope for countercyclical intervention when credit growth is weak and the reliance on O-SII buffers to address structural concentration risks. Their experiences parallel Greece in that respect though Cyprus in particular stands out for extending macroprudential logic beyond the banking system to cover investment firms. In this sense, the Maltese and Cypriot cases broaden the understanding of how European macroprudential policy is adapted in smaller, bank-dominated economies.

4.2.3.2 The Macroprudential Policies in the Scandinavian and Baltic countries

The Scandinavian experience with macroprudential policy since the global financial crisis displays a common preoccupation with housing-related vulnerabilities but had three distinct national philosophies of how to contain them. Sweden moved earliest and most assertively on borrower standards; Denmark combined a releasable countercyclical capital buffer with targeted product restrictions in mortgage credit; Finland relied more on structural capital overlays and incremental borrower constraints. Across the region, the tools were tested by a long period of low interest rates, by the pandemic-era release and subsequent rebuilding of buffers and – more recently – by the rapid interest-rate normalisation that stress-tested highly indebted households and market-funded banking models.

Sweden's experience illustrates the logic of early, borrower-focused intervention in an economy where household leverage and housing market dynamics have long been viewed as systemic. As early as the 1990s, Sweden experienced sharp credit and housing cycles, which left a legacy of political sensitivity around household debt. Interest deductibility, favourable taxation of owner-occupied housing and structural supply shortages created long-term upward pressure on prices and mortgage borrowing. Against this background, after the global financial crisis the Financial Supervisory Authority (*Finansinspektionen*) was tasked with designing a macroprudential framework fit for a highly leveraged society. Its first major step was the 2010 loan-to-value cap of 85%, which was intended to not only limit excessive leverage but also to send a signal that mortgage borrowing would no longer be unconstrained (Soultanaeva and Nordberg, 2010; FI, 2010). This was followed in 2016 by binding amortisation requirements: households with an LTV above 70% had to repay at least 2% of principal per year and those between 50% and 70% at least 1%. In 2018, a further add-on linked amortisation to income that required households with mortgage debt above 4.5 times gross income to repay an additional percentage point annually (FI, 2017). These measures were not without controversy. Critics argued that they penalised younger households and risked deepening intergenerational inequalities, while defenders emphasised their preventive role in steering the riskiest loans towards repayment discipline. In fact, in 2020, at the onset of the COVID-19 pandemic, the amortisation requirement was temporarily suspended to support household liquidity and was reinstated only in September 2021, thus underscoring the instrument's flexibility as both a stability tool and a demand-management device.

Capital-based instruments accompanied these borrower measures. To address the low model-based risk weights used by large Swedish banks on residential mortgages, FI introduced a 15% risk-weight floor in 2013, which was later raised to 25%. This was reinforced by Pillar II add-ons and, in 2015, by a systemic risk buffer of 5% for the largest banks (FI, 2013, 2018a, 2024). Sweden was also among the earliest countries in Europe to operationalise the countercyclical capital buffer (CCB). The buffer was raised steadily from 1% in 2015 to 2.5% by 2019 before being fully released to zero in March 2020 during the pandemic. It was then rebuilt in 2022–2023 and reached 2%, a level it has maintained through 2025 (FI, 2020, 2015). FI also applies the liquidity coverage ratio at 100% by significant currency, a measure that had been introduced in 2013 to address risks from wholesale funding in dollars and euros. Recent evaluations show that while the buffers increased resilience, they did not fully contain the rise of highly indebted households; by 2023, nearly one in five new borrowers had a debt-to-income ratio above 4.5, a figure close to pre-2018 levels (FI, 2018b, 2023). The FI-commissioned report by Muellbauer and Kaszowska-Mojša (2023) highlights this paradox and showed that borrower-based measures are effective in smoothing consumption and reducing vulnerability during downturns but their aggregate effect on debt ratios depends critically on housing supply, fiscal incentives and the distribution of credit. In short, Sweden has built one of Europe's most comprehensive borrower-based regimes but its effectiveness remains shaped by structural factors beyond the reach of financial regulators.

Finland, by contrast, has pursued a more gradual and structurally oriented path. The Financial Supervisory Authority (FIN-FSA), in close cooperation with the Bank of Finland and the Ministry of Finance, has consistently kept the countercyclical buffer at zero from its introduction in 2015 through 2025 (Financial Supervisory Authority, FIN-FSA, 2025). This decision, which has repeatedly been confirmed in quarterly reviews, reflected a view that credit developments did not justify time-varying capital surcharges and that the main vulnerabilities were structural. Instead, Finland leaned on other buffers. As early as 2015, the FIN-FSA designated Nordea Bank Finland, OP Cooperative and Danske Bank as other systemically important institutions (O-SIIs) and imposed surcharges of 2% alongside a smaller 0.5% requirement for Municipality Finance (FIN-FSA, 2015). When Nordea relocated its headquarters from Stockholm to Helsinki in 2018, the systemic weight of the Finnish banking system rose sharply, prompting a recalibration of the framework. A systemic risk buffer of 1% was introduced in the early 2020s with O-SII surcharges adjusted within a 0.5–2.5% range

(FIN-FSA, 2025, 2023). These measures reflected an explicit strategy: to build resilience through permanent structural overlays rather than temporary cyclical adjustments.

Borrower-based measures in Finland have remained modest but carefully targeted. As of July 2016, the statutory LTV cap has been set at 90% with a higher ceiling of 95% for first-time buyers (ESRB, 2017, 2019a). In 2021, the effective cap was tightened for repeat buyers to 85%, thus signalling a concern about excessive leverage among established households while preserving access for new entrants (BoF, 2021). Unlike in Sweden, no binding debt-to-income or debt-service-to-income cap has been legislated despite repeated recommendations from the IMF and ESRB. Political resistance and legal uncertainty have blocked such proposals though discussions continue. To address bank-side risks, the FIN-FSA introduced a minimum mortgage risk-weight floor of 15% in 2018 but allowed it to expire in 2021 concluding that systemic risks were better handled through the O-SII and SyRB overlays (FIN-FSA, 2017). Evaluations by the IMF and domestic authorities suggest that these measures improved resilience without constraining credit supply excessively but they also underline that Finland's framework remains incomplete without an income-based borrower cap. As of 2025, such an instrument remains under review, which reflects both political caution and the incremental nature of Finnish macroprudential policy.

Denmark illustrates yet another approach, which was shaped by its unique mortgage-credit model that is built around specialised institutions and covered bonds. Danish banks and mortgage-credit institutions issue callable covered bonds that are closely linked to the loans on their balance sheets, which exposes the system to refinancing and interest-rate risks. These structural features have long drawn attention from the ESRB and the IMF and have informed Denmark's macroprudential trajectory. The Systemic Risk Council was established in 2013 as a multi-agency body bringing together Danmarks Nationalbank, the financial supervisor and key ministries. The CCB was first activated in 2019 and reached 2.5% before being fully released in March 2020 in order to support lending during the pandemic. It was rebuilt quickly, returning to 2.5% in 2023, where it remains in 2025. The Council has repeatedly emphasised that the CCB is not a symbolic tool but a genuinely releasable buffer that is central to Denmark's countercyclical stance.

More distinctive still has been Denmark's reliance on borrower-product restrictions. In 2018 the Council introduced the so-called growth area guidelines, which were initially targeted at Copenhagen and Aarhus. These rules prevent borrowers with both high debt-to-income ratios (above four times gross income) and high LTV ratios (above 60%) from taking interest-only variable-rate mortgages, instead requiring them to choose amortising or fixed-rate products. The objective was to reduce the concentration of the riskiest debt combinations, which amplify systemic risk and increase household vulnerability to shocks. As interest rates rose sharply in 2022–2024, these guidelines were reinforced and extended. Analyses by Danmarks Nationalbank show that limiting risky combinations of interest-only and high-leverage loans would have significantly reduced the volatility in household consumption during past downturns, thus underscoring the effectiveness of the measure. Alongside the CCB, O-SII buffers for the largest mortgage-credit institutions and targeted supervisory measures on refinancing risk, Denmark's approach demonstrates a philosophy of combining structural capital with rules that directly influence product design.

In a comparative perspective, the three Scandinavian countries highlight both convergence and divergence within a common European framework. All three recognise that systemic risk lies less in exotic derivatives or complex global exposures than in the prosaic but powerful combination of household leverage, real estate markets and market-based funding structures. Yet their responses differed. Sweden's activism has produced one of Europe's most elaborate borrower-based regimes alongside the active use of cyclical buffers and structural overlays. Finland has relied on structural surcharges and incremental borrower rules, eschewing cyclical activation of the CCB. Denmark, for its part, has coupled a fully usable CCB with borrower-product restrictions that reshape mortgage markets at the margin. Recent research, including the FI-commissioned study by Muellbauer and Kaszowska-Mojša (2023), underscores that borrower-based measures are highly state-dependent; they work best when calibrated to constrain the riskiest tails of the distribution and not average borrowers.

By 2025, this insight helps to explain why high aggregate debt ratios persist across Scandinavia, even as financial systems appear to be more resilient. Structural constraints – tax incentives, housing supply shortages and intergenerational imbalances – remain beyond the reach of prudential policy but macroprudential measures have nonetheless reduced the amplification mechanisms and created buffers that make future crises less damaging.

While the Scandinavian experience highlights the use of borrower-based measures, capital buffers and liquidity requirements in relatively advanced and deeply integrated financial systems, the Baltic countries present a different yet closely related case. Their banking sectors are smaller and more concentrated, often dominated by subsidiaries of Nordic banks, particularly Swedbank, SEB and Luminor and their institutional frameworks for macroprudential policy were established later. This strong financial and supervisory linkage means that developments in Sweden, Denmark and Finland have direct spillover effects on Estonia, Latvia and Lithuania. At the same time, the Baltic authorities have had to adapt macroprudential tools to domestic challenges, including rapid credit growth before the crisis, strong dependence on foreign currency lending and more limited fiscal and monetary policy space. Examining their experience offers a useful contrast with the Scandinavian cases and illustrates how systemic risk management evolves in smaller, open economies that are closely tied to larger neighbours.

In Lithuania, responsibility for macroprudential policy has rested with the Bank of Lithuania since the 2014 Macroprudential Mandate Law (BoL, 2025). From the outset, the authorities relied on both capital- and borrower-based tools. The countercyclical capital buffer (CCB) was introduced in June 2015 at 0% and held there until 2019 when credit growth justified activation at 1% (BoL, 2015, 2019). The buffer was released in 2020 in order to support lending during the pandemic before being rebuilt to 1% in 2022 (BoL, 2020). Alongside this cyclical tool, Lithuania made heavy use of structural overlays: since 2016, O-SII buffers ranging from 0.5% to 2% have been applied to the main systemic banks (SEB, Swedbank, DNB and Šiaulių bankas) (BoL, 2025). Borrower-based measures, which were introduced as early as 2011 and refined in 2015, form the backbone of Lithuania's regime. Housing loans are capped at an LTV of 85%, a DSTI of 40% and a maximum maturity of 30 years (BoL, 2011, 2015). These rules, which are grounded in the 2011 Resolution No. 03-144 and its amendments, require lenders to assess repayment capacity based on stressed income scenarios rather than collateral values. Evaluations by the Bank of Lithuania and external observers suggest that these measures significantly reduced excessive risk-taking, shortening average maturities and limiting high-DSTI lending. In 2022, with interest rates rising, stress assumptions were tightened further, thus ensuring that new borrowers could withstand sharper shocks. By 2025, Lithuania has developed one of the most comprehensive macroprudential frameworks in the EU with a robust mix of structural buffers and binding borrower constraints that are designed to smooth the housing-credit cycle.

Latvia, by contrast, moved more slowly, which reflected its difficult post-crisis recovery and the fragility of its banking sector in the mid-2010s. The institutional framework was established in 2013 when the Macroprudential Council was created by an agreement between the Ministry of Finance, the Bank of Latvia and the Financial and Capital Market Commission (FCMC) (OECD, 2016). The CCB was introduced in 2017 at 0% and remained inactive until 2023 when it was raised modestly to 0.5%, effective as of December 2024 (LB, 2022). The more decisive measures were structural. The FCMC designated the main banks – Swedbank, SEB, Citadele, DNB and, until its resolution, ABLV – as O-SIIs with buffers between 1% and 2%, which were phased in between 2016 and 2018 (ESRB, 2019c; LB, 2025). The rationale was clear: the Latvian banking system is highly concentrated and the failure of even one institution would have systemic implications. Borrower-based measures entered later. In 2020, the authorities introduced binding caps on LTV and DSTI, which were broadly harmonised with the Lithuanian framework (IMF, 2021). Stress tests required that borrowers had to be able to service mortgages under significant increases in interest rates, a provision that gained importance in the 2022–2024 tightening cycle. By 2025, Latvia has converged towards the regional norm with a layered regime of structural buffers and borrower-based limits but its early reluctance to

activate cyclical capital instruments illustrates a cautious philosophy that was shaped by the memory of crisis.

Estonia pioneered borrower-based macroprudential instruments in the region, embedding them in binding regulations as early as 2015 (Kukk et al., 2023). Under the Eesti Pank Act, macroprudential policy is shared between the central bank, the Financial Supervision Authority and the Ministry of Finance with strong cross-border cooperation through the Nordic-Baltic Macroprudential Forum Eesti Pank (2025). The CCB was first considered in 2015 but kept at zero given the negative credit-to-GDP gaps. It was eventually raised to 1% in 2022 and 1.5% in 2023 (Eesti Pank, 2023). In Estonia, the systemic risk buffer was initially set at 2% in 2014, which decreased to 1% in 2016 and was temporarily lowered to 0% during the COVID-19 period. Since 2022, a 2% buffer has been applied to retail exposures that are secured by residential property in Lithuania. Moreover, 2% O-SII buffer was set to Swedbank and AS SEB Pank, which are justified by the extraordinary concentration of the system – these two banks together account for more than 60% of assets and close to 70% of GDP (ESRB, 2019d). Borrower-based tools have also been central. Since March 2015, new mortgages must meet an LTV cap of 85% (90% if state guaranteed by KredEx), a DSTI cap of 50% and a maximum maturity of 30 years (Eesti Pank, 2014). These rules apply equally to foreign branches, which reflects the open structure of the Estonian banking market. Importantly, lenders must stress test repayment capacity against a six-percentage-point rise in interest rates (Eesti Pank, 2024). Empirical evidence indicates that these rules have limited the share of high-risk loans and contributed to greater stability of household balance sheets even as housing prices continued to rise strongly in the late 2010s.

Taken together, the Baltic experience highlights both commonalities and distinctions. All three economies introduced the CCB but activation was cautious and buffers were quickly released during the pandemic before being rebuilt from 2022 onwards. Structural overlays – O-SII and systemic risk buffers – played a prominent role, thus reflecting their concentrated banking sectors, which are dominated by the Nordic groups. Borrower-based measures are the area of greatest variation: Lithuania moved earliest in 2011 and most comprehensively, Estonia followed with equally binding rules in 2015, while Latvia only introduced caps a decade later, in 2021. By 2025, however, the region has converged on a common philosophy: macroprudential stability rests on three pillars – structural capital surcharges for concentrated banking systems, cyclical buffers that can be released in stress and binding borrower-based constraints that anchor household leverage. Reciprocity has been another distinctive feature with Baltic authorities systematically recognising the measures that have been applied by their Nordic neighbours, thereby ensuring consistent treatment of cross-border banks. In this sense, the Baltic countries illustrate how small, open economies can leverage the European toolkit to address vulnerabilities that are both domestic and imported, building resilience not only through national measures but also through regional coordination.

4.2.3.3 The Macroprudential Policies in the Central and Eastern European countries

In Poland, the modern macroprudential framework was codified by the Act on macroprudential supervision over the financial system and crisis management, which entered into force on 1 November 2015 (NBP, 2015a). Long before that date, however, supervisory practice had already exhibited a macroprudential flavour. Since the 1990s, the General Inspectorate of Banking Supervision (GINB) and, from 2008, the Polish Financial Supervision Authority (PFSA, KNF) issued resolutions and recommendations to stabilise the financial system and build resilience against external shocks.

A minimum capital requirement (CAR) of 8% was first set by Resolution No. 7/93 of the President of the NBP of 20 May 1993 (Ord. 7/93, 1993) and then embedded in the Banking Law of 29 August 1997 (Banking Law, 1997). During the euro-area debt crisis, the PFSA tightened distributive practices in order to support capital. On 29 December 2011, it recommended restricting dividends to strengthen buffers and liquidity, directing banks with a solvency ratio below 12%, Tier 1 below 9%, BION (Bank-Specific Risk Assessment Process) score worse than 2.5, high FX-mortgage

shares or weak parent-group capital to retain earnings. Follow-up stances in 2012, 2013 and 2014 specified the conditions for partial or full payout (with 50–100% caps depending on capital, stress-test projections and BION assessments) and introduced stricter thresholds for banks with a significant share of non-financial sector deposits. From 2015 onwards, dividend policy continued to be framed through individual PFSA recommendations and explicit add-ons for FX mortgage risk with payout caps linked to Total Capital Ratio (TCR)/Common Equity Tier 1 (CET1) plus conservation/specific buffers, leverage ratio (LR), BION and bank size.

The Polish rules on risk weights evolved through a sequence of KNB/KNF (PFSA) resolutions. Resolution No. 5/2001 (NBP, 2011) assigned a 50% weight to claims that were secured by residential mortgages. Resolution No. 4/2004 (Dz.Urz. NBP, 2004) and Resolution No. 1/2007 (NBP, 2007) refined the scope and statistical methods. Resolution No. 153/2011 (PFSA, 2011a) introduced, among others, a 75% retail weight and a 100% weight for retail exposures where instalments depend on exchange rates that are different from the borrower's income currency; likewise, for mortgage exposures with FX-linked instalments. Subsequent CRR/CRD IV implementation carried these prudential intents into the EU-harmonised framework.

KNF's (PFSA's) Recommendation S consolidated good practices for mortgage-backed exposures (irrespective of whether the immediate aim is real-estate financing) and – though not a statute – functions as a *de facto* standard with on-site inspections and institution-specific follow-ups for domestic banks. The 2006 version asked banks to adopt internal LTV limits that are calibrated to collateral recovery, property type, tenor, currency, rate type and other risk drivers. The 2011 update introduced a hybrid approach: for FX retail mortgages, the maximum debt-service-to-income (DSTI) should not exceed 42%. Property valuations were to be refreshed at least every three years if the current LTV exceeded 80% (annually if it was above 100%). According to the Recommendation, the loan-to-value (LTV) ratio may be set differently based on the analysis of collateral, but in any case the LTV should not exceed 80% for exposures with an original maturity exceeding five years, and 90% for other exposures.

The 2013 revision tightened practices for banks significantly engaged in mortgages (i.a. portfolio share higher than 2% of sector mortgage exposures), formalised internal LTV/DTI governance and limits and set external reference points; for residential mortgages, initial LTV should not exceed 80% or 90% if the part above 80% is insured/fully collateralised (and 75/80% for commercial real estate). The recommendation also limits currency-mismatch lending, guides maturities (generally up to 25 years; 35 with additional risk controls) and requires that portfolio concentrations be monitored with an escalation when internal limits or maximum LTVs are breached.

Recommendation T addressed broader retail credit risk. The original version set indicative DTI ceilings at 50% for below-average-income borrowers and a hard cap at 65% with explicit recognition of family size, residence and fixed obligations. The 2013 update moved to bank-specific DTI limits that were anchored in risk appetite and governance but added macroprudential cushions for FX lending; when income and loan currency differ, analysis must assume at least a 20% PLN depreciation (and FX interest rates no lower than domestic rates) and DTI limits must incorporate an additional buffer.

Prudential limits on single-name and group exposures have long been in Polish law. The 1989 Banking Law set early caps (15% to a single entity; 10% per contract) followed by a 1997 re-codification capping exposures to a client or connected group at 25% of own funds and requiring that the sum of all large exposures not exceed 800%. The 2003 amendment refined links to ownership/control and added prompt reporting for exceedances above 10%. Supervisory Recommendations A–C (1997) and the revised Recommendation C (2002) complemented the statute with definitions of groups of connected clients; gross exposure measurement; and internal limits by sector, region, collateral type and product. PFSA Resolution No. 382/2008 (PFSA, 2008) and Resolution No. 208/2011 (PFSA, 2011b) further specified measurement, exemptions and the treatment of holdings.

Liquidity oversight has statutory roots in the Banking Law and evolved through NBP guidance (1990), Recommendation P (1996; revised 2003) and PFSA (KNB/KNF) resolutions in 2007 and 2008. The framework requires written policies covering current, short-, medium- and long-term liquidity; defines short-term measures (i.e. liquidity gap that should be greater or equal to 0; short-term liquidity ratio that should be greater or equal to 1) and long-term measures (i.e. coverage of illiquid assets by own funds that should be greater or equal to 1; coverage of illiquid and limited-liquidity assets by own funds plus stable funding that also should be greater or equal to 1). Proportionality applies to very small institutions, which must still maintain simplified ratios. Long-term management must analyse maturity mismatches and funding access/costs with daily calculation for supervisory measures.

To implement CRD IV buffers, Poland enacted the 2015 macroprudential law. Macroprudential supervision is defined as identifying, assessing and mitigating systemic risk – both to strengthen financial-system resilience and to support sustainable growth – and crisis management as maintaining or restoring stability in the case of direct threats. The law established the Financial Stability Committee (FSC, *Komitet Stabilności Finansowej*) as the designated authority for macroprudential oversight; for national measures under CRR Art. 458, the competent authority is the Minister of Finance. The FSC comprises the Minister of Finance, the NBP President, the PFSA (KNF) Chair and the President of the Bank Guarantee Fund (BGF) with the NBP President or the Minister chairing depending on the task. The Act introduced a conservation buffer (2.5% CET1), a countercyclical capital buffer (CCB), buffers for global and other systemically important institutions (G-SII, O-SII) and a systemic risk buffer (SyRB) with reciprocity rules and combination standards aligned to ESRB guidance. In practice, the pre-2015 regime relied on recommendations and resolutions, while the 2015 Act embedded the CRD IV architecture within a domestic governance structure, which was complemented by bank-specific FX mortgage add-ons and payout restrictions. In October 2016, KNF introduced bank-specific additional capital requirements (*domiar kapitałowy*), which was tied to the exposure to FX mortgages. As guidance, minimum capital ratios for banks with such portfolios rose to 10.25% for Tier 1 and 13.25% for TCR. Institution-specific TCR add-ons ranged widely. These add-ons fed directly into dividend constraints; payout ratios were reduced or suspended where FX risk add-ons and combined buffer requirements were binding.

Since 2017, the Polish framework has entered a more mature stage. Between 2016 and mid-2024, the countercyclical capital buffer (CCB) was kept at 0%, which reflected the weak post-crisis credit dynamics (NBP, 2025a). A systemic risk buffer of 3% on domestic exposures was introduced in 2018, although the obligation to maintain the systemic risk buffer was repealed in 2020 (NBP, 2025c). The identification of other systemically important institutions (O-SIIs) has remained relatively stable. The applied buffer rates have ranged between 0.25% and 1% (NBP, 2025b). Dividend policy has continued to serve as an important prudential tool. PFSA maintained strict payout restrictions through the pandemic linking maximum dividends to capital ratios, BION scores and bank-specific FX mortgage add-ons. In 2023–2024, the stance was gradually normalised though conditionality remains. Borrower-based measures, anchored in Recommendations S and T, were updated in 2019 and 2021 to strengthen affordability tests under rising interest rates and to ensure that mortgage maturities and debt-service burdens remain sustainable. FX housing loans, once a major systemic concern, have virtually disappeared from new lending but supervisory stress scenarios continue to incorporate exchange-rate shocks. Finally, liquidity supervision has been fully aligned with EU-wide LCR and NSFR standards, while Recommendation P continues to guide the internal liquidity policies of banks. Taken together, these developments reflect the gradual consolidation of the Polish macroprudential framework: a shift from institution-specific guidance and crisis-era dividend policies towards a layered buffer system and borrower-based rules that address both cyclical and structural sources of systemic risk in the period up to 2025.

The Polish experience shows how macroprudential policy evolved in a large, relatively resilient economy with a diversified banking sector and strong domestic demand. Yet, Poland's position in Central Europe also makes it part of a wider regional pattern. The neighbouring Czech Republic and

Slovakia faced many of the same structural challenges, such as rapid credit expansion, exposure to foreign currency lending and the dominance of foreign-owned banks. At the same time, their policy responses were shaped by smaller financial systems, greater openness and closer integration with the euro area. Comparing these cases with Poland therefore allows us to see how similar vulnerabilities were addressed through different macroprudential strategies and how country size, institutional frameworks and external linkages influenced the choice and calibration of instruments.

In the Czech Republic, the Czech National Bank (CNB) acts as both the macroprudential and designated authority. Its mandate, which was strengthened by the 2013 amendment to the Act on the CNB, explicitly includes safeguarding financial stability and the sound functioning of the system (CNB, 2024e). As early as 2014, the CNB introduced the countercyclical capital buffer (CCB), initially set at 0%. By 2015, the authorities had signalled a gradual increase with the first activation at 0.5% in 2017 and a further rise to 1% in 2018 (CNB, 2015, 2017). The CNB raised the countercyclical capital buffer (CCB) rate to 5% with effect from 1 July 2019, subsequently reduced it to 0% during the COVID-19 pandemic, then increased it again to 2.5% as financial stability risks re-emerged, and gradually lowered it to 1.25% in 2023–2024 (CNB, 2018, 2020, 2022a, 2024d). The CNB complemented these measures with capital conservation requirements at the standard 2.5% level and by designating a set of systemically important institutions that were subject to additional buffers (CNB, 2024c,a).

Alongside these capital-based measures, the CNB relied heavily on recommendations regarding lending standards. These included limits on loan-to-value ratios with a general ceiling of 90% and a cap on the share of new loans in the 80–90% range (CNB, 2018). Borrower-based recommendations also covered debt-to-income and debt-service-to-income ratios, thus encouraging lenders to test affordability under adverse conditions. Maximum maturities were capped at 30 years, while stricter limits were applied to buy-to-let mortgages where LTVs were not to exceed 60% (Hodula et al., 2022; CNB, 2019). After 2017, the framework became considerably more binding. Amendments granted the CNB legal authority to set hard borrower-based limits rather than relying solely on recommendations. From 2022, binding caps were introduced: an LTV limit of 80% (with slightly higher thresholds for first-time buyers), a DTI limit of 8.5 (9.5 for younger borrowers) and a DSTI limit of 45% (50% for younger households) (CNB, 2024b, 2022b). The Czech framework now combines cyclical capital buffers with legally binding borrower-based measures, thereby providing a comprehensive approach to credit-related risks.

In Slovakia, the National Bank of Slovakia (NBS) has acted as the macroprudential and designated authority, which is formally entrusted with systemic risk oversight, since 2013 (NBS, 2013, 2025c). The countercyclical buffer was introduced in 2014 at 0% and gradually increased in the run-up to 2019 as signs of overheating in the mortgage market became apparent (NBS, 2025a). In parallel, the NBS applied buffers to other systemically important institutions and, where appropriate, imposed a systemic risk buffer to address concentration risks. Unlike many EU countries, Slovakia moved relatively quickly to borrower-based measures. Supervisory guidance tightened loan-to-value standards and progressively restricted the share of high-LTV loans (NBS, 2021). The authorities also expressed concern about long maturities and the vulnerability of households to rising interest rates.

After 2017, Slovakia significantly expanded its borrower-based toolkit. A binding DTI cap of 8 was introduced between 2018 and 2019 alongside stricter DSTI rules and limits on excessive maturities. These measures proved effective in curbing the riskiest segments of new lending, particularly among younger and lower-income borrowers (NBS, 2018, 2025b). The countercyclical buffer, which had been reduced to 1.0% during the pandemic, was subsequently reactivated and currently stands at 1.5% (from mid-2023) (NBS, 2025a). Policymakers continue to emphasise the need to contain interest rate risk in household portfolios by promoting longer fixation periods, while maintaining a positive capital buffer to ensure resilience against cyclical shocks.

Hungary represents a distinctive case within Central Europe as its macroprudential policy framework was strongly shaped by the legacy of widespread foreign-currency lending in the pre-crisis period. The National Bank of Hungary (MNB), which is designated as the macroprudential authority in 2013 (MNB, 2016), inherited the task of addressing the vulnerabilities that had been created

by high household indebtedness in Swiss francs and euros as well as a banking sector that was dependent on foreign funding. A decisive step was the conversion of foreign-currency mortgages into forint loans between 2014 and 2015, which substantially reduced the exchange rate risk for both households and the banking system (MNB, 2015b). In parallel, the MNB introduced a borrower-based framework that set binding loan-to-value (LTV) limits that were differentiated by the currency of denomination and established a debt service-to-income (DSTI) ratio as early as 2015 (MNB, 2015a). These measures were among the first in the region to directly constrain household borrowing capacity.

After 2017, Hungary expanded its macroprudential toolkit further. The countercyclical capital buffer was initially maintained at 0% (MNB, 2025a). By 2023, the CCB had been raised to 0.5% with a further increase to 1% in 2024 (MNB, 2025b). The authorities also refined borrower-based measures; the DSTI framework was recalibrated to reflect the maturity and type of loans with stricter limits applied to variable-rate mortgages, thereby encouraging households to lock in longer interest rate fixation periods (MNB, 2018). At the same time, the systemic risk buffer was selectively applied to institutions that had a high exposure to problem assets, particularly non-performing commercial real estate loans.

A comparison of the Polish framework with those of the Czech Republic, Slovakia and Hungary illustrates both regional similarities and important institutional differences. In all four cases, central banks were entrusted as the key macroprudential authorities, which reflected a broader Central European pattern of concentrating financial stability functions in monetary institutions. The institutional independence of the National Bank of Poland (NBP), the Czech National Bank (CNB), the National Bank of Slovakia (NBS) and the Hungarian National Bank (MNB) permitted the relatively swift adoption of capital buffers and lending restrictions in the aftermath of the global financial crisis. Yet, within this common framework, their approaches diverged in notable ways.

In terms of capital-based instruments, all four countries adopted the capital conservation buffer at the EU standard of 2.5%. Poland made only limited use of the countercyclical buffer, while both the Czech Republic and Slovakia moved earlier to active calibration. Borrower-based measures reveal the clearest contrasts. Poland relied largely on supervisory recommendations, which gradually tightened LTV ratios and promoted prudent DSTI assessments but without any binding legal force until very recently. By contrast, the CNB issued strong recommendations already before 2017 and since 2022, these recommendations have been transformed into legally binding limits. The Czech regime now enforces caps on LTV, DTI and DSTI ratios with only minor exemptions for first-time buyers. Slovakia followed a similar path but somewhat earlier. Hungary, however, had already embedded such measures several years earlier. As early as 2014, the MNB introduced a comprehensive debt cap framework combining loan-to-value and payment-to-income (PTI) ratios. Uniquely, these caps were differentiated by currency denomination with much stricter limits on euro- and other foreign-currency loans. This design was directly aimed at reducing the vulnerabilities that stemmed from Hungary's legacy of widespread foreign-currency mortgages. Subsequent refinements adjusted the framework to encourage longer interest fixation periods and more stable repayment structures. These features positioned Hungary as a regional outlier that applied a legally binding, forward-looking approach to household indebtedness at a much earlier stage than its neighbours.

All four countries identified domestic O-SIIs and imposed capital surcharges but the Czech Republic relied more heavily on systemic risk buffers, which were applied across large banks, while Slovakia combined O-SII surcharges and systemic buffers in a tiered fashion. In Poland, systemic buffers were applied primarily at the sectoral level, most notably to foreign-currency exposures, rather than as institution-specific surcharges. Hungary adopted a distinctive approach by linking the systemic risk buffer to the problem exposures of individual banks, particularly in commercial real estate portfolios. Institutions with high shares of non-performing or restructured loans were required to hold additional capital. This selective design contrasted sharply with the broader application of systemic buffers in the frameworks of their neighbours.

Finally, Hungary diverged from the regional pattern by complementing borrower-based and capital-based instruments with funding-side requirements. The Mortgage Funding Adequacy Ratio

(MFAR) (MNB, 2015c), which was phased in between 2017 and 2018, required banks to match a minimum share of their mortgage lending with long-term, covered bond-style instruments. The measure was designed to reduce maturity mismatches and promote a stable market for mortgage-backed securities, thus tying household lending more directly to domestic capital market funding (MNB, 2017). Such an instrument had no parallel in Poland, the Czech Republic or Slovakia, where mortgage market vulnerabilities were addressed primarily through direct borrower constraints.

Taken together, these cases illustrate both convergence and divergence in Central European macroprudential policy. Poland, the Czech Republic and Slovakia shared a broad reliance on capital buffers and a gradual move towards borrower-based limits but differed in timing and legal enforceability. Hungary stands out for its early and comprehensive use of borrower-based measures, its innovative systemic risk buffer linked to problem exposures and the unique introduction of funding adequacy rules. While the other Central European frameworks concentrated primarily on the credit cycle, Hungary combined credit-side, balance-sheet and funding-side measures in a more structured approach. These variations not only reflect divergent legal mandates but also the specific vulnerabilities that each economy faced: high foreign-currency exposures in Hungary, rapid mortgage growth in the Czech Republic and Slovakia and structural imbalances in Poland.

Beyond Poland, the Czech Republic, Slovakia and Hungary, the southern tier of Central and Eastern Europe – including Croatia, Bulgaria, Romania and Slovenia – offers a revealing contrast. These countries shared a history of rapid pre-crisis credit growth, high foreign-currency exposures and the dominance of foreign-owned banks with their northern neighbours but their macroprudential frameworks evolved under somewhat different institutional and historical conditions.

Institutional arrangements reflected national legacies. In Croatia, macroprudential oversight was vested in the Financial Stability Council with the Croatian National Bank as the designated authority (HNB, 2014). Bulgaria followed a similar pattern with the Financial Stability Advisory Council coordinating measures that were implemented by the Bulgarian National Bank (BNB, 2017). Romania opted for a single integrated body, the National Committee for Macroprudential Oversight, which concentrated decision-making across central bank, government and supervisory agencies (CNSM, 2025). In Slovenia, the Financial Stability Board was created by statute in 2013, with the Bank of Slovenia acting as designated authority.

Before the global financial crisis, the mix of macroprudential tools in Croatia, Bulgaria and Romania relied more heavily on reserve requirements, differentiated provisioning rules and administrative lending constraints than in the northern group. Croatia made particularly active use of marginal reserve requirements on foreign borrowing and credit growth-linked reserve rules, which were aimed at curbing capital inflows and foreign-currency credit (Kraft and Galac, 2011; Dimova et al., 2016). Bulgaria tightened reserve requirements and introduced higher risk weights on high-LTV mortgages, while Romania imposed early loan-to-value and debt-service-to-income limits (Neagu et al., 2015). Slovenia, in turn, introduced innovative tools such as the Gross Loans to Deposits Flow (GLTDF) measure in 2014 to address maturity mismatches (Šuler Štavl, 2014).

The global financial crisis forced a reversal. Much like in Poland or Hungary, unconventional reserve-based measures were rolled back. Croatia abolished its marginal reserve requirements in 2008 and reduced foreign-currency liquidity ratios, while Romania and Bulgaria eased classification and provisioning rules. Slovenia, which had only recently established its macroprudential framework, entered the crisis with relatively weak buffers and relied instead on capital injections and EU support to stabilise its banking system (IMF, 2013b).

From 2014 onwards, convergence with the EU's CRR/CRD IV framework accelerated. Croatia introduced a systemic risk buffer in 2014 and later O-SII surcharges Bulgaria and Romania applied O-SII buffers in line with ESRB guidelines and Slovenia implemented the countercyclical capital buffer from 2016 at a neutral rate. Borrower-based measures also gained importance. Romania formalised DSTI caps in 2018, Croatia strengthened recommendations on mortgage lending and Slovenia recommended but did not legally enforce LTV and DSTI ceilings. Bulgaria moved more

gradually but after ERM II entry in 2020, it introduced explicit borrower-based rules to align with banking union practices.

By 2017, the picture across the wider CEE region was one of broad alignment but with persistent national differences. The northern countries – the Czech Republic and Slovakia in particular – were most advanced in adopting binding borrower-based limits, while Hungary stood out for its early and comprehensive framework. The southern group had dismantled their unconventional pre-crisis instruments but replaced them with EU-standard buffers and, increasingly, borrower-based tools.

After 2017, these differences were again visible. Croatia's macroprudential policy was re-oriented around euro adoption. Bulgaria, after joining ERM II and the banking union in 2020, aligned its framework with the ECB's supervisory standards, activating the CCB and applying stronger O-SII surcharges. Romania tightened its DSTI rules and maintained a cautious stance on household credit. Slovenia, meanwhile, relied mainly on recommendations and on monitoring a broader set of indicators, such as property prices, credit growth and bank profitability rather than enforcing strict borrower-based caps.

In a comparative perspective, therefore, the CEE region illustrates both convergence and diversity. All of the countries now operate within the EU's macroprudential framework, apply countercyclical buffers and have identified systemically important institutions. Yet the timing, intensity and binding character of instruments vary. Northern CEE relied more on capital buffers and binding borrower-based caps, southern CEE experimented with administrative and reserve-based tools but later converged towards the EU model. The coexistence of common EU standards with enduring national legacies provides a natural laboratory for studying the optimal combination of macroprudential tools in heterogeneous institutional and financial environments.

The experience of Central and Eastern European countries illustrates both the rapid institutional catch-up in macroprudential policy and the constraints that arise in small, highly open economies. Their frameworks were often shaped by external vulnerabilities – foreign-currency lending, capital inflows and the pressures of EU accession and later euro adoption. By contrast, the larger “core” economies of the EU entered the global financial crisis with deeper capital markets, more diversified banking sectors and, in some cases, pre-existing institutional buffers. They appeared to be more resilient in the face of the initial shock, which raised the question of whether this outcome was primarily the result of more robust regulatory and policy frameworks or whether structural features, such as market depth, funding models and economic diversification played the decisive role. It is to these core countries and to the interplay between regulation and structure in shaping resilience that we now turn.

4.2.3.4 The Macroprudential Policies in the Core EU countries

Among the EU's larger, more mature economies, Germany, Austria and the Netherlands established robust macroprudential frameworks early on, which evolved steadily after the adoption of the CRR/CRD IV package. Germany's Financial Stability Committee (G-FSC), established in 2013, provided an institutional anchor by coordinating oversight between the Bundesbank, BaFin and the Ministry of Finance. In the first few years, the countercyclical buffer (CCB) was introduced into law but kept at 0%, while attention focused on designating O-SIIs and phasing in their surcharges. The period was one of consolidation rather than the active use of cyclical tools. Only from 2019 did Germany begin gradually raising its CCB to 0.25%, before suspending it during the pandemic. It was reactivated in 2022 at 0.75% in 2023 (BaFin, 2025). Concurrently, systemic surcharges expanded; Deutsche Bank remained a G-SII, while a broader group of O-SIIs faced progressively higher buffers. Recently, supervisory guidance on mortgage affordability checks was tightened though Germany still avoided binding borrower-based caps.

Austria followed a similarly cautious trajectory in the immediate post-CRD IV years. Its Financial Market Stability Board, supported by the Austrian National Bank (OeNB) and the Austrian Financial Market Authority (FMA), introduced the CCB in 2016 but maintained it at 0% up to

2025, while progressively phasing in O-SII and systemic risk buffers. In 2022, authorities introduced binding borrower-based measures, including loan-to-value (LTV), debt-service-to-income (DSTI) and maturity caps, which reflected concerns over housing market overheating (OeNB, 2024). The result was a framework that combined capital surcharges with borrower-based rules in a balanced stance that was adapted to Austria's open, cross-border banking sector.

The Netherlands with its very large mortgage market and structurally high household leverage pursued a somewhat different course. As early as 2013, its authorities began to tighten mortgage standards by lowering the maximum LTV ratio (Zhang, 2023). Since June 2013, DNB has raised the capital conservation buffer four times, revised the CCB framework during the pandemic, and increased the CCB to its neutral 2 percent level after May 2022. It also introduced a minimum risk weight for Dutch mortgage loans in January 2022 (IMF, 2024). Thus, the Dutch framework relied on borrower-based constraints earlier, supplementing them later with cyclical capital buffers as pressures rebuilt.

Luxembourg entered the macroprudential domain later with the creation of the Systemic Risk Committee in 2015 (Law of 1 April 2015, 2015). In the initial phase up to 2017, Luxembourg focused on building its macroprudential framework and implementing reciprocity arrangements. The CCB remained at 0%, while O-SII capital surcharges were gradually introduced. The CCB was activated in 2018 at 0.25%, and then raised to 0.5% in 2019 (BCBS, 2025), with structural surcharges and cross-border coordination continuing to play a central role.

France adopted a more assertive stance from the outset. The High Council for Financial Stability (HCSF), established in 2013, brought together the Ministry of Finance, the Banque de France, the Prudential Supervision and Resolution Authority and the financial market regulator (Ministry of Economy and Finance, France, 2025). Between 2014 and 2017, France maintained the CCB at 0% and relied mainly on reciprocity with Nordic and Baltic countries where real estate markets were booming. The HCSF also issued recommendations on prudent lending standards but these remained non-binding. From 2018, however, the Council activated the CCB raising it to 0.25% and then 0.5%. It was released in 2020 during the pandemic but swiftly reintroduced in 2022 firstly at 0.5% and then raised to 1% (BCBS, 2025). Importantly, at the end of 2022, the HCSF converted its mortgage-related recommendations into binding borrower-based rules with DSTI caps and maturity limits now enforced (ESRB, 2021). This turned France's framework into one of the most comprehensive in the euro area.

Belgium, where the National Bank of Belgium (NBB) holds both supervisory and macroprudential mandates, also began cautiously. The CCB was formally available from 2016 but kept at 0% till 2019. In 2014–2017, Belgium instead focused on housing market vulnerabilities imposing add-ons to risk weights on mortgage portfolios, particularly those under internal models. These measures were gradually refined after 2017 to differentiate between higher- and lower-risk exposures. O-SII surcharges were also phased in over this period. With lending growth picking up, the CCB was finally activated at 0.5% in 2019, lowered to 0% during pandemics and raised to 0.5% in 2023 and 1% in 2024 (BCBS, 2025). Belgium's framework thus combined structural mortgage-related measures with later cyclical activation. Across these six core countries, the post-2017 period marked a shift from cautious, capital-only approaches to more diversified frameworks that blended cyclical buffers, borrower-based limits and systemic surcharges.

4.2.3.5 *A Brief Commentary on the UK Case*

The United Kingdom presents a special case in this discussion as it is no longer a member of the EU but remains a crucial reference point for macroprudential policy. Its institutional framework was reshaped after the global financial crisis culminating in the formal establishment of the Financial Policy Committee (FPC) at the Bank of England in 2013 (BoE, 2025, 2013). The FPC, which had existed in an interim form since 2011, became the designated macroprudential authority, while the Bank of England served as the institutional home for its work. The Committee normally has thirteen

members: six drawn from the Bank (the Governor, four Deputy Governors and the Executive Director for Financial Stability Strategy and Risk), five external experts who were appointed for their industry experience, the Chief Executive of the Financial Conduct Authority and a non-voting representative of HM Treasury. This collegiate structure was designed to combine central banking expertise with supervisory oversight and independent perspectives.

From the outset the FPC was equipped with a broad toolkit, including the countercyclical capital buffer, sectoral capital requirements, leverage ratio tools and borrower-based measures, such as limits on loan-to-value and debt-to-income ratios for owner-occupied and buy-to-let mortgages. In 2014, it issued a recommendation that no more than 15% of new residential mortgages should be granted at loan-to-income ratios above 4.5, thereby constraining the riskiest forms of lending in an overheated housing market (BoE, 2014). In addition, the FPC put in place a framework for the reciprocity of foreign buffers under which countercyclical capital requirements imposed abroad would normally be recognised in the United Kingdom up to 2.5%, a feature that was particularly relevant given the international footprint of UK banks (BoE, 2016). By 2017, the UK had already activated the CCB at 0.5% of risk-weighted assets with the clear intention of raising it further to 1% by late 2018 (BoE, 2017).

After 2017, the UK framework was tested repeatedly. The FPC increased the CCB to 1% in 2018, which reflected strong credit growth and a tightening labour market. However, the buffer was released in its entirety as part of the Bank of England's response to the Brexit and pandemic. By December 2021, with the economy recovering and household credit demand accelerating, the CCB was re-activated at 1% and in 2022 it was raised to 2%. Alongside the CCB, the FPC refined the leverage ratio framework and maintained its recommendation on loan-to-income limits, which had become a permanent feature of the UK mortgage market. Sectoral capital requirements for commercial real estate exposures were also considered intermittently although in practice the CCB and mortgage lending restrictions remained the most visible tools.

The United Kingdom thus illustrates both continuity and divergence. On the one hand, its framework shared many features with EU macroprudential regimes, particularly the reliance on capital buffers and borrower-based constraints. On the other, the combination of an independent FPC within the Bank of England and the UK's withdrawal from the EU has reinforced a distinctive approach with a more flexible use of the tools and no obligation to coordinate buffer settings with European institutions. By 2025, the United Kingdom stood out as one of the few jurisdictions to operate a fully active CCB at the upper end of the international range, while maintaining borrower-based measures as permanent constraints on mortgage lending.

The UK case, while distinct from the EU due to Brexit, underlines many of the same macroprudential dynamics that were observed in continental Europe: reliance on capital buffers, enduring borrower-based measures and cyclical adjustments to credit conditions. At the same time, its greater institutional independence highlights the contrast with the coordinated EU framework.

This comparison with the EU core countries provides a natural bridge to the next stage of this analysis. The question is no longer only how frameworks were designed but whether they were effective in practice: did the countercyclical buffers stabilise credit, did borrower-based limits curb excessive household leverage and did systemic surcharges strengthen resilience?

From there, the discussion extends to a broader normative perspective. Macroprudential policies not only mitigate systemic risk but also shape the distribution of credit and wealth. The following chapter therefore considers the optimal stance of macroprudential regulation from a social welfare and inequality perspective and introduces the use of agent-based models with heterogeneous agents as a framework for exploring these trade-offs between stability and inclusiveness.

4.2.4 Effectiveness of Macroprudential Policies

The effectiveness of macroprudential policies is a subject of growing importance in both academic research and policymaking, yet the evidence remains spotty and contested. These policies were

long in use in some emerging economies but their widespread adoption in advanced countries only followed the global financial crisis (Claessens et al., 2012). As a result, most jurisdictions have little more than a decade of practical experience, which is often insufficient to cover a full financial cycle. Assessing effectiveness therefore means looking backwards, evaluating whether specific instruments achieved their intended goals and considering whether recalibration or complementary tools are needed. The experiences of countries outside the EU, especially in Asia and Latin America, often serve as useful benchmarks (Cerutti et al., 2017), given the relatively short history of macroprudential frameworks in the EU.

The effectiveness of an instrument can be understood in two complementary ways: its contribution to strengthening the resilience of the financial system and its ability to influence credit dynamics and asset prices (Galati and Moessner, 2011b). The first dimension relates to the so-called spatial or structural component of systemic risk and asks whether the system is better equipped to withstand shocks once new measures are introduced. For example, limits on loan-to-value or loan-to-income ratios can be assessed by analysing the distribution of these ratios among households after the measures have been applied. Studies for euro area countries and for Hong Kong suggest that such restrictions can reduce the build-up of vulnerabilities in mortgage markets (Wong et al., 2011; Lim et al., 2011). The second dimension refers to the temporal component of systemic risk and asks whether instruments affect the credit cycle itself. Here, the main challenge lies in separating the effect of policy from the other factors that shape credit supply and demand.

The literature so far offers cautious conclusions. Capital-based tools, such as countercyclical capital buffers or additional requirements for systemically important institutions appear to enhance resilience and support lending in downturns although their impact during booms is weaker (Repullo and Saurina, 2011; Jiménez et al., 2017a). In the short term, higher capital requirements can dampen credit growth but in the medium term, the effects are modest. There is also evidence that such measures reduce the probability of crises and allow banks to maintain lending during stress periods, thereby supporting recovery in the aftermath of shocks. Sectoral tools, such as higher risk weights on mortgage lending similarly strengthen resilience but their effects on the pace of credit growth remain ambiguous and at times contradictory. Risk weights and sector-specific buffers may restrict lending to targeted sectors, yet their effectiveness can be undermined by spillovers as lending is redirected to other jurisdictions or markets. Cross-border leakage has been observed particularly in the case of capital requirements, while borrower-based instruments such as LTV or DSTI limits tend to have more localised effects.

Evidence from emerging markets points to the stronger effects of borrower-based tools, which have been relatively effective in slowing credit booms and containing property price inflation (Crowe et al., 2013). In contrast, in developed and financially open economies the dampening effect of such measures is weaker and reflects the availability of cross-border financing and more complex financial systems. In the EU, the impact of liquidity requirements is also less clear as they address funding mismatches but do not necessarily constrain credit growth (ESRB, 2014b).

A further complication arises from the cross-border dimension of macroprudential policy. Instruments introduced in one country often affect the financial cycle in others (Farhi and Werning, 2012). Capital requirements are particularly prone to generating spillovers, while borrower-based measures are more insulated. For this reason, reciprocity arrangements have become a key component of the European framework (ESRB, 2014a). Nevertheless, experience has shown that coordination across jurisdictions remains a challenge and that effectiveness must be judged not only in terms of national outcomes but also in the light of regional and global financial integration.

The difficulties of evaluation are compounded by the timing of institutional reforms. Most European frameworks were created between 2013 and 2016, often in response to the financial crisis. As a result, many measures were introduced during a downturn when countercyclical tools were not binding. In most countries, the countercyclical capital buffer was maintained at zero until 2016. The Spanish experiment with dynamic provisioning further illustrates the challenges of calibration: the rule was based on historical data from earlier cycles and proved to be ill-suited to the crisis of

2009–2011 (Fernández de Lis and García-Herrero, 2009). Such examples show that even when tools exist, their effectiveness depends on timing, design and the surrounding economic environment.

The broader lesson is that macroprudential measures cannot be evaluated in isolation. Business and financial cycles are shaped not only by these policies but also by fiscal and monetary measures, structural reforms and changes in the institutional framework (IMF, 2013a). Restrictive monetary policy can reduce lending in ways that resemble macroprudential tightening, while expansionary fiscal policy may offset contractionary effects. Ignoring these interactions risks producing misleading assessments of effectiveness. For this reason, international institutions such as the IMF, the FSB and the ESRB increasingly emphasise evaluating the combined stance of macroprudential policy rather than the impact of individual instruments (FSB, IMF, BIS, 2011; ESRB, 2014b).

The empirical assessment of macroprudential effectiveness also faces methodological obstacles. Reliable econometric studies require a long time series of consistent data, yet such series are scarce. While international databases such as the IMF's Global Macroprudential Policy Instruments (GMPI) and the ECB's Macroprudential Database provide valuable information, access is limited and coverage remains incomplete (Alam et al., 2019). National central banks collect additional data but definitions and formats often differ. This fragmentation of information hampers robust cross-country comparisons and explains why much of the literature still relies on case studies or event studies rather than econometric models.

Methodologically, the field is diverse. Researchers employ event studies, expert assessments, regression analyses, panel studies, stress-testing frameworks, counterfactual simulations and micro-data analyses (Galati and Moessner, 2011b; Cerutti et al., 2017). Each approach has strengths and weaknesses but all face the same underlying problem: it is impossible to know with certainty what would have happened in the absence of policy intervention. Counterfactual analyses using simulation models such as DSGE or agent-based approaches offer one way forward, though they are better suited to questions of optimality – whether the chosen policy stance is appropriate for the system as a whole – than to questions of effectiveness narrowly defined.

Overall, the literature suggests that macroprudential instruments do make financial systems more resilient and can dampen credit excesses but their effectiveness is uneven, context-dependent and subject to leakages across borders. Their true potential is best realised when combined in a coherent policy mix, supported by strong institutional frameworks and complemented by other elements of economic policy (FSB, IMF, BIS, 2011; ESRB, 2014a). As research progresses and more data become available, a clearer picture will emerge but for now the study of effectiveness remains an evolving field that requires both caution in interpretation and flexibility in policy design.

In conclusion, the effectiveness of macroprudential instruments cannot be judged in isolation, nor can their role be reduced to short-term adjustments in lending or house price dynamics. What increasingly matters is the way in which these measures interact with one another and with the wider policy environment including monetary and fiscal interventions. Effectiveness, therefore, is only part of the story; it captures whether a particular instrument achieved its proximate target but not whether the overall policy mix was appropriate for the structure of the economy and the distribution of risks across sectors and agents.

This broader issue points directly to the question of optimality. A financial system is not homogeneous and neither are the agents within it. Households differ in their debt capacities, firms in their leverage and access to credit and banks in their business models and exposures. The heterogeneous character of the economy means that the same tool may have very different effects across groups and that combinations of instruments can generate outcomes that cannot be understood by studying individual tools in isolation.

For this reason, the next chapter turns to an analysis of optimal policy combinations in heterogeneous environments. We focus in particular on the use of agent-based models (ABM), which allow us to capture interactions among diverse households, firms and financial institutions. By simulating how these agents respond to different macroprudential settings, ABMs provide a powerful framework for exploring not only the effectiveness but also the optimality of policy mixes. This shift from

effectiveness to optimality marks the natural next step in understanding how systemic risk can be managed.

Notes

1. The Financial Stability Board was established after the Pittsburgh Summit. It is an international body aimed at monitoring and making recommendations about the global financial system that replaced the Financial Stability Forum (FSF).
2. The Basel II framework was applicable in the EU from 1 January 2008 and in the United States from 1 April 2010. It therefore cannot be treated as a direct cause of the crisis.
3. Currently Financial Stability Board (FSB).
4. For the assessments of the ESFS, *see* Jurkowska-Zeidler (2009), Fedorowicz (2011, 2014), Koleśnik (2013), Lo Schiavo (2014), Tröger (2014), Schoenmaker et al. (2014), Rogowski (2014), Faia et al. (2015), Szpringer and Szpringer (2017).
5. The legal basis includes: Regulation (EU) No. 1092/2010 establishing the ESRB; Regulation (EU) No. 1096/2010 conferring specific tasks upon the ECB concerning the functioning of the ESRB; Regulation (EU) No. 1093/2010 establishing the EBA; Regulation (EU) No. 1094/2010 establishing the EIOPA; Regulation (EU) No. 1095/2010 establishing the ESMA; and Directive 2010/78/EU (the ‘Omnibus Directive’) amending existing financial services legislation to ensure that the new authorities can work effectively, *see* EC (2010).
6. The legal basis for the SSM is Council Regulation (EU) No. 1024/2013 and Regulation (EU) No. 1022/2013. The latter established the European Banking Authority (EBA) and defined its role within the institutional and legal framework, *see* Council Reg. 1024 (2013); Reg. 1022 (2013).
7. The CMDI review amends Directive 2014/59/EU (the Bank Recovery and Resolution Directive or ‘BRRD’), Regulation (EU) No 806/2014 (the Single Resolution Mechanism Regulation or ‘SRMR’) and Directive 2014/49/EU (the Deposit Guarantee Schemes Directive or ‘DGSD’), *see* Council of the EU (2025).
8. Regulation EC No. 1060/2009, Regulation EU No. 513/2011 (CRAII), Regulation EU No. 462/2013 and Directive 2013/14/EU (CRAIII), *see* Reg. 1060 (2009); Reg. 513 (2011); Reg. 462 (2013); Dir. 14 (2013).
9. Directive 2011/61/EU, *see* Dir. 61 (2011b).
10. Directive No. 2009/65/EC, amended by Directive 2010/78/EU, Directive 2011/61/EU, Directive 2013/14/EU, Directive 2014/91/EU, *see* Dir. 65 (2009a); Dir. 78 (2010); Dir. 61 (2011a); Dir. 14 (2013); Dir. 91 (2014a).
11. Directive 2014/49/EU (Dir. 49, 2014).
12. The BRRD consists primarily of Directive 2014/59/EU establishing a framework for the recovery and resolution of credit institutions and investment firms (Bank Recovery and Resolution Directive), as subsequently amended – most notably by Directive (EU) 2019/879 (BRRD II), which strengthened loss-absorbing and recapitalisation capacity requirements (MREL). The BRRD operates alongside Regulation (EU) No 806/2014 (the Single Resolution Mechanism Regulation) within the EU Banking Union framework, *see* (Dir. 59, 2014; Dir. 879, 2019; Reg. 1075, 2016; Reg. 1624, 2018; Reg. 1751, 2021).
13. Directive 2011/89/EU (Dir. 89, 2011).
14. Directive 2002/87/EC, the Capital Requirements Directives (2006/48/EC and 2006/49/EC) and the Directive on Supplementary Supervision of Insurance Undertakings in Insurance Groups (98/78/EC) (Dir. 87, 2002; Dir. 48, 2006; Dir. 49, 2006; Dir. 78, 1998).
15. Directive 2004/39/EC, *see* Dir. 39 (2004).
16. Directive 2014/65/EU and Regulation No. 600/2014 (Reg. 65, 2014; Reg. 600, 2014).
17. Market Abuse Regulation No. 596/2014, *see* Reg. 596 (2014).
18. Regulation (EU) No. 1286/2014 (Reg. 1286, 2014).
19. Directive 2014/91/EU (Dir. 91, 2014b).
20. Directive (EU) 2024/927 (Dir. 927, 2024).
21. The CRR/CRD IV package consists of Directive 2013/36/EU and Regulation (EU) No. 575/2013 (CRD IV, 2013; Reg. 575, 2013b).
22. This package was embodied in Regulation (EU) 2019/876 (CRR II), Directive (EU) 2019/878 (CRD V), Regulation (EU) 2019/877 (SRMR II) and Directive (EU) 2019/879 (BRRD II) (Reg. 876, 2019; Dir. 878, 2019; Reg. 877, 2019; Reg. 879, 2019).
23. For further information about the CRR/CRD IV framework, *see, inter alia*: Brzozowski (2014), Dobrzańska (2014), Drzyzga and Drzyzga (2015), Kowalczyk (2015), Piskorz (2017).
24. Subsequent amendments under CRR II/CRD V further strengthened the capital framework by refining eligibility criteria for Tier 1 and Tier 2 instruments and aligning the EU regime with international Total Loss-Absorbing Capacity (TLAC) standards to ensure genuinely loss-absorbing capital.
25. In Basel II, Tier I and Tier II instruments were treated on an almost equal footing. For more details on Basel I and II, *see, inter alia*: Iwanicz-Drozdowska et al. (2004), Marcinkowska (2010), Olszak (2011), Grzywacz and Jabłońska (2012).
26. For further discussion of the relationship between capital regulation, procyclicality and systemic risk, *see* Covas and Fujita (2010), Repullo and Suarez (2013), Landau (2009) and Arjani (2009).
27. For exceptions, *see*: Olszak (2015, p. 417).
28. 0.25% of risk-weighted assets for Santander and BBVA.

5 Analysing the Effects of Macroprudential Policies Through an Agent-Based Model with Heterogeneous Agents

As was argued in the previous chapter, the discussion of effectiveness inevitably leads to a deeper question: not only whether macroprudential tools work but whether the overall policy stance is *optimal* in terms of social welfare and distributional outcomes. This concern has become central to the research agenda of both academics and policymakers. One stream of the literature relies on the dynamic stochastic general equilibrium (DSGE) models, in particular the DSGE-3D framework developed by the European Systemic Risk Board (ESRB) and the European Central Bank (ECB). This model, with its three layers of default (Clerc et al., 2015a), has been widely used to analyse the effects of stylised macroprudential interventions. Yet, despite incorporating important financial frictions, the DSGE-3D framework still relies on the representative agent assumption, which severely limits its capacity to capture the “true” heterogeneity of economic agents. Where heterogeneity is introduced, it typically applies only to broad sectors, such as households, firms or banks rather than to the diversity of individual agents, thus leaving important distributional dynamics unaccounted for.

An alternative has been developed in recent years using agent-based modelling (ABM). This chapter builds in part on earlier studies including Kaszowska-Mojša and Pipień (2020) and the more recent work of Kaszowska-Mojša, which reports results from the MACROPRU project. In the 2020 study, we introduced an ABM framework that is designed to move beyond the representative-agent assumption by incorporating heterogeneous households, firms and financial institutions. This approach made it possible to conduct counterfactual simulations that highlight not only resilience and stability but also welfare outcomes, inequality and the distribution of risks across different sectors of the economy.

In this chapter, we build on that approach to examine the optimal combination of macroprudential instruments in heterogeneous environments using Poland as a calibration case for a small open economy, while drawing broader implications for the design of policy in Europe. The central aim is to move beyond stability alone and to assess how different policy mixes affect welfare and inequality across diverse groups of agents.

5.1 Analysis of the Tools for Studying the Effects of Macroprudential Policy on Social Welfare and Inequality

In what follows, we contrast two complementary approaches to the study of macroprudential policy. We begin with the DSGE perspective, which, despite its limitations, remains the dominant benchmark

for welfare analysis in macroeconomics. This provides a useful point of reference before moving to more flexible frameworks. The subsequent sections therefore broaden the analysis by considering the impact of macroprudential policies on inequality including insights from data-driven models and by turning to agent-based modelling, which enables a richer exploration of welfare and distributional effects in heterogeneous environments.

5.1.1 The Impact of Macroprudential Policies on Welfare Within the DSGE Approach

Mainstream economics has developed a framework in which the social consequences of economic policies and their impact on market outcomes are assessed using welfare comparisons. Welfare is perceived as the sum of the satisfaction of individuals from their consumption and dissatisfaction from their labour as experienced over the horizon of their lifespan. As such, it is measurable and expressed by the level of utility that is experienced by individuals. Despite the fact that utility is taken as a purely ordinal measure of the preferences of individuals, it still enables the possible economic outcomes to be ranked in terms of their compatibility with the objective functions of individuals, which according to the general consensus consists of utility maximisation. This enables the different market outcomes to be compared in terms of their consequences for the level of satisfaction for individuals and a society.

Welfare comparisons have become especially popular within the general equilibrium framework. Because DSGE models are based on a representative agent's assumptions, there is a direct transition from the individual to the social welfare levels, which makes the comparisons straightforward. The technical simplicity of the approach has resulted in the development of numerous analyses that assess the social consequences of policy interventions. Recently, additional attention has been attracted by macroprudential policies.

The research on macroprudential policies within DSGE models builds on the literature that describes the role of financial frictions and market imperfections in amplifying business cycles. Two broad approaches can be distinguished: (i) demand-side frictions where constrained access to credit arises from swings in household or firm net worth (Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Carlstrom and Fuerst, 1997; Iacoviello, 2005); and (ii) supply-side frictions where bank balance-sheet constraints generate a "capital channel" for financial shocks (Gerali et al., 2010; Meh and Moran, 2010).

Demand-side instruments such as loan-to-value (LTV) or loan-to-income (LTI) caps have been studied extensively (Lambertini et al., 2013; Falagiarda and Saia, 2017; Jensen et al., 2018; Gelain et al., 2013). Likewise, supply-side tools such as capital requirements (Mendicino et al., 2018; Angeloni and Faia, 2013; Clerc et al., 2015a), reserve requirements (Tavman, 2015; Chawwa, 2021; Ben-Gad et al., 2022) and liquidity regulations (Adrian and Boyarchenko, 2018) have been examined. These studies generally conclude that macroprudential tools, when used countercyclically and in coordination with monetary policy, can reduce financial amplification mechanisms and improve stability.

Parallel to this, a growing literature investigates inequality and redistribution. Frost and van Stralen (2018) emphasise that macroprudential policies can prevent crisis-related welfare losses but also impose costs in booms. Studies incorporating borrower-lender heterogeneity, such as Lambertini et al. (2013) and Rubio and Carrasco-Gallego (2014) show that LTV limits stabilise cycles and preserve consumption though they may redistribute housing wealth towards savers. More general models (Quint and Rabanal, 2014; Ozkan and Unsal, 2014) highlight the trade-offs in open economies where foreign intermediation weakens national policy tools. Later contributions such as Mendicino et al. (2018) and Rubio and Unsal (2017) focus on optimal capital requirements and show asymmetries across borrowers and lenders as well as implications for inequality.

Overall, DSGE research establishes three stylised facts: (i) macroprudential policies dampen credit cycle volatility; (ii) they redistribute welfare across groups, often worsening inequality; and (iii) coordination – both with monetary policy and internationally – improves outcomes. At the same time, DSGE models are constrained by representative-agent structures, which limits their ability to

capture the full distributional consequences. Recent progress with HANK models (Kaplan et al., 2018; Auclert, 2020) partially addresses this but a full treatment of heterogeneity remains incomplete.

5.1.2 *The Impact of Macroprudential Policies on Inequality and Data-Driven Models*

The reliance of DSGE models on representative agents raises questions about their suitability for distributional analyses. Empirical and data-driven approaches therefore increasingly focus on inequality as an outcome of macroprudential regulation.

A seminal contribution by Stiglitz (2016b) shows how collateral constraints in credit markets can amplify wealth inequality in a growth model. Carpentier et al. (2018) extended this to an overlapping-generations setting demonstrating how LTV ratios, bequest motives and housing markets shape wealth inequality. Using microdata from the Eurosystem Household Finance and Consumption Survey, they confirmed that higher LTV allowances do not necessarily reduce inequality. More recent quasi-experimental evidence from South Korea (Park and Kim, 2023) confirmed that LTV tightening disproportionately affects lower-wealth households.

Cross-country studies broaden the picture. Frost and van Stralen (2018) use macroprudential policy indices to show how reserve requirements and exposure limits influence inequality. Georgescu and Vila Martin (2021) employed Bayesian VAR simulations to trace the effects of borrower-based measures on Gini coefficients and showed mixed distributional impacts depending on crisis conditions. Finally, Konstantinou et al. (2022) analysed transition economies and found that while some tools (dynamic provisioning, leverage limits) reduce inequality, many others transfer wealth from poorer to richer households.

These studies suggest that macroprudential policy entails a trade-off between stability and inequality and that distributional consequences vary across contexts. However, empirical research is constrained by short time series, data fragmentation and measurement problems. This highlights the need for complementary modelling approaches that are able to capture heterogeneity in greater depth.

5.1.3 *The Impact of Macroprudential Policies on Welfare and Inequality Within the ABM Approach*

Agent-Based Models (ABMs) provide a complementary perspective to the DSGE and econometric approaches by explicitly modelling the heterogeneity of households, firms and financial institutions. Unlike representative-agent frameworks, ABMs simulate the interactions among heterogeneous agents whose behavioural rules, balance sheets and adaptive expectations generate emergent macroeconomic dynamics (Farmer and Foley, 2009b; Bookstaber, 2017). This makes them well-suited for studying the redistributive and welfare effects of macroprudential policies, which often depend on second-order interactions and spillovers that are invisible in aggregated models.

Early applications focused on housing markets. Geanakoplos et al. (2012) demonstrated how leverage cycles amplify systemic risk. Building on this, Baptista et al. (2016) modelled the UK housing market and tested the LTV and LTI caps. Their results showed that such tools dampen house price cycles and reduce debt though at the cost of tighter credit for low-income households. Extensions applied similar frameworks in Spain (Carro, 2023), Denmark (Cokayne, 2019), Italy (Catapano et al., 2021) and Greece (Laliotis et al., 2020) and confirmed the stabilising effects but also distributional trade-offs.

Beyond housing, ABMs have been used to study banks and policy interactions. Cincotti et al. (2012) showed that dynamic capital requirements outperform static ones. Popoyan et al. (2017) explored Basel III tools and found that simpler frameworks could yield similar stability as more complex ones. Da Silva and Lima (2017) examined joint calibration of interest rates and capital requirements and illustrated complementarities but also trade-offs between stability and volatility.

More recently, ABMs explicitly addressed inequality. D’Orazio (2019) showed that the phase of the cycle and income profiles determine the distributional effects of prudential tools. Tarne et al.

(2022), extending Baptista et al. (2016), introduced borrower-specific LTV caps: limiting leverage for buy-to-let investors reduced wealth inequality, while restricting first-time buyers increased it. Pangallo et al. (2019) and Guerrero (2020) also highlighted how housing transactions shape inequality.

Overall, ABMs reveal distributional effects that depend on heterogeneity across the entire distribution of agents. Limiting leverage for speculative investors may improve stability and equality, while when the same is applied to constrained households, it worsens inequality. This underscores the fact that optimal macroprudential policy requires a heterogeneous-agent lens. Agent-based models (ABMs) provide a flexible framework for analysing macroprudential policy by capturing heterogeneity, adaptive behaviour and network effects that are difficult to represent in more aggregate approaches. They should not, however, be regarded as substitutes for DSGE or econometric models but rather as complementary instruments within the central banking toolkit.¹ ABMs are particularly valuable for exploring complex dynamics and distributional consequences, whilst DSGE frameworks and empirical methods remain useful in studying the general equilibrium effects.

5.2 Comparison of the ABM and DSGE-3D Model

The DSGE model with three layers of default (the so-called 3D model), which was developed at the ECB by Clerc et al. (2015b), constitutes one of the most important attempts to integrate financial frictions into a general equilibrium setting. The model explicitly incorporates defaults of households, firms and banks, which makes it possible to assess how insolvency propagates through an economy. The 3D model has been used to determine the optimal capital requirements and to analyse welfare effects within a social planner framework. This represents a clear advance compared to earlier DSGE models where defaults were either absent in the steady state or were assumed to be fully hedged away by contractual arrangements.

Nevertheless, the 3D model retains the standard assumptions of the DSGE tradition: representative or homogeneous agents, rational expectations and optimisation, which are subject to aggregate shocks. Insolvency arises mainly from idiosyncratic or systemic disturbances that reduce the ability of borrowers to repay. A borrower's default affects the lender's balance sheet, which in turn alters its optimal behaviour, while bank failures generate losses to households and firms even in the presence of deposit insurance. This formal structure creates a coherent framework for policy analysis but it is also restrictive since it cannot easily accommodate heterogeneity in expectations, adaptive decision-making or alternative behavioural rules. As a consequence, distributional aspects and the possibility of endogenous crisis dynamics are only partially represented.

Agent-based models (ABMs) approach the same issues from a fundamentally different perspective. They describe the economy as a collection of heterogeneous households, firms and financial institutions, each with its own balance sheet, behavioural rules and adaptive responses. Defaults emerge endogenously from market interactions and from the co-evolution of credit supply, investment and demand. Importantly, insolvency is not simply the result of exogenous shocks but can also be driven by the internal dynamics of the system, including the feedback between financial fragility, risk perception and credit conditions. This resonates with Minsky's financial instability hypothesis where periods of optimism and expanding leverage are followed by instability and crisis.

The treatment of heterogeneity illustrates the contrast between the two approaches. In DSGE models such as the 3D framework, deviations from the representative agent paradigm are typically introduced through idiosyncratic shocks and incomplete markets with equilibrium distributions that are derived numerically. In ABMs, by contrast, heterogeneity is intrinsic: households differ in income, wealth, consumption patterns and borrowing behaviour; firms differ in productivity, capital structure and investment strategies; banks differ in risk appetite, balance sheet conditions and lending policies. Decision-making is based on bounded rationality, adaptive expectations and heuristic rules, which makes it possible to capture the asymmetries, contagion and non-linear adjustments that are difficult to reconcile using equilibrium-based methods.

Another important distinction concerns the transmission of systemic risk. In the DSGE-3D model, contagion operates through balance-sheet linkages and is mediated by optimising responses under rational expectations. In ABMs, the transmission of defaults occurs not only through financial exposures but also through the changing perceptions of counterparty risk and uncertainty of agents. This “perception of perception” dimension – where expectations about the behaviour of others directly shape decisions – is difficult to incorporate into equilibrium models but plays a crucial role in real-world crises. ABMs can therefore capture the amplification of shocks through behavioural channels in addition to the purely financial mechanisms that are already present in the DSGE framework.

The differences also extend to policy evaluation. The 3D model provides a transparent framework for calibrating optimal capital requirements and quantifying their effects on social welfare. It highlights how distortions such as deposit insurance or the costs of insolvency justify macroprudential intervention. ABMs, while less suited to closed-form welfare optimisation, offer a flexible environment in which to explore alternative regulatory regimes, distributional outcomes and systemic resilience. They can, for instance, evaluate how policy changes affect different income groups, how credit allocation interacts with housing or demographic factors or how localised shocks spread across the network of firms and banks.

In terms of underlying theoretical foundations, the 3D model is firmly rooted in the financial accelerator literature (Bernanke et al., 1999) where the net worth of borrowers drives credit supply. The ABM approach instead draws on the Minskyan tradition, which emphasises the endogenous build-up of fragility and the role of uncertainty in driving cycles of boom and bust. Both perspectives have strengths and limitations. The accelerator mechanism provides a tractable and well-established framework for quantifying amplification effects, while the instability hypothesis highlights the structural vulnerabilities and behavioural dynamics that could undermine equilibrium assumptions.

Ultimately, both approaches formally model the interconnectedness of households, firms and banks, yet they also embody different conceptions of the economy. DSGE models rely on equilibrium concepts, rational expectations and representative optimisation, which make them powerful for calibration and forecasting. ABMs rely on heterogeneity, bounded rationality and interaction-based dynamics, which make them powerful for exploring instability, non-linearities and distributional consequences.

The DSGE-3D model provides a disciplined benchmark for quantifying policy effects and for comparing scenarios in a consistent welfare framework. ABMs provide a simulation laboratory for testing the robustness of these results under more realistic assumptions about heterogeneity, behaviour and systemic feedback. Taken together, they enrich the toolkit that is available to central banks and regulators (Muellbauer and Kaszowska-Mojša, 2023; Borsos et al., 2025).

5.3 Model Description

The model presented in this chapter is an agent-based framework that is designed to explore the interaction between the financial system and the real economy. It provides a laboratory in which the behaviour of households, firms, banks and other institutions can be observed under varying conditions and where the consequences of their actions reverberate through the economy as a whole. In order to capture these dynamics, the model combines a detailed representation of agents and their attributes along with rules that govern how they interact and adapt over time. The design follows the spirit of *A Common Protocol for Agent-Based Social Simulations* (Richiardi et al., 2006) and emphasises transparency in how agents are defined, how they relate to one another and how a system evolves step by step. The model is also presented in comparison with the current leading benchmarks in data-drive macro ABMs, namely those of Poledna et al. (2023); Hommes et al. (2022) and Wiese et al. (2024).

At the heart of a system are the agents themselves: banks, individuals, households, consumers, firms, establishments, suppliers, properties and industries. Each category fulfils a specific role and

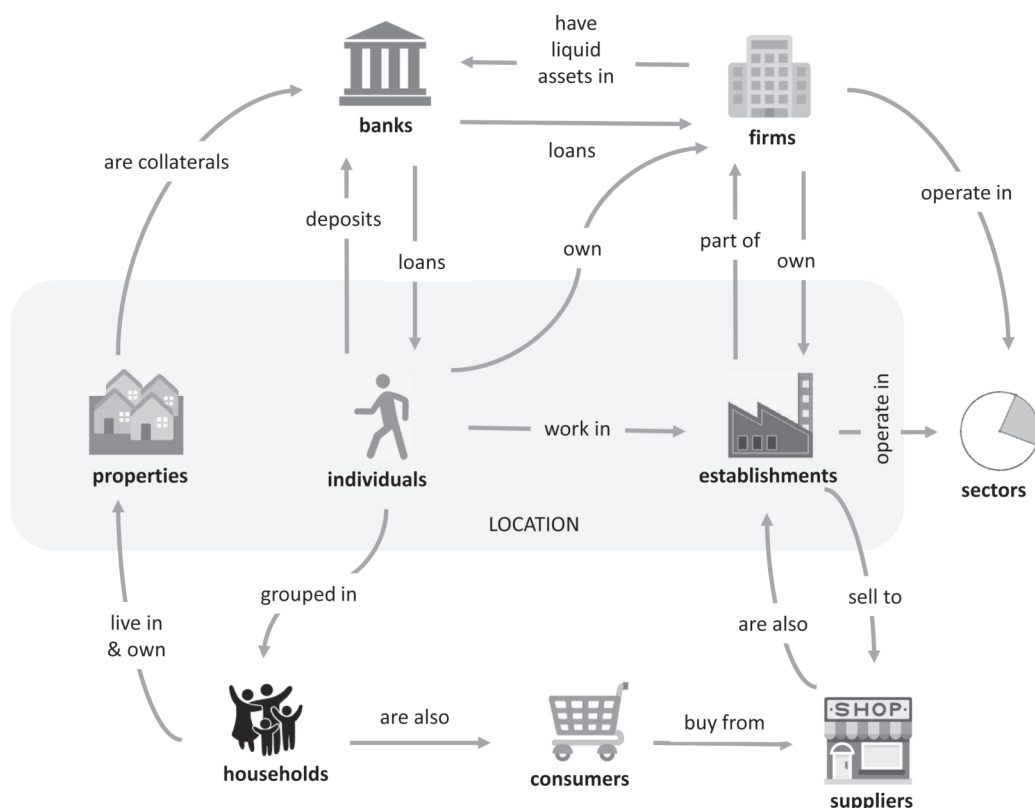


Figure 5.1 Schematic representation of the model used in the Minsky-moment simulations and in the MACRO-PRU project.

The figure was also included in the Report for FI (Muellbauer and Kaszowska-Mojša, 2023).

together they recreate the network of economic and financial relationships that characterises a modern economy. Their interactions are illustrated in a schematic representation of the model (Figure 5.1), which depicts the core flows of income, credit and goods and services that connect the different agents. Detailed attribute lists for each agent type are provided in the tables at the end in order to keep the exposition here focused on the overarching logic of the model.

Households provide the natural starting point. They are composed of individuals who earn income, form families, consume goods and services and save or borrow according to their circumstances. Household income is pooled from wages, transfers and sometimes rents from property; some of it is consumed, while the remainder is saved or invested. Consumption choices are shaped not only by income but also by prices, product quality and the accessibility of suppliers. When incomes fall short, households may resort to consumer credit, the conditions of which depend on their creditworthiness and the willingness of banks to lend. Housing decisions add further complexity: households can rent or purchase property, which is financed by savings or by mortgages. Properties themselves, which can be bought, sold or repossessed depending on the household's wealth and plans, are also objects in the model. Defaults on mortgages, for example, ripple through the system by weakening bank balance sheets and depressing property markets.

Firms occupy an equally central position. They produce goods and services, hire workers and seek financing for investment. Their survival depends on profitability, which is influenced by demand conditions, costs and access to credit. Some firms grow, expand their establishments and merge with competitors; others stagnate or exit. Establishments, in turn, provide a spatial dimension to

production, tying firms to particular regions and enabling the model to capture patterns of local demand, employment and supply chains. Production decisions within establishments take account of inventories, debt levels and prudential limits, while their purchases from suppliers reflect not only prices and quality but also geographical availability.

Banks act as the critical intermediaries. They extend loans to households and firms, accept deposits and are constrained by regulatory requirements. The model incorporates a range of prudential indicators – capital adequacy ratios, large exposure limits, loan-to-value thresholds, leverage and liquidity ratios – ensuring that lending behaviour reflects the constraints that are faced by financial institutions. Crucially, banks are not portrayed as passive conduits of funds but as active agents whose risk-taking is shaped by reputation, competition and their perception of uncertainty. This means that credit supply is not constant but varies with the circumstances of banks and with their expectations of the behaviour of others.

Industries and suppliers provide a higher-level structure. Industries represent the sectors of the economy within which firms and establishments operate. They serve both as benchmarks – for example, by setting average profitability or productivity against which entrepreneurs gauge opportunities – and as channels of systemic exposure since banks monitor their lending to each industry relative to the regulatory thresholds. Suppliers mediate the flow of inputs across establishments and industries, thus embedding production in wider supply chains.

The dynamic aspect of the model lies in the sequential updating of agents. At each iteration, households adjust their consumption and savings, firms decide on production and investment, banks revise their lending policies and properties and industries update their states accordingly. Defaults and bankruptcies are not imposed from outside but arise organically from these interactions; a household that loses income may default on a mortgage, thus reducing a bank's capital, which in turn may tighten credit conditions and affect other households and firms. In this way, the simulation reproduces the feedback loops that characterise actual economies where local shocks can trigger broader systemic effects.

Taken together, the model forms a detailed representation of a credit- and property-driven economy where heterogeneous actors interact under bounded rationality and adaptive expectations. By embedding macroprudential constraints and allowing for both financial and real variables to evolve together, the simulation provides a powerful tool for examining how regulation, shocks and behavioural responses shape the stability of the system.

5.4 Inequality Measures and Distributional Effects

Having laid out the mechanics of the ABM – its state variables, interactions and policy levers – the natural next step is to examine what the simulated microdata reveal about how gains and losses from macroprudential policy are distributed across agents. Unlike representative-agent frameworks, the ABM generates full cross-sectional and joint distributions (of income, wealth, leverage, liquidity, default risk and consumption) as well as their dynamics over the cycle. This allows us to move beyond aggregate stability metrics and ask who bears adjustment costs, who benefits from resilience and whether policy mixes amplify or mitigate disparities. Accordingly, the next section introduces the inequality measures and distributional diagnostics we used – covering both levels and tails, dispersion and mobility – to translate the micro-level outcomes into welfare-relevant statistics. This provides a consistent lens for comparing counterfactual policies, identifying unintended side effects and linking stability objectives to distributional consequences.

5.4.1 Distributions, Inequality and Concentration Measures

The model is initialised at $t = 0$ from a *micro-consistent* dataset that brings together household survey data, firm and sectoral information and bank-level statistics. To construct this foundation, we

harmonised definitions across sources, aligned reference periods and imposed stock–flow consistency so that the sectoral aggregates in the model corresponded to their national counterparts. Attributes such as income, assets, liabilities and liquidity buffers were then sampled from joint empirical distributions and assigned to agents in a way that preserved observed heterogeneity.

For households, the primary source was the Household Finance and Consumption Survey (HFCS). In the case study presented here, we used the Polish HFCS though the same procedure applies to any of the 22 participating countries, which makes the calibration portable beyond this single setting. The resulting distributions provided a detailed cross-sectional snapshot of household finances. These empirical distributions formed the benchmark against which the policy scenarios were assessed. Building on this initial heterogeneity, we computed a suite of inequality and concentration statistics at both the baseline and along simulated paths for $t > 0$. By comparing how these measures evolved under alternative counterfactual policies, we were able to assess not only the aggregate stabilisation but also its distributional consequences. The analysis highlighted who gained and who lost, how risks were reallocated across agents and whether the macroprudential instruments served to mitigate or to deepen existing disparities.

5.4.2 *Gini Coefficient and Measures of Asymmetry*

Inequality within the model is first summarised using the Gini coefficient (Gini, 1909; Chen, 2016) and its graphical counterpart, the Lorenz curve (Lorenz, 1905).² These indicators provide a concise representation of how income and wealth are distributed across households and are computed from the simulated microdata at both quarterly and annual frequencies.

At baseline, the Gini coefficient for household income was 0.3943179 (39.43%) when estimated from the quarterly sample. Using the annual figures produced an almost identical value of 0.3945987 (39.46%). When a bias correction was applied, the estimate rose only marginally to 0.3947129 (39.47%). These closely aligned values indicated that the choice of frequency or correction procedure did not materially affect the measure of income inequality in the baseline dataset.

The baseline estimates can be set in context by comparing them with previous studies. The 2008 *Report on Household Wealth and Debt* reported a Gini of 38.4% for income, slightly lower than the 39.4% that was found here. The difference arose from the adoption of an oversampling procedure that was targeted at the most affluent households, which tended to raise measured inequality. Similarly, Grejcz and Żółkiewski (2017) reported a value of 39.2%, which was again close to our estimates. By contrast, international institutions report somewhat lower values; the OECD published a coefficient of 35.5%, while the World Bank reported 32.08% for 2014. Other national surveys also display variation depending on sampling and methodology: 32.6% in Central Statistical Office (GUS) (2015), 30.7% in Central Statistical Office (GUS) (2014) and 28.5% in Czapiński and Panek (2015).

Wealth inequality was, as expected, considerably more pronounced. The Gini coefficient for wealth in the baseline was 0.6004731 (60.04%). This is broadly consistent with earlier findings including the Narodowy Bank Polski (2015) estimate of 57.9% and the 58.7% that was reported by Grejcz and Żółkiewski (2017).

Taken together, these results confirm that the model reproduced the high degree of inequality that was observed in survey data, particularly for wealth. They also underline how sensitive measured inequality can be to methodological choices such as oversampling of affluent households or the choice of reference dataset, thus reinforcing the importance of cross-validating with multiple sources.

According to Eurostat, the Gini coefficient for income distribution in Poland stood at 30.8% in 2014 and 30.6% in 2015. These values place Poland close to the European Union average, which was 30.9% in 2014 and 31.0% in 2015 across the 28 Member States. Comparable levels of income inequality were recorded in several other countries: Croatia reported 30.2% in both years, Ireland 31.1% in 2014 and 29.8% in 2015, Germany 30.7% in 2014 and 30.1% in 2015, while Great Britain displayed slightly higher figures of 31.6% in 2014 and 32.4% in 2015.

Wealth inequality is more pronounced. Grejcz and Żółkiewski (2017) reported a Gini coefficient of 68.6% for wealth distribution in the euro area, which was considerably above the Polish baseline but was broadly in line with the values for countries such as Malta, Belgium and Italy (Sierminska and Medgyesi, 2013). Interestingly, the comparison also reveals that some countries that are geographically and socially closer to Poland displayed significantly different patterns of both income and wealth inequality, thus underscoring the role of institutional and structural factors in shaping distributional outcomes.

As Chen (2016) reminds us, “not all inequality curves yielding the same Gini coefficient are unequal in the same way”. This insight is crucial not only for cross-country comparisons but also for tracing the evolution of inequality within a single economy over time. When policies are introduced or when counterfactual scenarios are explored, the Gini coefficient alone may mask important shifts in the structure of inequality. The agent-based simulation framework allows us to track how the Gini coefficient evolves across iterations as specific policies are applied but it also permits a deeper investigation. By examining complementary indicators – such as measures of asymmetry or of spatial inequality – we gain a more accurate picture of how the burden of adjustment is distributed and how policies alter the shape, rather than just the scale, of inequality.

Among the measures that are most useful for detecting patterns in inequality is the Lorenz asymmetry coefficient (LAC) (Kotz et al., 1983; Shumway and Koide, 1995; Damgaard and Weiner, 2000) together with a family of related triangular measures that are derived by expressing the coefficient in polar coordinates. The LAC, often denoted by S , provides information that the Gini coefficient alone cannot capture as it highlights whether inequality is driven primarily by the lower or the upper tail of the distribution. In this sense, it complements the Lorenz curve by quantifying its asymmetry. The formal definition of the Lorenz asymmetry coefficient is given as

$$S = F(\mu) + L(\mu), \quad (5.1)$$

where the functions F and L correspond to those that are used in constructing the Lorenz curve and μ denotes the mean of the distribution. In practical terms, the statistic is calculated from an ordered dataset $(x_1, x_2, \dots, x_m, x_{m+1}, \dots, x_n)$ where the values are ranked from lowest to highest.

The procedure begins by identifying the position of the mean within this ordered set. A proportionality factor δ is then computed as

$$\delta = \frac{\mu - x_m}{x_{m+1} - x_m}, \quad (5.2)$$

which locates the mean in relation to the two adjacent observations. This factor enters directly into the definition of the two Lorenz components:

$$F(\mu) = \frac{m + \delta}{n}, \quad (5.3)$$

$$L(\mu) = \frac{L_m + \delta x_{m+1}}{L_n}. \quad (5.4)$$

Here, $F(\mu)$ denotes the cumulative population share up to the mean, while $L(\mu)$ measures the cumulative share of income (or wealth) up to the mean, which is scaled by the total L_n .

Together, these elements yield the value of S , which summarises the asymmetry of the Lorenz curve. Values of S greater than one indicate that inequality is driven disproportionately by the upper tail of the distribution, while values less than one suggest that the lower tail is more influential. A value equal to one corresponds to a symmetric Lorenz curve. In this way, the Lorenz asymmetry coefficient provides a simple but powerful extension of the Gini index capturing not only the overall degree of inequality but also its directional bias within the distribution.

As was shown by Damgaard and Weiner (2000), the Lorenz asymmetry coefficient highlights an important limitation of the Gini measure: two different Lorenz curves may yield the same Gini

coefficient, yet their shapes can diverge substantially, thereby pointing to very different underlying patterns of inequality. The value of the LAC helps to distinguish between these cases. When the coefficient is less than one, inequality is driven primarily by the presence of a relatively large share of poorer units. By contrast, when the coefficient exceeds one, inequality reflects the weight of a small number of extremely rich entities.

For the purposes of further analysis, it is also useful to identify the point on the Lorenz curve where its first derivative is equal to one within the interval $(0, 1)$. Following Chen (2016), this point can be denoted as $[\mu, f(\mu)]$ and it provides a convenient reference for interpreting the shape and asymmetry of the curve. In the context of our agent-based simulations, this distinction becomes especially relevant; scenarios may yield similar Gini coefficients, yet the Lorenz asymmetry coefficient can reveal important shifts in the tails of the distribution, thus indicating whether policy interventions disproportionately affect the poorest or the wealthiest groups.

When the Lorenz asymmetry coefficient was calculated for income distribution using quarterly data, the result is 0.9790896. For annual data the value was quite similar at 0.9788734. The coefficient for wealth distribution was somewhat lower at 0.942073944. Intuitively, when the coefficient falls below one, the point $[\mu, f(\mu)]$ lies below and to the left of the axis of symmetry. This was precisely the case that was observed for Poland although the values remain close to unity, which would correspond to perfect symmetry.

For income distribution, the point $[\mu, f(\mu)]$ was located at $(0.63; 0.35)$. This outcome corresponded to the first of the two situations that were discussed earlier where inequality is driven by the relatively large number of poorer agents. For wealth distribution, the point was $(0.68; 0.26)$, which again fell into the same category. These results indicate that both income and wealth inequality in Poland were primarily associated with the presence of a substantial share of households that were positioned at the lower end of the distribution. This confirms that, despite relatively modest deviations from symmetry, the main driver of inequality in Poland laid in the prevalence of poorer households rather than in the concentration of extreme wealth.

Our simulation framework also made it possible to compute Gini coefficients for Poland under a variety of counterfactual policy scenarios. Yet, when the changes in inequality were relatively subtle, the Gini coefficient alone may not be sufficient to capture the full picture. In such cases, it is useful to complement the analysis by examining the Lorenz asymmetry coefficient (LAC) and by expressing Lorenz asymmetry in polar coordinates. This approach allows us to derive an additional indicator, the adjusted azimuthal asymmetry (AAA), which provides further nuance in distinguishing the sources and directions of inequality (see Chen (2016) also and the discussion in Kaszowska-Mojša and Pipień (2020)).

In this approach, the position of the point $[\mu, f(\mu)]$ can be described relative to $(\frac{1}{2}, \frac{1}{2})$, the midpoint that divides the line of equality in half. Specifically, $[\mu, f(\mu)]$ can be characterised by its radial distance from $(\frac{1}{2}, \frac{1}{2})$ and by the azimuthal angle that is formed by that radius with respect to the line of symmetry. By convention, these two measures are denoted ρ and θ , respectively. For a graphical explanation of ρ and θ see Chen (2016). Both provide an enriched interpretation of the Lorenz asymmetry coefficient.

The maximum radial distance of $[\mu, f(\mu)]$ from $(\frac{1}{2}, \frac{1}{2})$ is $\frac{1}{\sqrt{2}}$, while the azimuthal angle that is formed between the axis of symmetry and the line segment connecting $(\frac{1}{2}, \frac{1}{2})$ to $[\mu, f(\mu)]$ lies within the interval $\pm \frac{\pi}{2}$. Together, ρ and θ make it possible to represent Lorenz asymmetry in polar coordinates, thus offering a complementary perspective to the information that is contained in the LAC. Within our simulations, these measures proved particularly valuable in counterfactual scenarios where overall inequality changed only slightly; they revealed subtle shifts in the distributional asymmetry, thus indicating whether the policy interventions tilted the burden more towards the lower or the upper tail of the population. The radial distance ρ provides a measure of the concavity of the Lorenz curve. It is calculated as

$$\rho = \sqrt{\left(\mu - \frac{1}{2}\right)^2 + \left(f(\mu) - \frac{1}{2}\right)^2}. \quad (5.5)$$

This distance reflects how far the point $[\mu, f(\mu)]$ lies from the midpoint $(\frac{1}{2}, \frac{1}{2})$ of the line of equity.

The azimuthal angle θ measures the position of $[\mu, f(\mu)]$ relative to the axis of symmetry in angular terms and is defined as

$$\theta = \arcsin\left(\frac{S-1}{\rho\sqrt{2}}\right). \quad (5.6)$$

This measure adds precision and a more intuitive geometric interpretation to the Lorenz asymmetry coefficient. As was noted by Chen (2016), “whereas the primary use of S has been binary – negative values lie to the left of the axis of symmetry, while positive values lie to the right – θ locates $[\mu, f(\mu)]$ with precision within the unit triangle”.

It is important to note that S , ρ and θ are all constrained by the Gini coefficient. For any given value G , the admissible ranges of these measures are bounded: the minimum value of S is G itself, while its maximum value is $2 - G$. In this way, the three measures are interrelated with S providing the asymmetry index, ρ capturing the curvature and θ offering the exact angular position of inequality within the Lorenz framework.

An illustrative case is provided by the Polish distributions. For income, where $[\mu, f(\mu)] = (0.63; 0.35)$, the radial distance ρ measured how far this point laid from the midpoint of the equality line, while θ positioned it slightly to the left of the axis of symmetry. This confirmed that income inequality in Poland was driven mainly by the prevalence of poorer households. For wealth, with $[\mu, f(\mu)] = (0.68; 0.26)$, the measures again placed the point below and to the left of the axis, thus underscoring that wealth inequality too was shaped more by the weight of relatively poor households than by the concentration of extreme wealth.

At the baseline of the simulation ($t = 0$), the results for income distribution were as follows:

$$\rho = 0.19908, \quad \theta = -0.07434, \quad t = \frac{\theta}{\pi/2} = -0.04733. \quad (5.7)$$

The distance from $(\frac{1}{2}, \frac{1}{2})$ to the orthogonal intercept along the line of symmetry was 0.19886. Given the Gini coefficient for quarterly data, the maximum admissible value of θ was 0.99369. Using this bound, the adjusted azimuthal asymmetry (AAA) coefficient for $t = 0$ was

$$AAA = \frac{\theta}{\theta_{\max}} = -0.07481. \quad (5.8)$$

For wealth distribution, the corresponding results are:

$$\rho = 0.30767, \quad \theta = -0.13353, \quad t = \frac{\theta}{\pi/2} = -0.08500. \quad (5.9)$$

Here, the distance from $(\frac{1}{2}, \frac{1}{2})$ to the orthogonal intercept was 0.3049. The maximum admissible θ for the quarterly Gini coefficient was 0.5880, which yielded an adjusted azimuthal asymmetry of

$$AAA = \frac{\theta}{\theta_{\max}} = -0.22783. \quad (5.10)$$

As was emphasised by Chen (2016), “adjusted azimuthal asymmetry promises a two-fold advantage over the unadorned Lorenz asymmetry coefficient. First, the asymmetry is more intuitively and more accurately expressed in angular terms than as the sum of two Cartesian coordinates. Second, because adjusted azimuthal asymmetry accounts for the maximum angular distance from the axis of symmetry for a particular value of G , it expresses a sense of proportionality that raw θ to say nothing of S , cannot”.

Taken together, these results confirm that, while both income and wealth distributions in Poland exhibited modest deviations from symmetry, the adjusted azimuthal asymmetry highlighted that the distortions were proportionally more pronounced for wealth than for income.

5.4.3 Spatial Dimensions of Inequality and Inequality Aversion

The measures discussed so far capture the overall degree and asymmetry of inequality but they do not explicitly address its spatial or subgroup dimensions. Yet, for both research and policy analysis, it is often crucial to understand whether disparities arise primarily between regions or sectors or whether they are driven by differences within them. To explore this aspect, we turned to entropy-based measures of inequality, which permit a clear decomposition into between-group and within-group components.

Although our spatial analysis was conducted using the Theil index (TI), it is helpful to begin with the more general formulation from which the Theil index is derived: the generalised entropy (GE) index. It is defined as

$$GE(\alpha) = \begin{cases} \frac{1}{N\alpha(\alpha-1)} \sum_{i=1}^N \left[\left(\frac{y_i}{\bar{y}} \right)^\alpha - 1 \right] & \alpha \neq 0, 1, \\ \frac{1}{N} \sum_{i=1}^N \frac{y_i}{\bar{y}} \ln \frac{y_i}{\bar{y}} & \alpha = 1, \\ -\frac{1}{N} \sum_{i=1}^N \ln \frac{y_i}{\bar{y}} & \alpha = 0, \end{cases} \quad (5.11)$$

where N is the number of individuals or households, y_i denotes the income of entity i and $\bar{y}$ is the mean income. The parameter α governs the sensitivity of the index to distances between incomes in different parts of the distribution.

The generalised entropy family of indices has been proposed as an improvement over the Gini coefficient because of its property of additive decomposability (Shorrocks, 1980). This means that overall inequality can be expressed as the sum of between-group and within-group components, which makes the GE framework particularly well-suited for analysing the spatial dimensions of inequality. The Theil index is simply a special case of this family, that is obtained when $\alpha = 1$ and forms the basis of the analysis presented in the following section.

If we set $\alpha = 1$, that is $GE(1)$, the expression simplifies to the Theil index (TI). One of the key advantages of the TI is that it can be decomposed into two components: the weighted average of inequality within subgroups and the inequality that exists between those subgroups. For instance, inequality in Poland can be expressed as the average inequality within each region weighted by that region's share of income plus the inequality that is observed between regions.

Formally, if the population is divided into k subgroups with s_i denoting the income share of group i , T_{T_i} the Theil index of subgroup i and $\bar{x}_i$ the average income in group i then the overall Theil index is given by

$$T_T = \sum_{i=1}^k s_i T_{T_i} + \sum_{i=1}^k s_i \ln \frac{\bar{x}_i}{\bar{x}}. \quad (5.12)$$

This decomposition makes it possible to assess the relative importance of the spatial dimension of inequality – that is, how much of the overall disparity can be attributed to regional differences as opposed to variation within regions (Novotný, 2007).

At the baseline of the simulation ($t = 0$), using empirical data on income and wealth, we computed both the entropy measure (EM) and the Theil index (TI) for Poland. For income, the results were $EM = 0.2721004$ and $TI = 0.2836961$, while for wealth they were considerably higher at $EM = 0.7599967$ and $TI = 0.6753153$. These values reflected the greater degree of concentration and dispersion that is typically observed in wealth distributions compared with income.

The decomposition of the TI provides a natural way to analyse the spatial dimension of inequality in Poland. For confidentiality reasons, however, we cannot disclose results by specific regions since the coding of regions and districts (1–4) from the Central Statistical Office cannot be made public. What can be presented and what is exploited in the counterfactual simulations, are the changes

in spatial inequality across scenarios. These can be visualised using maps, which permit shifts in regional disparities to be traced over time without revealing the underlying confidential identifiers.

The generalised entropy index can also be expressed as a subclass of the Atkinson index (AI) with $\varepsilon = 1 - \alpha$ for $0 \leq \alpha < 1$. The Atkinson index is defined as

$$A_{\varepsilon}(y_1, \dots, y_N) = \begin{cases} 1 - \frac{1}{\mu} \left(\frac{1}{N} \sum_{i=1}^N y_i^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} & \text{for } 0 \leq \varepsilon \neq 1, \\ 1 - \frac{1}{\mu} \left(\prod_{i=1}^N y_i \right)^{\frac{1}{N}} & \text{for } \varepsilon = 1, \end{cases} \quad (5.13)$$

where ε is the inequality-aversion parameter.

The parameter ε plays a central interpretive role. When ε approaches 0, the index becomes more sensitive to changes at the upper end of the income distribution; in this case, there is essentially no aversion to inequality and a complete redistribution yields no gain in social utility. By contrast, as ε increases, the index becomes more sensitive to changes at the lower end of the distribution, thus implying that redistribution generates higher social utility as inequality aversion grows. Relatively low values of the AI therefore signal a more equal distribution, while higher values indicate greater inequality, given a particular degree of inequality aversion.

Applying this measure to the empirical distributions for Poland, we obtained an Atkinson index of 0.1314228 for income and 0.3438987 for wealth, which again reflected the much higher concentration that is typically observed in wealth distributions.

To broaden the analysis, we also computed additional measures of concentration. For income, the Herfindahl–Hirschman index (HHI) equaled 0.0005451883 and the Rosenbluth index (RI) equaled 0.0004778672. For wealth, the corresponding values were HHI = 0.001255462 and RI = 0.4313275. These complementary statistics confirm the greater degree of concentration in wealth relative to income and provide additional insights into the sources of inequality in Poland.

Taken together, the results on spatial inequality and inequality aversion underline two key insights. Firstly, while the overall level of inequality in Poland was shaped by both income and wealth disparities, the decomposition of the Theil index revealed that regional differences played a non-negligible role with counterfactual simulations showing how policies can either narrow or widen these spatial gaps. Secondly, the application of the Atkinson index highlights how inequality was experienced differently depending on society's degree of aversion to it; income inequality appeared to be modest under low aversion but rose substantially when more weight was placed on the lower end of the distribution and the contrast was even starker for wealth. Additional concentration measures, such as HHI and RI, confirm the disproportionate role of wealth concentration in driving overall disparities. Together, these findings show that a multidimensional approach – that combines spatial decompositions with inequality-aversion measures – provides a richer and more policy-relevant picture than reliance on a single index alone. Importantly, this multidimensional framework also provided the foundation for the counterfactual policy simulations that follow where macroprudential tools could be evaluated not only in terms of aggregate stability but also in terms of their spatial and distributional consequences.

The next subsection builds directly on these insights. Having traced how inequality manifests across households and regions, we now turn to the question of indebtedness and the macroprudential ratios that shape it, linking distributional outcomes to the credit dynamics at the core of financial stability.

5.4.4 Indebtedness of Households and Macroprudential Ratios

The analysis of household indebtedness begins with the key prudential ratios that link borrowing to repayment capacity and collateral: the distributions of debt service to income (DSTI), debt to income

(DTI), loan-to-value for housing loans (LTV_H) and debt-to-assets (DTA). At the baseline ($t = 0$), these distributions provide a snapshot of the financial position of households, while the subsequent changes over time ($t > 0$).

In the initial cross-section, the proportion of households with a DSTI above the commonly used supervisory thresholds was relatively modest: around 6% exceeded 30% of income and only 3.5% exceeded 40%. Similarly, the share of households with high debt-to-income burdens was also limited: 3.6% had a DTI ratio greater than 3 and 1.7% exceeded 4.5. These figures indicate that, although a majority of households borrow within prudential limits, a non-negligible minority operated close to or above the levels that are associated with elevated credit risk.

The dataset also reveals the scale and structure of household borrowing. None of these individuals held more than five loans simultaneously and on average, each borrower carried 1.4 consumer loans. In addition, 43 008 housing loans remained to be repaid, thus highlighting the importance of mortgage debt as a defining component of household balance sheets.

These statistics illustrate the dual nature of household indebtedness in Poland; while broad aggregates appear sustainable, the tails of the distributions matter. A relatively small group of households with high DSTI or DTI ratios could amplify systemic vulnerabilities, especially under stress scenarios. By capturing the heterogeneity of indebtedness – how many loans households hold, how burdens are distributed across the population and how far some deviate from prudential benchmarks – the model provides a more realistic basis for evaluating the resilience of the financial system and the effectiveness of macroprudential policy.

5.5 Results of the Simulations

The agent-based simulation makes it possible to explore the dynamics of a heterogeneous economy under counterfactual scenarios and to examine the effects of public policy interventions with particular attention to the stabilising and distributional roles of macroprudential tools. Three scenarios frame the analysis.

The first follows the logic of H. Minsky's classic accounts of financial fragility in *Stabilizing an Unstable Economy* (1986) and in his *Financial Instability Hypothesis* (1992). The model reproduces the endogenous build-up of risk as borrowing expands, speculative behaviour takes hold and the system drifts towards instability. The second scenario introduces the macroprudential policies that are designed to mitigate such risks and to contain the self-reinforcing cycles that make the economy vulnerable to crisis. Finally, a third line of inquiry investigates which particular stance of macroprudential regulation best stabilises a heterogeneous economy, while also tracing the distributional consequences of these policies across households, firms and financial institutions.

Together, these scenarios allow us to compare a baseline of inherent instability with policy counterfactuals and to ask not only whether the economy can be stabilised but also at what cost and with which distributional side effects.

5.5.1 Minsky Moment

According to Minsky (1986), “capitalist economies exhibit inflations and debt deflations which seem to have the potential to spin out of control”. Economies, in his view, are unstable by nature – an instability that, in the most general terms, is rooted in the industrial structure and finance. In making this point, Minsky drew on Kindleberger's 1970s definition of self-sustaining disequilibrium. The capitalist economy, he argued, is only conditionally coherent. Rather than assuming a permanent state of equilibrium, attention should instead be directed towards periods of tranquillity and apparent stability which, paradoxically, are themselves destabilising. A discussion of this so-called Minsky moment and the results of simulations follows Kaszowska-Mojša and Pipień (2020).

The neoclassical synthesis tries to explain how a decentralised economy achieves *coherence* and *coordination* in production and distribution (in other words, how market mechanisms lead to a sustained, stable-price and full-employment equilibrium). Conversely, the Minsky theory focuses on the capital development of an economy and *the impact of the activity of financial institutions on production and distribution*. The optimum that is derived from the neoclassical decentralised market processes “rules out interpersonal comparisons of well-being and ignores the inequity of the initial distribution of resources and thus of income”. As Minsky stated, “inasmuch as our aim is to indicate how we can do better than we have and as the best is often the enemy of the good, we can forget about the optimum [in neoclassical terms]. Even though a tendency towards coherence exists because of the processes that determine production and consumption in market economics, the processes of a market economy can set off interactions that disrupt coherence” (Minsky, 1986).

Minsky’s theory can be interpreted in two ways. In Keynesian terms, it should be understood in terms of accumulation of capital in the economy. In Knightian terms, it should rather be interpreted as a problem of allocating resources under risk and uncertainty. We begin with interpretations of the instability hypothesis in Keynesian terms. Minsky’s theory refers to the general theory of Keynes from the 1930s. Nonetheless, in *Stabilising an unstable economy*, the process of capital accumulation described by Keynes is accompanied by an exchange of current money for the future. At the heart of this theory are not only capital stock and investment but primarily cash flows. Any attempt to model the instability hypothesis must therefore be stock-flow consistent. In reference to the Minsky theory, in the simulation, three types of stylised cash flows are developed: income, balance sheet and portfolio. The income cash flow refers to all payments in the production and sale of inputs and final goods, thus also the one in the supplier searching and purchase modules. The balance sheet cash flow refers to the repayment of debts. The third type of cash flow occurs due to transactions in which capital and financial assets are acquired by a new agent. Money in cash form is not analysed explicitly in the model but the general idea of money and settlements has been taken into account in the model. As Minsky noted, “money is created in the process of financing investment and positions in capital assets. An increase in the quantity of money first finances either an increase in the demand for investment output or an increase in the demand for items in the stock of capital or financial assets. As money is created, borrowers from banks enter upon commitments to repay money to the lending banks. In its origins in the banking process, money is part of a network of cash-flow commitments, a network that for the business side of the economy ultimately rests upon the gross profits, appropriately defined, that firms earn” (Minsky, 1986).

The current money is used to purchase inputs that are used in the production of investment and consumption goods. The purchase of inputs can be funded by the firm from the liquid assets and capital. Otherwise, external funding can be obtained. Financial institutions on the market generate profits from lending funds. “The financing terms affect the prices of capital assets, the effective demand for investment and the supply price of investment outputs” Minsky (1986). Firms, establishments and individuals are required to repay debt, that is, principal and interest rates within designated time frames. In Minsky’s basic theory, the focus was on investment. The government budget, the behaviour of consumption and the path of wages were secondary. To make the model more realistic and to ensure that it can be applied in modern policy making, all of the above-mentioned elements were included. Similarly, the flow of money described by Minsky included only loans to firms, while in the simulation, loans to individuals and households were also added. The flow of money in Minsky’s theory, similar to the simulation, has the following two directions. Individuals make deposits into banks and banks lend money to firms and individuals. In a later period, firms and individuals return funds to banks and banks to depositories.

In this theory the cash flows are influenced by the *expected* future profits; the flow of money from companies into banks occurs after the realisation of real profits. These expectations need not be always consistent with the final realisation of profits.

Funds can be obtained through negotiation in which risk perception and uncertainty as well as expectations play an important role. Firms that are willing to obtain money for conducting their

activity interpret financial results and the economic situation in an enthusiastic way and in fact, often create overly optimistic expectations. While bankers are inherently conservative and though they are profit-seeking, they are more restrictive in assessing potential gains from a deal. Despite being more restrictive, bankers are also aware that investment in innovation and new products, services and industries is the most profitable. Consequently, their propensity to finance projects from the most dynamic and profitable sectors is usually greater than the projects from other industries even if the riskiness of the project is higher than average.

Minsky's theory incorporates elements of Kalecki-Levy theory, according to which the structure of aggregate demand determines profits. The profit expectations depend on the expected level of investment in the future and actual returns on investment. Investments continue on the assumption of both entrepreneurs and bankers that investment will also take place in the future. In order to increase investment, the agents borrow additional funds, frequently assuming unrealistic returns in the future.

According to Minsky, there are three types of agents that are characterised by their relation between income and debt. "Hedge financing units are those which can fulfil all of their contractual payment obligations by their cash flows. (...) Speculative finance units need to roll over their liabilities, [that is,] issue new debt to meet commitments on maturing debt. (...) For Ponzi units, the cash flows from operations are not sufficient to fulfil either the repayment of principle or the interest due on outstanding debts by their cash flows from operations. Such units can sell assets or borrow. Borrowing to pay interest or selling assets to pay interest on common stock lowers the equity of a unit even as it increases liabilities and the prior commitment of future incomes. A unit that Ponzi finances lowers the margin of safety that it offers the holders of its debts" (Minsky, 1986). The higher the leverage ratio of firms, the higher the probability of defaulting on debt. Therefore, the decrease in the collateral that was required and the lower credit rating requirements in this scenario leads to an increase in the percentage of speculative and Ponzi agents. Changes in creditworthiness requirements also affect the percentage of hedging, speculative and Ponzi-type agents in an economy. The higher the level of speculators and Ponzi-type agents, the greater the probability of a crisis.

An investment boom increases aggregate demand and spending through a multiplier effect and sales increase. Profits increase with increasing investment, which encourages further investment. In this way, the instability of a system is strengthened until the percentage of speculative investors increases significantly. In the case of prolonged prosperity, assuming that no prudential policies have been applied, the economy becomes unstable due to the increasing number of speculative and Ponzi-type agents.

Minsky's instability hypothesis is a study about the extent to which debt affects the behaviour of a system and how the level of debt is considered to be adequate in terms of dynamics of the system. According to this theory, there is no need for external shock for a crisis to occur. A crisis is generated endogenously by agents taking on too much risk and by the desire of entrepreneurs and bankers to obtain ever-increasing profits. At the same time, this situation also has consequences for households. In the event of an increase in insolvencies, banks may default and thus depositors would lose the funds. In addition, the situation on the labour market determines changes in the income and wealth of households.

According to Minsky's theory, increase in investment "would never trickle down to the poor and would tend to increase inequality by favouring the workers with the highest skills working in industries with the greatest pricing power" (Minsky, 1986). This mechanism was modelled in the simulation. Firms hire individuals according to their work skills and in industries with the greatest pricing power. Consequently, this leads to inequality. The changes in inequality can be measured using the Gini coefficient as well as other measures of asymmetry and spatial inequalities.

The dynamics of the real estate market also changes. The increased percentage of job seekers influences their shift to cheaper properties and partly ineligible mortgage loan repayment, which again puts banks in a difficult position. Banks are in possession of properties for which there is no demand and their prices are gradually lowered in order to find a buyer.

Two main components of the theory are the two-price system and the lender's and borrower's risk, both of which are derived from the theories of Kalecki and Keynes.

The first price system concerns current output prices, that is, costs and mark-ups, which need to be set at a level that will generate profits for a firm from the sale of consumer goods, investment goods and goods and services that are purchased by the government in public contracts. If, in the analysis, the increase in the external fund is also taken into account, the supply price of capital plus the interest rate and lender's risk must also be considered.

The second pricing system refers to assets. Assets are expected to generate cash flow in the future. These flows are not known and their estimation depends on subjective expectations. How much is to be paid for such a financial asset depends on the amount of external finance that is required. The more a borrower becomes indebted, the greater the risk of insolvency; in this sense, the price of an asset includes the borrower's risk. Investments occur when the demand price exceeds the supply price of assets. Prices also include collateral. After a crisis, larger amounts of collateral are usually required, while in an expansion period, they are lowered significantly.

As Minsky (1986) states, "the costs of financing the production of investment is a cost that enters the supply price of output like the costs of labour and purchased inputs. The fact that a firm has to borrow to pay wages raises the effective costs by the interest payments on the borrowings". "The decision to invest therefore involves a supply function of investment, which depends upon labour costs and short-term interest rates; a demand function for investment, which is derived from the price of capital assets; and the anticipated structure and conditions of financing. Whereas the structure of balance sheets reflects the mix of internal funds (gross retained earnings) and external funds (bonds and equity issues) that are actually used, the investment decision is based upon expected flows of internal and external funds" (Minsky, 1986).

5.5.2 Simulating an Unstable Economy

In the first scenario, we simulated the role and impact of financial institutions on the production and distribution of income and wealth in an economy. As Minsky argued, under the neoclassical assumptions, the initial distribution of income and wealth is considered to be irrelevant: models of this kind assume that policies do not affect income and wealth distributions *ex post* and that incorporating heterogeneity *ex ante* has no bearing on aggregate outcomes.

The simulation presented here challenges this view. In line with Minsky's observation that the processes of a market economy can "set off interactions that disrupt coherence", our model shows that introducing heterogeneity *ex ante* fundamentally shapes outcomes *ex post*. By explicitly incorporating diverse households, firms and financial institutions, we were able to observe not only aggregate instability but also the evolving distributions of income and wealth. This highlighted how instability emerged endogenously from the interaction of heterogeneous agents and why ignoring distributional aspects – as in neoclassical models – misses key mechanisms of financial fragility.

In accordance with Minsky's hypothesis, the database and model design placed emphasis not only on heterogeneity in capital stock and investment choices but also on balance sheet changes and cash flows. These features make it possible to capture how fluctuations in profitability and financing constraints translate into broader dynamics of instability.

In the simulated scenario, firms operated across eight sectors through their establishments, which group industries according to NACE sections. At the outset, the first sector proved to be the most profitable and therefore attracted the highest share of new investors, while other sectors drew in smaller proportions of new entrants. As the iterations progressed, relative profitability fluctuated across sectors and reflected the rhythms of the business cycle. In the early rounds of the simulation, stock fluctuations were mainly driven by the intrinsic dynamics of the economy. In later iterations, however, the volatility intensified; stock fluctuations grew and an increasing proportion of establishments were forced to suspend production.

These processes were reflected in the changing number of establishments. At $t = 0$, there were 18 727 establishments in the database. After one period, 14 112 of those remained active, while 4 615 ceased operations. At the same time, the higher profitability in selected sectors attracted 9 887 new establishments, leaving a total of 24 000 active establishments at $t = 1$. At $t = 2$, 15 727 establishments from the previous period continued on the market, while 2 773 new ones were created for a total of 18 500. By $t = 3$, however, deteriorating market conditions reduced both survival and entry; 15 357 establishments continued but only 1 546 new ones were formed, which left a total of 16 903 fewer than at the baseline. At $t = 4$, the same 15 357 establishments remained active, but were supplemented by 1 491 new entrants, which yielded 16 848 in total.

Overall, the pattern revealed a cycle of entry and exit that was shaped by fluctuations in sectoral profitability. Some firms went bankrupt, while others shut down specific establishments that were operating in less profitable sectors. The dynamics highlight both the vulnerability and adaptability of the system; periods of apparent expansion give way to contraction, which is consistent with Minsky's view that instability is generated endogenously by the interaction of investment, profitability and financial conditions.

In the subsequent iterations, the sectors that had been most profitable in earlier periods began to accumulate higher levels of debt and leverage, which increased their financial vulnerability. As the simulation progressed, the number of bankruptcies rose with each period indicating more firm failures than the previous one. This pattern points to the gradual *endogenous* generation of crisis dynamics within the system.

Another sign of growing fragility was the disruption of supply chains. With an increasing number of establishments ceasing operations, firms more frequently encountered difficulties in finding suppliers, which led to interruptions in the network of transactions that underpinned production. Such breakdowns amplified financial distress turning local shocks into system-wide instability.

Although the data could be extended to cover more than four iterations (one year), the purpose here is to demonstrate that a crisis can emerge endogenously in a relatively short period of time. Indeed, the model reproduced a compressed version of what was observed during the global financial crisis when severe instability unfolded within just a few quarters (Q2 2008–Q2 2009). The problem of searching and matching suppliers in the supply chain module became increasingly important as the simulation unfolded. The time required to find a new supplier rose because the transaction relationships had to be established with firms that were located in more distant territorial units than before. These frictions highlighted how production networks transmit and amplify shocks; when one link in the chain breaks, firms are forced to adapt by searching further afield, which increases both cost and delay.

As market uncertainty grew and indicators of profitability and riskiness deteriorated, fewer firms were deemed eligible for credit. Establishments lost their creditworthiness, which restricted their ability to borrow and invest, which in turn forced reductions in production and aggravated the downturn in economic conditions. As financial stress intensified, firms increasingly transitioned from a position in which they could finance operations from current revenues to one in which they required external borrowing to sustain activity. At the outset of the simulation ($t = 1$), 62.5% of the establishments remained in the more favourable category, while 37.5% already depended on credit access to support their operations. The distribution shifted markedly in the following period ($t = 2$) with the less favourable group becoming the majority (51.39% vs 48.61%), before partially reversing as conditions stabilised (55% vs 45% at $t = 3$; 57.5% vs. 42.5% at $t = 4$). These dynamics captured the tightening of financing constraints and the growing fragility of firms under mounting macroeconomic stress. These changes illustrate how credit allocation tightened as instability builds with an increasing share of firms pushed into the less favourable category.

The financial condition of firms and establishments was thus closely tied to the difficulties being faced by particular industries and to fluctuations in the broader economy. Supply chain disruptions and declining creditworthiness interacted to create feedback loops that reinforced the endogenous crisis dynamics that were already being observed in the model.

As expectations of lower profits spread, the flow of funds between companies and banks weakened; firms reduced their repayments and demand for credit, while banks became more cautious in their lending. Banks recognised the higher risk that was associated with granting loans to companies that qualified for the liquidity-problem procedure, yet they also saw an opportunity to earn a premium. Overall, however, lending horizons shortened as uncertainty rose, which reflected an environment in which neither side of the credit relationship could commit with confidence.

Within this simulation cycle under the first scenario, the number of companies with higher debt and leverage gradually increased. The agent-based framework made it possible to track not only the rise in average indebtedness but also the changing distribution of debt and leverage across firms. As the crisis deepened, the burden of excessive leverage became unsustainable for a growing share of companies. Bankruptcies and closures multiplied, particularly among establishments that were operating in less profitable sectors, thus illustrating how fragility emerges from the interaction of balance sheets, expectations and market conditions.

The initial boom also encouraged households to increase consumption, which fuelled a rise in indebtedness. As borrowing increased, key vulnerability indicators – including the debt-service-to-income (DSTI), debt-to-income (DTI), debt-to-assets (DTA) and loan-to-value (LTV) ratios – adjusted accordingly. For the DSTI, the analysis tracks the shares of households that exceed 30% and 40% of their income devoted to debt servicing; for the DTI, thresholds of 3 and 4.5 are considered.

At the end of the first iteration, 4.7% of households exceeded a DSTI ratio of 30% and 2.7% surpassed 40%, while 3% had a DTI above 3 and 1.3% above 4.5. Conditions temporarily improved in the second iteration with these shares falling to 3.6% and 2.2% for DSTI, and to 2.1% and 0.9% for DTI. However, this easing was short-lived. By the third iteration, 4.6% of households again exceeded a DSTI of 30% and 3.2% exceeded 40%, while 1.9% and 0.9% crossed the DTI thresholds. After one year, household strain stabilised slightly above the initial levels with 5.04% above the 30% DSTI threshold and 3.5% above 40% and 2.2% and 1.1% above DTI values of 3 and 4.5, respectively.

Overall, the share of highly indebted households at $t > 0$ remained lower than at $t = 0$. Two mechanisms explain this pattern. First, households with the most excessive debt defaulted and were removed from the system. Second, those with high leverage refrained from applying for new loans and gradually repaid their existing loans. Yet this adjustment was temporary. As soon as their creditworthiness improved through repayment, they were drawn back into the market and the ratios began to deteriorate once more – a dynamic that is consistent with Minsky's description of cyclical financial behaviour.

These shifts also revealed the uneven impact of instability across households. While many reduced their exposure during the downturn, individuals with lower skills and educational attainment experienced a gradual worsening of their financial position on average. In this way, the simulation showed how aggregate cycles of debt and credit are refracted through heterogeneous households, which reinforces inequalities within the economy.

The distributional consequences became evident when the inequality measures were tracked over time. After one year, the Gini coefficient for income reached 39.9% and for wealth 60.8%. After two years, these values rose further to 41.1% and 61.3%, respectively, thus signalling a widening gap in both dimensions. The Lorenz asymmetry coefficient (LAC) equalled 0.96901 for income and 0.93896 for wealth after four quarters. The corresponding points on the Lorenz curve were $[\mu, f(\mu)] = (0.63; 0.33)$ for income and $(0.66; 0.26)$ for wealth, while the adjusted azimuthal asymmetry (AAA) measures were -0.07541 and -0.21341 , respectively. These statistics confirm that wealth inequality remained more skewed than income and that the overall trend was towards greater asymmetry.

Endogenous changes in the decisions of agents and their interactions also reshaped the broader dynamics of the economy. In particular, labour market stress and rising mortgage burdens spilled over into the real estate sector. As more households struggled to service their loans, properties were put up for sale, which pushed prices downward. On average, real estate prices decreased by around

2% within one year. Although further detail can be obtained by examining changes at the level of individual regions, such spatial results cannot be disclosed here for confidentiality reasons.

As economic conditions deteriorated, the number of insolvencies rose and the ratios of non-performing loans (NPLs) of banks increased. The growth of NPLs, in turn, constrained the supply of credit in subsequent iterations, which tightened financing conditions across the economy.

The model incorporated two alternative methods for determining credit supply. In the first, banks adopted broadly similar strategies in groups, which produced a relatively homogeneous lending behaviour. In the second, their strategies were more heterogeneous and reflected a wider spectrum of risk assessments and business models. In both cases, however, the same qualitative pattern emerged: rising NPLs eroded the willingness and ability of banks to lend, which fed back into the broader instability of the system. An additional advantage of the model is its ability to distinguish NPL dynamics by loan type, thereby capturing yet another dimension of heterogeneity. This allowed us to examine not only aggregate credit supply but also how stress was transmitted differently through consumer loans, mortgages and corporate lending. Moreover, the simulation made it possible to track the profitability of banks and their compliance with capital and liquidity requirements, which were initially set at levels that proved to be too low.

These dynamics mirror real-world episodes. During the global financial crisis and later in the Eurozone crisis, rising NPL ratios forced banks to retrench, reduce lending horizons and concentrate credit in safer segments, thereby amplifying the downturn. The simulation thus not only captured theoretical mechanisms but also reflected empirically observed patterns, which underlines its relevance for understanding systemic fragility.

The first scenario highlighted how instability can emerge endogenously from the interaction of heterogeneous agents, rising leverage and tightening credit, ultimately feeding into bankruptcies, NPLs and systemic distress. To complement this baseline of fragility, the second scenario introduced macroprudential policies into the same framework. This enabled us to explore how regulatory tools, if applied consistently, can alter the trajectory of the system, mitigate the build-up of risk and reduce the severity of a crisis.

5.5.2.1 Stabilising an Unstable Economy via Macroprudential Tools

In the second scenario, the behaviour of the economy was simulated under the assumption that macroprudential policies were implemented with the explicit goal of stabilising the unstable system. Banks uniformly complied with the capital requirements that were set by the regulator and applied binding recommendations on debt-to-income (DTI), debt service-to-income (DSTI), debt-to-assets (DTA), loan-to-value (LTV) and leverage (LR) ratios.

Economic activity continued to be organised across sectors, which were grouped by NACE industries. In this setting, the third sector proved to be the most attractive for new entrants, while the eighth sector remained relatively less profitable. Unlike in the first scenario, however, no sharp decreases in sectoral profitability were observed. The dramatic shifts in the role of particular sectors – such as the surge and subsequent contraction of the real estate sector that had been noted earlier – did not occur here. Instead, sectoral performance remained relatively balanced.

Most importantly, the introduction of macroprudential tools prevented the sudden discontinuities that characterised the first scenario. There was no wave of bankruptcies or collapse of production, nor did product prices display the kind of volatility that signals instability. The stabilising influence of the prudential ratios was visible both in the smoother evolution of sectoral dynamics and in the absence of disruptive feedback loops between banks, firms and households.

This finding resonates not only with theory but also with practice. In several Central and Eastern European countries after 2010, macroprudential authorities introduced caps on LTV and DSTI ratios together with tighter capital requirements, specifically to contain credit-driven real estate booms. The simulation reflects similar dynamics: by constraining excessive risk-taking, these tools help to slow down the Minskyan build-up of fragility. In this sense, the model confirms a central insight of Minsky

– that instability is an inherent feature of capitalist economies – but also shows that well-designed regulatory frameworks can temper the boom–bust cycle and sustain systemic coherence for longer periods.

Expectations in this second scenario evolved in a much more consistent and stable manner than in the first. They differed only slightly from those that had formed in the previous period and adapted to fluctuations in the economy smoothly. Stock movements remained in line with underlying economic dynamics without the excessive accumulation or abrupt halts in production and sales that had been observed earlier. Leverage levels remained moderate and only a small percentage of establishments were forced to cease production entirely.

Equally important, no major search-and-matching problems arose between establishments and suppliers. Supplier choice was guided by the quality-to-price ratio relative to sectoral benchmarks and in most cases, suitable partners were found within the same spatial unit. Where firms needed to search beyond their local unit, the additional costs of transportation remained moderate and corresponded to normal market conditions. This ensured that supply chain frictions did not amplify shocks, in contrast to the disruptions that had been seen under instability.

Firms also maintained adequate liquidity buffers and sufficient creditworthiness, which allowed them to channel additional funds into new investment rather than survival. Only a very small fraction of establishments were subject to creditworthiness checks that were linked to transitional liquidity problems and these difficulties stemmed mainly from temporary fluctuations in particular industries. Banks, for their part, applied broadly similar requirements to firms that were considered to be less risky, while adjusting criteria more carefully for businesses that faced liquidity or financial stress. The adoption of tighter, risk-sensitive lending standards proved to be effective in preventing the escalation of crisis dynamics.

Of particular importance is the emphasis that was placed on return on assets (ROA), return on equity (ROE), financial risk indicators and the credit histories of firms in guiding credit decisions. By anchoring lending in these prudential criteria, banks played an active role in maintaining stability and preventing the feedback loops that otherwise would have spread fragility across the system.

In a small number of cases, establishments were forced to readjust the quantity of inputs purchased, ultimately buying less than they had originally intended. Banks that were financing these purchases displayed differing degrees of risk aversion and adopted varied market strategies. In some instances, network effects were preserved; establishments returned to their matched bank to obtain credit, thus maintaining the existing transaction link in the financial network. In other cases, however, firms switched to alternative banks. When searching for short-term loans to finance inputs, companies were guided primarily by interest rates and the availability of credit.

The model allowed two distinct approaches to determining credit supply. In the first, banks adopted similar strategies in groups, which produced relatively homogeneous behaviour. Under this setting, network effects were largely maintained as individuals chose banks based on offered interest rates for consumer loans, while the granting of credit depended on available supply and sectoral exposure requirements. In some cases, banks exhausted their supply of consumer loans; when this occurred, they redirected funds towards other activities such as short- and long-term corporate lending or residential and commercial mortgages for households.

In the second approach, a higher degree of heterogeneity in bank strategies was observed. Over the course of the year, the same number of individuals applied for loans at their matched banks and a very high percentage of these applications were approved. Network effects remained intact in this case as well though the total number of consumer loans was limited by the interaction of the credit supply of banks and their sectoral exposure thresholds.

Together, these results underline how the structure of credit supply – whether more uniform or more heterogeneous – shapes the resilience of the financial network. Where banks act in groups, credit allocation is smoother but more prone to collective constraints; where heterogeneity dominates, risk assessments diverge but the system retains a degree of flexibility. Crucially, unlike in the first scenario, these dynamics prevent bottlenecks in credit provision and reduce the likelihood of crisis

escalation, thus illustrating the stabilising effect of macroprudential discipline. Similar patterns were observed in practice after 2010 when several EU member states introduced caps on consumer lending and stricter mortgage requirements; such measures curbed excess risk-taking and contributed to greater financial resilience across the region.

In both variants of the simulation, no significant search-and-matching problems arose between consumers and suppliers of goods. Supplier choice was guided by the relative quality-to-price ratio within each sector, which served as the key determinant of purchasing decisions. In most cases, households and establishments could find suitable suppliers within their own spatial unit with sufficient quantities of goods available. Only occasionally did searches extend beyond the local unit, thereby generating modest transportation costs. These additional costs, however, did not impose an excessive burden on households.

Demand from establishments and households was complemented by public procurement. Government contracts were typically awarded to the largest firms in the market, which were also able to produce high-quality products. This channel of demand provided an additional stabilising influence by supporting the production capacity of established companies.

Households facing “housing stress” encountered accommodation costs that became excessive, whether for mortgage repayments or rent. These households typically responded by moving to cheaper properties. Housing market dynamics, while present, remained moderate and consistent with household income fluctuations. Only a very small proportion of households fell into insolvency, which contributed to a marginal increase in the non-performing loans of banks. Property prices fluctuated over time but remained relatively stable within individual regions, thus avoiding the sharp swings characteristic of the first scenario.

The simulation also made it possible to distinguish between households that were purchasing new properties outright in cash and those that were relying on residential or commercial loans. Demographic processes were fully preserved within the model with the probabilities of survival or death calibrated to Central Statistical Office data. As a result, inheritance flows also shaped the financial system; surviving heirs typically received deposits or, in some cases, took over firms or properties. Where inheritances involved negligible assets, they were often rejected, while properties that were burdened with outstanding loans were repossessed by banks and resold at lower values. Among survivors, the dynamics of completed education were also preserved, which ensured that the model reflected both demographic and socio-economic transitions alongside financial interactions.

Not all companies that initiated the process of market entry succeeded in becoming operational. Some failed to obtain business licences, while others lacked the necessary funds to sustain activity. Credit applications represent a special case, since entrepreneurs compared interest rates across banks before deciding. On the banks’ side, loan approval also depended on whether supply-side restrictions were met and whether sectoral exposure limits were respected. These limits proved to be effective in curbing potentially excessive credit growth in the most profitable sectors, including real estate, which typically expands rapidly during periods of prosperity. Larger companies, by contrast, relied more on entrepreneurs’ own contributions for funding. During the expansionary phase of the cycle, average goodwill scores increased, while the structure of the market shifted as some activities closed and new ones opened, particularly in sectors with medium or high risk profiles.

Overall, the evolution of firm numbers and structures mirrored the usual dynamics of a functioning economy. There was no evidence of heightened capital concentration, clustering of business activity, excessive bankruptcies or large-scale layoffs in existing establishments. Analysis of the distributions that describe the attributes of firms and establishments likewise revealed no patterns that were typical of financial or economic crises or symptoms of overheating. Neither a surge in risk-taking nor disproportionate growth in specific industries emerged. On average, business risk across the market remained moderate.

This outcome was closely linked to regulatory limits on maximum exposure to individual sectors, which prevented risk from concentrating in a single area of activity. Banks, as a result, remained stable throughout the scenario. Under both procedures for determining credit supply, NPL ratios

stayed moderate. Liquidity requirements were met in most cases, while capital requirements were fulfilled at the regulatory threshold of 8%. No banks declared insolvency. Similarly, only a very small share of individuals experienced insolvency due to persistently negative net savings. Both the stock and flow of NPLs in the banking sector were modest, thus underlining the stabilising role of macroprudential rules.

Taken together, these results demonstrate how regulatory discipline can temper the endogenous sources of fragility that were highlighted in the first scenario, replacing crisis dynamics with more balanced growth and moderate risk.

The stabilising effects of macroprudential policies on the economy and the financial system are clear. Yet their impact on inequality is more ambiguous. The wealthiest agents remained mostly unaffected by the prudential rules, however, in some cases they strengthened their position – effectively, the rich got richer. After one year, the Gini coefficient for income stood at 39.7%, while the wealth Gini reached 60.6%. After two years, the figures rose modestly to 40.1% for income and 60.9% for wealth. The Lorenz Asymmetry Coefficient (LAC) was calculated at 0.97672 for income and 0.94782 for wealth. The corresponding Lorenz curve points were $[\mu, f(\mu)] = (0.62; 0.36)$ for income and $(0.67; 0.26)$ for wealth. Adjusted azimuthal asymmetry (AAA) was equal to -0.07541 in the case of income and -0.21341 in the case of wealth. These results remained broadly stable across the next four iterations, which suggests that the distributional profile of inequality did not change markedly over time when the prudential instruments were well-calibrated and their implementation had been coordinated.

The second scenario shows that macroprudential tools can substantially dampen instability and avert the self-reinforcing crises that can emerge in the absence of regulation. However, the resulting distributional profile is far from neutral. Even under this deliberately favourable and coordinated policy configuration – one designed to give the instruments their best chance of success – stability did not translate into broad-based gains. The economy avoided a destabilising spiral, yet wealth continued to concentrate at the top. Traditional inequality measures such as the Gini coefficient moved only modestly, but alternative indicators revealed a clear pattern: the rich continued to accumulate resources more rapidly than the rest of the population.

This outcome reflects the inherent scope of macroprudential policy: it ensures system-wide resilience, but it does not, on its own, reverse any accumulated structural disparities. Importantly, the simulation assumes an almost ideal alignment of policy levers, where prudential tools are not undermined by conflicting fiscal, monetary or social dynamics. In reality, such coordination is rarely achieved. When these instruments operate in isolation, or worse – against the backdrop of uncoordinated policies – the distributional effects can turn markedly regressive. Rather than the moderate divergence observed here, the burden of adjustment is likely to fall disproportionately on the most vulnerable households. Under real-world frictions and policy incoherence, the outcome is not merely that the rich get relatively richer; it is that the poorest risk becoming absolutely poorer as instability and tightening credit conditions amplify any pre-existing vulnerabilities.

5.5.3 *Optimality of Macroprudential Policy Stance*

Thus far, the possibility of stabilising an unstable economy using macroprudential policy has been analysed. Simulation has permitted an analysis of the degree to which macroprudential policies influence the distribution of variables including the distribution of income or the distribution of wealth, which permitted a fuller welfare analysis. However, the main question is which policy combination to choose from in order to utilise the possible combinations of tools to stabilise the economy and financial system as well as to ensure a more homogeneous distribution of wealth and income. Optimal choice is understood here to mean the method of choosing the most advantageous combination of macroprudential tools. In contrast to the social planner approach, the abstract concept of Bentham's social utility is not focused on; the focus is on the stability of the economic and financial system and the measures of welfare that quantify the changes in income and wealth distributions.

Based on the scenarios, it can be concluded that using a combination of macroprudential tools (appropriately calibrated) might lead to the stabilisation of the system. Nonetheless, this combination of policies was not optimal in the sense that the statistical equilibrium was achieved at a level which did not guarantee a sufficient decrease in inequality in a system. The optimal policies would be the ones which enable a decrease in inequality in the system (to an acceptable level). The results were shown to be robust using the Monte Carlo procedure. The exact results for the Polish system (including the optimal combination of macroprudential tools) are not reported here due to confidentiality of the data of individual banks and firms. The simulation can, however, be performed using data that is available from the National Bank of Poland, which would enable plausible results to be obtained. The results in the scenarios are mostly illustrative of the new methodology that was developed.

We analysed the stabilising effects of macroprudential policies in a heterogeneous economy using an agent-based framework as an alternative to the widely used DSGE-3D model of the European Systemic Risk Board and the ECB. While the DSGE-3D framework offers a disciplined apparatus for welfare evaluation, its reliance on representative or narrowly defined agents limits its ability to capture second-order spillovers and distributional consequences. The agent-based model presented here addresses this shortcoming by placing heterogeneity at the centre; households, firms and banks differ in their income, wealth, leverage, liquidity and behavioural rules and their interactions generate endogenous dynamics of leverage cycles, defaults and systemic feedbacks. This permits the model to function as a laboratory for counterfactual policy experiments, in which the Minskyan mechanisms of boom and bust can be observed alongside the stabilising role of prudential regulation.

The simulations confirmed that binding macroprudential tools can attenuate instability: defaults are less frequent, the balance sheets of banks remained stronger and real-side disruptions were more contained than in the unregulated scenario. Yet the results also showed that greater stability does not automatically translate into a more equitable distribution of welfare. Even when income and wealth distributions appeared to be smoother for much of the population, the richest groups often remained unaffected or even improved their relative position. Poor calibration or non-binding prudential measures can therefore blunt the stabilisation effects while exacerbating inequality – an outcome that is consistent with earlier findings by the ECB and other scholars on the distributional consequences of macroprudential regulation.

These insights carry important implications. Macroprudential policy cannot be viewed as a substitute for redistributive or social policy, nor can welfare be assessed solely through aggregate volatility or output measures. A heterogeneous-agent perspective highlights that stabilisation always entails distributional trade-offs and that the design of prudential tools – where they bind, how predictably they are applied and how they interact with other policy domains – determines whether they mitigate or entrench inequality. The agent-based approach thus complements, rather than replaces, DSGE modelling; where DSGE provides analytical clarity and disciplined welfare comparisons, the ABM tests the robustness of those prescriptions under realistic heterogeneity, adaptive behaviour and systemic feedbacks.

The broader conclusion echoes Minsky's insight that periods of apparent stability can conceal the accumulation of fragile positions. Macroprudential policy can reduce such fragility but only if it is designed with explicit awareness of its distributional consequences. A policy stance that is both stability-oriented and distribution-aware offers a way forward; it can secure resilience in the financial system while ensuring that the burdens and benefits of prudential intervention are more evenly shared across society.

Final remarks

This chapter examined macroprudential policy through a heterogeneous-agent lens and contrasted the discipline and tractability of the DSGE-3D framework with the flexibility of an agent-based model

capable of tracing distributional consequences in detail. Calibrated to a small open economy, the ABM served as a laboratory in which Minskyan boom–bust mechanisms, balance-sheet interactions and adaptive expectations generate macro-financial dynamics endogenously. In the benchmark scenario without prudential brakes, leverage cycles and optimism-driven credit expansions culminated in increased insolvencies, tightened credit and sectoral contagion. With a prudential stance in place, these feedback loops were visibly attenuated; defaults were rarer, bank balance sheets were stronger and real-side disruptions were less frequent.

Yet the central finding is that stability gains do not automatically translate into broad-based improvements in welfare. The distributions that were generated by the ABM revealed that the inequality metrics – Gini levels, Lorenz asymmetry (LAC) and its angular refinement (AAA) and spatial decompositions of the Theil index – shifted only modestly when prudential tools were activated and well calibrated. In some configurations, the upper tail remained largely insulated. This is consistent with representative-agent and two-agent DSGE results that document welfare reallocation across borrower–saver groups (e.g. Frost and van Stralen, 2018; Mendicino et al., 2018; Rubio and Unsal, 2017) but the ABM clarifies *where* along the distribution these reallocations occur and *through which* balance-sheet margins they propagate. In short, macroprudential policy can stabilise the system while leaving the social distribution of gains and losses uneven.

The contrast with the DSGE-3D benchmark is instructive. The 3D model's explicit treatment of default across households, firms and banks offers a coherent welfare apparatus within a social-planner environment but its reliance on representative or narrowly partitioned agents limits visibility on second-order, distributional spillovers. Heterogeneity in the ABM is not an add-on but the organising principle; agents differ in income, wealth, leverage, liquidity and behavioural rules and their networked interactions produce non-linear adjustments that are hard to reconcile with equilibrium-centric approaches. This difference is not merely philosophical. It explains why borrower-based measures that bind first on speculative investors compress dispersion and mitigate amplification, while identical parameters that bind first on constrained first-time buyers can unintentionally entrench gaps – an effect echoed in housing-market ABMs (Baptista et al., 2016; Tarne et al., 2022) and quasi-experimental evidence (Park and Kim, 2023).

A second implication concerns how we evaluate policy. A single scalar welfare criterion obscures the trade-offs that policy makers actually face. The ABM enables one to view policy choice as a movement along a frontier that jointly spans stabilisation and distributional objectives. Lower volatility, fewer defaults and safer banks are desirable but transparency about *who* bears adjustment costs is equally important. Reading changes in Gini, LAC/AAA and spatial Theil alongside traditional resilience indicators makes those trade-offs explicit and contestable. In this sense, the chapter advances a distribution-aware reading of macroprudential policy: effectiveness is not exhausted by dampening cycles; it must also be judged by how tools reshape the cross-section of opportunities and risks.

At the same time, the results argue for careful instrument design. Calibrating limits so that they bind on the margins that generate systemic externalities – rather than on households with high marginal utility of credit – improves both resilience and fairness. Prudential tightening that is predictable, state-contingent and symmetric across the cycle reduces the need for abrupt adjustments and limits the build-up of fragility. Where access risks arise, prudential measures can be paired with access-preserving interventions outside the prudential perimeter (targeted refinancing, income-contingent relief or well-governed guarantees) so that the pursuit of stability does not inadvertently shift the burden to the most vulnerable. None of this displaces the value of DSGE analysis; rather, the two approaches are complementary. The DSGE-3D model offers an anchor for disciplined welfare comparisons; the ABM tests the robustness of those prescriptions under realistic heterogeneity, adaptive behaviour and network effects.

These findings come with limitations. Behavioural rules, risk-perception dynamics and data confidentiality shape the quantitative magnitudes that are reported here, even if the Monte Carlo exercises point to qualitative robustness. Future work could incorporate richer expectation formation

beyond simple adaptivity, fully endogenise regional housing and rental markets and connect macroprudential instruments with fiscal transfers to study joint policy design. A structured comparison with HANK-type DSGE models under a common calibration would further clarify which distributional features are model-specific and which are policy-invariant (Kaplan et al., 2018; Auclert, 2020).

The overarching conclusion is aligned with Minsky's insight: periods of tranquillity can be destabilising when they disguise the accumulation of fragile positions. Macroprudential policy can and does reduce that fragility; however, if designed without a heterogeneous-agent perspective, it might leave distributional asymmetries largely intact. A macroprudential stance that is explicitly distribution-aware – attentive to the shape, not only the level, of inequality – offers a way to stabilise *systems* without overlooking *societies*. The ABM presented in this chapter provides a practical platform for such an approach and yields policy guidance that is both stabilising and sensitive to who gains, who loses and why, in Poland and, by extension, across European economies.

Notes

1. On the role of ABMs in central banking, see Borsos et al. (2025).
2. This part is based on Kaszowska-Mojša and Pipień (2020), previously published in *Entropy*.

Conclusions

The journey through this book has shown that systemic risk is not merely a technical matter for financial supervisors or a puzzle for theorists. It is, at its core, a phenomenon that shapes the way modern societies experience crises. When markets falter, what begins as a disruption in a single segment of the financial system can grow into a global disturbance, spreading across borders, institutions and households. The financial crisis of 2008–2009 made this painfully clear. What looked at first like a correction in the U.S. housing market soon became a breakdown of trust in the entire financial architecture. The collapse of Lehman Brothers was not only the end of a bank but the start of a cascade that revealed how deeply connected the fates of banks, states and ordinary citizens had become.

Europe's experience after 2009 highlighted another crucial dimension: that systemic risk expresses itself differently depending on institutional arrangements and domestic vulnerabilities. In the United States, the turmoil centred on the shadow banking system, securitisation markets and the fragility of financial giants. In Europe, the pressure points were more diverse and were rooted in the heterogeneity of Member States. Some countries faced weaknesses in their banking sectors, others struggled with overheated real estate markets and still others carried high levels of private or public debt. These vulnerabilities were endogenous, shaped by national choices, regulatory gaps and structural imbalances within the euro area. What connected them was the tendency for fragility in one sector to spill into others. The European experience was therefore not a simple echo of events in the United States but the result of multiple domestic risks converging within a shared financial and monetary framework. If the American crisis was born out of excess in private finance, Europe's turmoil demonstrated how systemic risk arises from within states themselves migrating between sectors and reinforcing existing fragilities.

Taken together, the comparison underscores that crises cannot be reduced to single causes or uniform patterns. Rather, systemic risk should be seen as a dynamic process that takes on different forms depending on the institutional and economic context. It is generated inside financial systems, it is transmitted within networks of contracts and expectations and it amplifies itself through feedback loops between markets, governments and households. It is not something "out there" waiting to strike but something created by the very structures of finance and the behaviours of its participants. And it is not only a matter of numbers on balance sheets. Crises of systemic origin always leave a social footprint: rising unemployment, widening inequality and an erosion of trust. The economic dislocations are inseparable from their social consequences and both feed back into the fragility of the system itself.

The crisis also forced us to reconsider the theoretical tools we rely upon. For decades, mainstream macroeconomic models treated the financial system as a neutral backdrop, a set of frictions that could be added or ignored without changing the picture too much. The events of 2007–2012 proved otherwise. Knight's distinction between measurable risk and unmeasurable uncertainty regained its urgency. Traditional models that assumed agents who perfectly anticipate probabilities found

themselves blind to the reality of panic, contagion and the sudden evaporation of trust. In this light, complexity-based approaches and agent-based modelling are not just methodological curiosities but essential attempts to capture how real-world economies behave. They enable us to see finance not as a smooth machine returning to equilibrium but as a living network of agents capable of cascading failures, herd behaviour and unexpected reorganisations.

Policy, too, has had to evolve. The wave of reforms that followed – Basel III, the creation of the European Systemic Risk Board, the development of macroprudential tools – marked an acknowledgment that stability cannot be secured by looking at banks one by one. The system as a whole matters. And yet, regulation has not solved the deeper dilemma: how to protect financial stability without worsening inequality or transferring risks onto the most vulnerable. As simulations in this book have shown, poorly calibrated rules can stabilise balance sheets while exacerbating social divides. Conversely, well-targeted measures have the potential to both reduce fragility and promote fairness. This is perhaps one of the clearest lessons of the last decade: systemic stability and social equity are not opposing goals but two sides of the same challenge.

Looking forward, it would be a mistake to think that the story of systemic risk ended with the last crisis. New forms of fragility are emerging. The pandemic reminded us how quickly a health shock can destabilise global production and finance. Climate change poses risks that are slower but potentially more devastating that could alter the value of assets and the solvency of states. The rapid spread of digital technologies and artificial intelligence has introduced unprecedented speed and opacity into financial decision-making, raising the possibility of new kinds of contagion. Add to this the geopolitical tensions that unsettle trade and capital flows and the picture is one of a world in which systemic risk has not diminished but has multiplied in new forms.

The task ahead, then, is not to search for a model that promises certainty but to embrace a richer understanding of uncertainty itself. We must acknowledge that financial systems are complex, adaptive and deeply intertwined with society. We must also recognise that crisis prevention is not only a matter of buffers and capital ratios but of building institutions and policies that command trust and distribute burdens fairly. This book has argued for methodological pluralism and for embedding distributional concerns at the heart of macroprudential design. In practice, this means developing tools that are sensitive to heterogeneity, that capture the dynamics of inequality and that permit the exploration of counterfactual scenarios – what might happen if regulation leans too far in one direction or fails to anticipate the next source of fragility.

What emerges, in the end, is not a message of despair but of responsibility. Systemic risk is not an immutable law of finance; it is shaped by choices – of policymakers, regulators, investors and societies at large. We cannot eliminate it but we can learn to live with it more wisely, to manage its amplification and to limit the damage it inflicts when crises strike. The crises of the past two decades remind us of the cost of complacency. The challenge of the coming decades is to combine resilience with fairness, to build financial systems that are not only more stable but also more just.

If the global financial crisis forced us to confront the fragility of interconnected markets, the years since have taught us that systemic risk will always return in new guises. The question is whether we will continue to be surprised by it or whether we will use the lessons of theory, history and modelling to anticipate its pathways. The task is never finished but the direction is clear: only by taking systemic risk seriously – in finance, in society and in policy – can we hope to turn crises from moments of collapse into opportunities for renewal.

A The Bewley's Theorems

Notation and theorems extracted from Bewley (1986), inverted commas omitted for the convenience of reading.

Let's assume the following notation:

S is a finite set of states of nature.

If $B \subset S$, R^B is the set of real-valued functions on B . R^B is the subspace of R^S . The function $\Pi^B : R^S \rightarrow R^B$ is the natural projection.

The symbol e_B denotes the indicator function of B . That is, $e_B(s) = 1$ if $s \in B$ and $e_B(s) = 0$ otherwise.

If $x \in R^S$, x_s is the reward or utility in state s .

If x and y belong to R^S , $x > y$ means $x_n \geq y_n$ for all n and $x \neq y$.

If π is a probability on S , if $B \subset S$ and $x \in R^S$, then $E_\pi[x|B]$ denotes the expectation of x with respect to π , conditional on B .

The preference ordering consists of an ordering $\succ_B$ on R^S for each non-empty subset B of S . The expression $x \succ_B y$ means x is preferred to y if B is known to be true. Bewley wrote $\succ$ for $\succ_S$. No relation of indifference is assumed. However, x and y are said to be *equivalent* if for all z and B , $x \succ_B z$ if and only if $y \succ_B z$ and $z \succ_B x$ if and only if $z \succ_B y$.

$\mathcal{A}$ is a field of subsets of S of objectively known probability, $q : \mathcal{A} \rightarrow [0, 1]$ is the objective probability.

Then, the Bewley's formulation assumptions are:

(1.1.) For all non-empty subsets, B , of S and all x and y in R^S , $x \succ_B y$ if and only if $\Pi^B x \succ \Pi^B y$.

(1.2.) $x > \mathbb{E}y$ implies $x \succ y$.

(1.3.) $x \succ y \succ z$ implies $x \succ z$ and for no x is $x \succ x$.

(1.4.) For all x , $\{y|y \succ x\}$ is open in R^S .

(1.5.) For all x , y and z and for all $\alpha \in (0, 1)$, $y \succ z$ if and only if $\alpha x + (1 - \alpha)y \succ \alpha x + (1 - \alpha)z$.

(1.6.) For all $A \in \mathcal{A}$, e_A is equivalent to the lottery $q(A)e_s$.

The first assumption expresses the relationship between conditional and unconditional preference ordering. The second assumption states that we prefer more utility to less. The third assumption specifies that we analyse the case of a strict preference ordering, that is, there is no indifference. The fourth assumption is technical; it states that, for all utilities x , the set of utilities y conditional on the preference ordering between y and x is open in R^S . This assumption refers to lotteries yielding x with probability α and y with probability $1 - \alpha$. The fifth assumption states that, for all known

probabilities, we gain 1 in state $s \in B$ with objective probability q and 0 otherwise. The known probabilities of events in A are treated as they should be.

The Bewley's theorems are:

Theorem 1.1.¹

If the $\succ_B$ satisfy assumptions 1.1–1.6, then there is a closed convex set Δ of probabilities of S such that:

- (i) for all x and y and B , $x \succ_B y$ if and only if $\mathbb{E}_\pi[x|B] > \mathbb{E}_\pi[y|B]$, for all $\pi \in \Delta$.
- (ii) for all $A \in \mathcal{A}$, $\pi(A) = q(A)$,
- (iii) for all $\pi \in \Delta$, $\pi(B) > 0$, for all non-empty subsets, B , of S .

Preferences for lotteries over consequences:²

Let X be a finite set of consequences.

Let Λ be the set of probability distribution in X .

Identify $x \in X$ with probability measure $\delta_x \in \Lambda$ which assign probability one to x .

For a non-empty subset B of S , let $\Lambda^B = \prod_{s \in B} \Lambda$ and let $\prod^B : \Lambda^S \rightarrow \Lambda^B$ be the natural projection.

Fix $x^* \in X$ and identify $\lambda \in \Lambda^B$ with the vector $\lambda' \in \Lambda^S$ defined by $\lambda'_s = \lambda_s$, if $s \in B$ and $\lambda'_s = \delta_{x^*}$, if $s \notin B$.

With this identification, λ^B is thought of as a subset of λ^S . λ^S is given the usual topology as a subset of a Euclidean space.

Preferences are expressed by orderings $\succ_B$ on Λ^S , where B varies over the non-empty subsets of S .

Completeness of ordering

An ordering $\succ_B$ is said to be complete if for each $\lambda \in \Lambda^S$, Λ^S equals the closure of $\{\lambda' | \lambda' \succ_B \lambda \text{ or } \lambda_B \succ \lambda'\}$.

Bewley's assumptions (cont.)

Let $\Lambda_{diag}^S = \{\lambda \in \Lambda_S | \lambda_s = \lambda'_s, \text{ for all } s \text{ and } s' \}$.

(1.7.) The restrictions of $\succ_{\{s\}}$ to Λ_{diag}^S is the same for all $s \in S$.

(1.8.) For all $s \in S$, $\succ_{\{s\}}$ is complete.

(1.9.) For any s , $\delta_x \succ_{\{s\}} \delta_{x'}$, for some x and x' in X .

(1.2.*) $\lambda \succ \lambda'$ if $\lambda \succsim \lambda'$, for all s and $\lambda \succ_{\{s\}} \lambda'$, for some s .

(1.4.*) For all λ , $\{\lambda' | \lambda' \succ \lambda\}$ and $\{\lambda' | \lambda' \prec \lambda\}$ are open in λ^S .

(1.6.*) For any $A \in \mathcal{A}$ and any λ and λ' in Λ , the vector $\lambda_1 \in \Lambda^S$ defined by $\lambda_{1s} = q(A)\lambda + (1 - q(A))\lambda'$, for all s , is equivalent to the vector λ_2 defined by $\lambda_{2s} = \lambda$, if $s \in A$ and $\lambda_{2s} = \lambda'$, if $s \notin A$.

Assumpt. (1.1.), (1.3.) and (1.5.) apply to the $\succ_B$ defined on Λ^S rather than R^S .

If $u : X \rightarrow R$ and $\lambda \in \Lambda^S$, $E_\lambda u \in R^S$ denotes the vector whose s^{th} component is $\sum_{x \in X} \lambda_s(x)u(x)$.

Theorem 1.2.

If the $\succ_B$ satisfy assumptions 1.1, 1.2a, 1.3, 1.4a, 1.5, 1.6a and 1.7–1.9, then there exists a function $u : X \rightarrow R$ and a closed convex set Δ of probabilities in S such that:

- (i) for all λ, λ' and B , $\lambda \succ_B \lambda'$ if and only if $\mathbb{E}_\pi[E_\lambda u|B] > \mathbb{E}_\pi[E_{\lambda'} u|B]$, for all $\pi \in \Delta$.
- (ii) for all $A \in \mathcal{A}$, $\pi(A) = q(A)$, for all $\pi \in \Delta$ and
- (iii) for all $\pi \in \Delta$, $\pi(B) > 0$, for all non-empty subsets B of S .

Both theorems 1 and 2 are presented here only to show that Knight's behaviour is consistent with the strong notions of rationality. From the perspective of Knight's theory, inertia assumption and structural assumption are the key elements.

Structural Assumption 1.10

For each non-empty subset B of S , there is a preference ordering $\succ_B$ on R^S such that $x \succ_B y$ if and only if $\prod^B x \succ_S \prod^B y$. The ordering $\succ_S$ is transitive and irreflexive and is monotone in the sense that $x \succ_S y$ whenever $x > y$.

Structural Assumption 1.11

There is a set Δ of probabilities on S such that if $x \succ_B y$, then $\mathbb{E}_\pi[x - y|B] > 0$, for all $\pi \in \Delta$. Also, $\pi(B) > 0$, for all $\pi \in \Delta$ and for all non-empty subsets B of S . The “fatness” of Δ is a measure of the Knightian uncertainty about events in S .

Notes

1. Proof in Bewley (1986, pp. 43–44).
2. We infer the existence of a von Neumann-Morgenstern utility function.

B A General-Equilibrium Framework for Macprudential Analysis

This appendix presents a compact general-equilibrium framework that clarifies how macroprudential policy can be formalised and mapped to implementable instruments. The structure is inspired by Farhi and Werning (2016) but we streamline the exposition, add interpretation at each step and emphasise how the objects of the model connect to systemic risk and uncertainty. Where helpful, we depart from their notation and highlight practical readings for policy.

B.1 Technology, Preferences and Constraints

TECHNOLOGY.

Output in state s is produced across goods $j \in J_s$ and must satisfy a convex feasibility set

$$F(\{Y_{j,s}\}) \leq 0, \quad F: \mathbb{R}^N \rightarrow \mathbb{R},$$

where $Y_{j,s}$ is production of good j in state s . Convexity captures diminishing returns and aggregation constraints.

AGENTS AND UTILITY.

Each agent $i \in I$ consumes $\{X_{j,s}^i\}$ and has state-contingent utility

$$\sum_{s \in \mathcal{S}} U^i(\{X_{j,s}^i\}; s),$$

with $U^i(\cdot; s)$ concave. Heterogeneity in i allows differences in marginal propensities to spend across goods and states – crucial for aggregate-demand externalities.

BUDGETS AND INCOMES.

Let Q_s be the price of one unit of state- s income today and $P_{j,s}$ the price of good j in state s . Agent i chooses state-contingent income D_s^i subject to

$$\sum_{s \in \mathcal{S}} D_s^i Q_s (1 - \tau_{D,s}^i) \leq -T^i,$$

and state-by-state goods budgets

$$\sum_{j \in J_s} P_{j,s} X_{j,s}^i \leq -\hat{T}_s^i + D_s^i, \quad \hat{T}_s^i \equiv T_s^i - x^i \sum_{j \in J_s} P_{j,s} Y_{j,s}.$$

Here, $\tau_{D,s}^i$ are financial taxes that implement macroprudential wedges (defined below), T^i is a lump-sum term determined ex ante and T_s^i is an ex post transfer. The term with x^i permits simple profit/ownership rebates.

QUANTITATIVE (PRUDENTIAL) CONSTRAINTS.

Non-price constraints capture borrowing limits, collateral rules, or portfolio bounds:

$$B_s^i(\{X_{j,s}^i\}) \leq 0, \quad \forall s, i,$$

with B_s^i convex. This accommodates LTV/DTI-type caps in a reduced form.

NOMINAL FRICTIONS AND POLICY CONSTRAINTS.

Price rigidities or monetary/exchange-rate constraints are represented by

$$\Gamma(\{P_{j,s}\}) \leq 0, \quad \Gamma: \mathbb{R}^N \rightarrow \mathbb{R}^M,$$

encompassing, for example, a zero lower bound or a fixed exchange-rate arrangement.

GOVERNMENT.

The public sector trades Arrow–Debreu income claims $\{D_s^g\}$ and balances

$$\begin{aligned} \sum_{s \in S} D_s^g Q_s + \sum_{i \in I} \sum_{s \in S} \tau_{D,s}^i D_s^i Q_s &= \sum_{i \in I} T^i, \\ \sum_{j \in J_s} P_{j,s} Y_{j,s} + \sum_{i \in I} \tilde{T}_s^i + D_s^g &= 0, \quad \forall s \in S, \end{aligned}$$

with $\tilde{T}_s^i$ denoting net state-contingent transfers inclusive of ownership rebates. These conditions ensure fiscal feasibility given the chosen instruments.

B.2 Equilibrium

An equilibrium is a collection $\{X_{j,s}^i, Y_{j,s}, D_s^i, D_s^g, Q_s, P_{j,s}, \tau_{D,s}^i, T^i, T_s^i\}$ such that: (i) agents maximise utility subject to their constraints; (ii) prices obey $\Gamma(\{P_{j,s}\}) \leq 0$; (iii) government constraints hold; and (iv) markets clear:

$$Y_{j,s} = \sum_{i \in I} X_{j,s}^i \quad \forall s, j \quad \Rightarrow \quad D_s^g + \sum_{i \in I} D_s^i = 0 \quad \forall s.$$

B.3 Wedges and their Interpretation

Define marginal products $F_{j,s} \equiv \partial F / \partial Y_{j,s}$ and pick a reference good $j^*(s)$ in state s . For any feasible allocation, the (good-specific) wedge is

$$1 - \tau_{j,s} = \frac{P_{j^*(s),s}}{P_{j,s}} \cdot \frac{F_{j,s}}{F_{j^*(s),s}}.$$

A positive $\tau_{j,s}$ signals *insufficient* demand for good j (relative to the reference), a negative value signals *excess* demand. In macroprudential terms, wedges summarise the misalignment between private and socially efficient allocations that policy should target—akin to a state-contingent, multi-good “output gap”.

B.4 Planner's Problem and Targeting Conditions

Let λ^i denote Pareto weights and $V_s^i(I_s^i, \{P_{j,s}\})$ the indirect utility in state s . The Ramsey problem chooses an implementable equilibrium to maximise

$$\max_{\{I_s^i, P_{j,s}\}} \sum_{i \in I} \sum_{s \in S} \lambda^i V_s^i(I_s^i, \{P_{j,s}\})$$

subject to feasibility $F(\{\sum_i X_{j,s}^i\}) \leq 0$ and policy constraints $\Gamma(\{P_{j,s}\}) \leq 0$.

CORE FOCs (SCHEMATIC).

Two conditions are central:

(i) *Social equalisation of marginal utilities of income:*

$$\frac{\lambda^i V_{I,s}^i}{1 - \sum_{j \in J_s} P_{j,s} X_{I,j,s}^i \tau_{j,s}} = \frac{\mu F_{j^*(s),s}}{P_{j^*(s),s}}, \quad \forall i, s.$$

Intuition: optimal ex post income I_s^i equalises *social* marginal utilities across agents within each state once wedges are accounted for. This highlights the distributional channel behind aggregate-demand externalities.

(ii) *A generalised targeting rule for prices:*

$$\frac{\mu F_{j^*(s),s}}{P_{j^*(s),s}} \sum_i \sum_{j \in J_s} P_{j,s} \tau_{j,s} S_{k,j,s}^i = \nu \Gamma_{P_{k,s}}, \quad \forall s, k \in J_s,$$

where $S_{k,j,s}^i$ are (Hicksian) substitution terms. This nests New-Keynesian “gap-closing” rules and shows how nominal rigidities pin down admissible wedges.

B.5 Implementing Optimal Macprudential Policy

The planner's allocation can be decentralised with *state-contingent financial taxes*

$$\tau_{D,s}^i = \sum_{j \in J_s} P_{j,s} X_{I,j,s}^i \tau_{j,s},$$

i.e. a (state-specific) Pigouvian schedule that tilts private portfolios so that *ex post* wealth is higher in states where agents with larger marginal propensities to spend on high-wedge goods are most effective at stabilising demand. This is a macroprudential reading of “taxes on risk” that is calibrated to demand externalities, not to technological or preference externalities.

With a complete set of traded securities, a tax on any asset a (replicable by Arrow–Debreu payoffs $\{Z_{a,s}\}$) is a weighted average of the underlying state taxes:

$$\tau_a^i = \sum_{s \in S} \frac{\frac{F_{j^*(s),s}}{P_{j^*(s),s}} Z_{a,s}}{\sum_{s' \in S} \frac{F_{j^*(s'),s'}}{P_{j^*(s'),s'}} Z_{a,s'}} \tau_{D,s}^i.$$

In practice, this mapping helps interpret instrument choices (e.g. FX-debt-specific measures vs broad capital requirements) as targeting different “state components” of risk.

B.6 Time Consistency and Sequential Policy

To discuss credibility, one can model policy as a two-stage game: *ex ante* the government sets $\{\tau_{D,s}^i\}, \{T^i\}, \{Q_s\}, \{D_s^g\}$; *ex post*, after the state s is realised, it sets $\{P_{j,s}\}, \{T_s^i\}$. Under anonymous symmetric equilibria, the *ex post* problem equalises *social* (not private) marginal utilities of income across agents, subject to the weighted-average wedge conditions above. This makes clear why *ex ante* macroprudential tools are desirable; they shape portfolios so that *ex post* redistribution needed for stabilisation is smaller and time-consistency problems are attenuated.

B.7 Pecuniary Externalities and Borrowing Constraints

To incorporate pecuniary externalities, allow borrowing limits and effective income to depend on prices. Let A index assets with security a delivering $Z_{a,s}(\{P_{j,s}\})$ units in state s . Agent i faces

$$\sum_{a \in A} D_a^i Q_a (1 - \tau_a^i) \leq -T^i, \quad \sum_{j \in J_s} P_{j,s} X_{j,s}^i \leq -\hat{T}_s^i + \sum_{a \in A} D_a^i Z_{a,s}(\{P_{j,s}\}),$$

$$\Phi^i(\{D_a^i\}; \{P_{j,s}\}) \leq 0, \quad B_s^i(\{X_{j,s}^i\}, \{P_{j,s}\}) \leq 0,$$

where Φ^i captures price-dependent borrowing constraints (e.g. collateral tied to asset prices). To avoid trivial replication of complete markets via lump-sum instruments, restrict transfers by a convex set $\Omega(\{\hat{T}_s^i\}) \leq 0$. The planner's FOCs then pick up additional terms reflecting (i) policy/nominal rigidities, (ii) incomplete markets and (iii) prices-in-constraints effects. In short, wedges are generically non-zero whenever nominal rigidities bind, markets are incomplete, or balance-sheet constraints are price-sensitive – precisely the environments in which macroprudential tools are warranted.

B.8 From Wedges to Instruments

In applications with two agent types (borrowers vs savers, or domestic vs foreign), the model maps naturally to: (i) LTV/DTI caps (quantity restrictions affecting Φ^i or B_s^i), (ii) capital-based tools (taxes/requirements that shift τ_a^i on particular liabilities or asset classes) and (iii) capital-flow management (tilting the state profile of external claims $Z_{a,s}$, especially for FX debt). The key practical message is that greater heterogeneity across agents and instruments implies a higher “dimensionality” of the optimal policy (cf. targeting rules in multi-good NK models). This explains, in theory, why real-world macroprudential stances are *combinations* of tools rather than single instruments.

B.9 Generic Need for Macprudential Intervention

A constrained-efficient allocation can be decentralised *without* financial taxes only under knife-edge conditions that equalise the ratios of (wedge-adjusted) marginal utilities of income across all agents and states. Because such equalisation is fragile to heterogeneity, nominal rigidities and market incompleteness, macroprudential intervention is generically required to restore efficiency – either via Pigouvian pricing or via quantity constraints with equivalent implementation.

B.10 Systemic Risk and Uncertainty

This framework shows how macroprudential policy reduces *systemic risk* (by leaning against leverage, currency and maturity mismatches that amplify shocks) and *uncertainty* (by making the distribution

of outcomes across states less sensitive to self-reinforcing feedbacks). The wedges provide a clean diagnostic: where they are large and positive, demand is too weak relative to production possibilities; where they are large and negative, demand is excessive. Policy then targets the portfolio choices and constraints that move these wedges towards zero state by state.

Our presentation (i) keeps the same economic primitives but simplifies the mapping from wedges to instruments, (ii) foregrounds the policy interpretation at each step (especially the translation to LTV/DTI, FX-debt and capital-based tools) and (iii) integrates pecuniary and aggregate-demand externalities within a single, practitioner-oriented narrative. The objective is expository: to provide a bridge between formal targeting conditions and the multi-instrument macroprudential stances discussed in the main text.

C The Data-Driven Agent-Based Model

C.1 Initialisation of a Data-Driven Agent-Based Model

The model distinguishes six classes of agents. These are individuals and households, firms and establishments, banks, sectors (defined as groups of industries) and properties. All of the agents were initiated based on specific empirical data from the databases listed below, see Table C.1. The data sources are primarily from the European Central Bank (ECB), the Statistics Poland (GUS) and the Bank of Poland (NBP).

In addition to these classes of agents, four auxiliary objects were created: *Consumers*, *Suppliers*, *Property Owners* and *Firm Owners*. From an economic point of view, a household is a consumer of final goods in the model and each establishment is a supplier of goods (inputs) for other establishments in the model. However, in order to improve computation and data storage, additional classes of agents were introduced into the model. Household-consumers, denoted as H , purchased goods from S industries across T periods. The corresponding consumer table (CM) in the database therefore contained $H \times S \times 6 \times T$ elements, with six columns representing distinct attributes. Establishments acted as suppliers to one another and the supplier table (ES) held $E \times S \times 5 \times T$ elements with five columns corresponding to their attributes. Two further auxiliary objects supported ownership mappings: *Property Owners*, which linked owners to properties and was represented as a $P \times 2$ table and *Firm Owners*, which mapped owners to firms in a $F \times 2$ structure.

C.1.1 Household Finance and Consumer Survey Data – Data Mapping

The HFCS collects household-level data on the finances and consumption of households. The first wave was conducted in most countries in 2010 and 2011, the second between 2013 and the first half of 2015 and the third in 2017–2018. The fourth wave was conducted in 2020–2021 and anonymised microdata have been available to researchers since mid-2023 ECB (2023c). A detailed description of the HFCS data collection methodology for the respective waves is available in ECB (2023b,a). Details about the Polish edition are provided in NBP (2015b, 2017).

The data provided by the European Central Bank for all of the waves was divided into three samples: P , H and D . Sample P contained the data on individual entities, while sample H contained the data on households and D contained the information that was derived from the raw data, i.e. statistics and aggregates.

Taking into account the characteristics of the HFCS database, the model distinguished *Individuals* and *Households*, which were initiated based on the data from samples P , H and D , respectively. It is worth emphasising that although the distinction between individuals and households resulted primarily from the availability of HFCS data such a distinction between agents is also beneficial when modelling economic activity. First, the data from the HFCS P table enabled individual entity

Table C.1 Initialisation of agents in Minsky-type financial instability scenarios.

Class of agents		Source of data	# of Agents
Individuals	<i>I</i>	HFCS	971 520
Households	<i>H</i>	HFCS	442 240
Consumers*	<i>CM</i>	HFCS	47 761 920*
Properties	<i>P</i>	HFCS	427 392
Property_owners*	<i>PO</i>	HFCS	854 784
Industries	<i>S</i>	HFCS	
Firms	<i>F</i>	GUS (F-01)	18 727
Firms_owners*	<i>FO</i>	GUS (F-01)	37 454
Establishments	<i>E</i>	GUS (F-01)	18 727
Suppliers*	<i>ES</i>	GUS (F-01)	1 685 430*
Groups of banks	<i>B</i>	HFCS & NBP & GUS	14

*Auxiliary objects. In the case of auxiliary objects, information about the number of data elements that were processed at $t = 0$ are provided. Household Finance and Consumer Survey (HFCS); Statistics Poland(GUS). Specific form F-01 on balance sheets of firms.

attributes to be included in the model and a heterogeneous population of agents to be built. Because of the mapping of the data from the *P* and *H* databases, individuals could create heterogeneous households (who were also the final consumers). Household composition and consumption patterns could change over time as a result of many economic and demographic factors in the simulation. Individuals were heterogeneous within the model, they differed in terms of:

1. individual characteristics (such as gender, age or marital status)
2. the variables that characterised their status on the labour market (activity status) and workplace such as education level, experience on the labour market, number of periods since the last change of status on the labour market, professional qualifications
3. the variables that characterised their potential to become an entrepreneur and/or their experience of being an entrepreneur
4. welfare (including income, wage, social benefits, liquid and real estate assets and shares)
5. creditworthiness (including indebtedness and the probability of default).

Based on the HFCS, the value of consumer and mortgage loans as well as the instalments and interest on these loans were also determined. The information from the HFSC was supplemented by mapping the investment loans that were based on the Bank of Poland data. Data on the spatial location were only available in the 2014 data that was obtained from the National Bank of Poland. However, they were not available in the ECB data that was obtained for Wave 3 (2017). In that case, the spatial codes were drawn from the empirical distribution (the data was provided by Statistics Poland).

Households were also heterogeneous in the model. They were characterised by different:

- 1 ownership of properties
- 2 average cost of living
- 3 income and savings
- 4 property rental income
- 5 donations and alimony
- 6 values of macroprudential ratios (debt service to income (DSTI), debt to assets (DTA), debt to income (DTI) and loan to value ratios (LTV)).

The HFCS database also permitted *Properties* to be initialised. Based on the HFCS, the properties were mapped with their owners, the number of households living in them and/or renting properties.

Based on the HFCS, information about the price of a property was also obtained and the number of properties that were for sale were approximated (in order to introduce the housing market dynamics into the model). The properties were spatially located using the NUTS 1, NUTS 2 and NUTS 3 codes. This information was available on the Wave 2014. Later, the codes were drawn from the empirical distribution (in that case, the data was provided by Statistics Poland).

C.1.2 Reports on Revenues, Costs and Financial Results as well as the Expenditures on Fixed Assets – Data Mapping

In order to create the synthetic population of firms and establishments, the data from the “Reports on revenues, costs and financial results as well as the expenditures on fixed assets” (Statistics Poland (F01)) were used.

C.2 Individuals and Households Within the Model

The model distinguished between Individuals I ($i = 1, 2, \dots, I$) and Households H ($h = 1, 2, \dots, H$). A household could be composed of only one individual or it could be co-created by other individuals (adults and/or children). The empirical data from the HFCS determined the composition of the households within the model. Each individual agent and household was characterised by a series of attributes that are described in Tables in [Appendix D](#).

C.2.1 Marginal Distributions of Individual Characteristics

The model was initiated based on the empirical data. The distributions of the ages of the Polish population as well as the distributions of attributes such as gender, education levels and civil statuses were replicated. The representativeness of the sample and the robustness were determined using the Statistics Poland’s data (mainly the census data and labour force surveys).

C.2.2 Population Dynamics

To parameterise the population-dynamics module, we used official demographic data published by Statistics Poland (GUS), including annual series on births, deaths, marriages, divorces and migration flows. These empirical time series served as the basis for approximating model parameters governing demographic transitions within the agent-based framework. In particular, age-specific fertility and mortality rates were derived from the GUS cohort statistics, whilst marriage and divorce intensities were calibrated using the observed frequencies relative to the relevant population sub-groups. Where necessary, annual aggregates were translated into probabilistic event rates compatible with the model’s simulation frequency. This approach ensures that agents’ demographic behaviour — such as household formation, dissolution and generational turnover — reflects realistic population dynamics that are consistent with recent macro-level demographic trends in Poland. For instance, individuals could die or survive into the next period (the probability of survival was dependent on their age and gender). The probabilities were estimated by Statistics Poland. Potential deaths affected the inter-generational transfer of wealth and this can affect bank financial position, including non-performing loans. In turn, an individual’s survival not only affected their attributes such as age or consumer type but also initiated processes in the labour market as well as in the goods and housing markets.

C.2.2.1 Age, Gender and Consumer Type

The age of an agent increased at each time step in the model. There were six consumer types in the model:

- (1) Single over 67
- (2) Single under 67
- (3) Couple, at least one over 67
- (4) Couple, both under 67
- (5) Household with children
- (6) Household composed of more than two adults

There were several instances in which the consumer type was updated. The consumer type was modified if one of the members of household died and the composition of the household changed substantially (in particular, we were interested in identifying whether a change in the household composition would affect the consumption patterns, creditworthiness and behaviour in the labour and real estate markets) in the model.

The consumer type changed with the aging of individual agents. If an individual reached the age of 67, then the consumer type of the household that the individual belonged to was updated. Moreover, when an individual became an adult, then a new household was created and the consumer type was updated.

Finally, the consumer type could change when individuals got married or divorced or when children were born or adopted. If a woman had children from a previous marriage and got remarried, then the consumer type did not change. Otherwise, the ages of the individuals were checked. If at least one member of a household was over 67, the consumer type was updated. The same applied to households after getting a divorce. The ages of individuals were checked and when they were over or under 67, the corresponding consumer type was assigned. For simplicity, if a woman had children and got divorced, the consumer type did not change.

C.2.2.2 Education Levels

Each individual was characterised by the education level that had been determined using the HFCS data. If an individual continued to study and exceeded the number of periods that were needed to complete a particular level of education, then their education level was updated. Individuals could also continue studying. The likelihood of a given person continuing their studies depended on their age, gender and the education level that they had already completed. The probabilities were estimated by Statistics Poland (census data).

C.2.2.3 Marriages, Births and Divorces

The civil status of each individual was determined using the HFCS data. Every single adult could get married in the model. The probability of getting married depended on their civil status, age and gender. The probabilities were estimated by Statistics Poland (census data). It was assumed that the age difference between partners should not exceed ten years. A partner was only sought in a subsample of adults of the opposite sex who were not married. In the case of marriage, the marital status of the individuals as well as the codes that identified the households were updated. Marriages also affected the dynamics of the housing market and the banking sector (i.e. they affected the creditworthiness and loan repayment).

Children were born with a probability that was dependent on the age and civil status of the mother. The probabilities were estimated by the Statistics Poland (on census data). When an individual was born, new records for all of the individuals and household-consumers were created. The probability of divorce was also dependent on the ages of the spouses and the estimates were provided by Statistics Poland. After a divorce, a new household was created for the ex-husband and the consumer types were adjusted. In the case of a divorce, the assumption was made that children always stayed with the mother. The ex-husband would pay the alimony which was dependent on his earnings and the number of children. A divorce also affected the housing market and the banking sector as was the case with marriages. The consumer type of the household was adjusted as well. The ownership of any properties was also changed after a divorce.

C.2.3 Labour Market Dynamics

Each of the individuals had an activity status and economic activity from which they received an income or social benefits. However, there were also agents who were not earning any income such as students who were still described by a specific status on the labour market. At $t = 0$, the statuses on the labour market of all of the individuals were assigned in accordance with the HFCS data (and rechecked with Statistics Poland's data).

An individual agent was not, however, a consumer in the model. A consumer in the model was a household with the shared income of family members. As was explained earlier, this was the direct consequence of using the HFCS data when initialising the model.

The activity status of individuals was characterised into active (I^{act}) and inactive persons (I^{inact}).¹ Within the group of active persons, workers ($I^W(t)$) and owners of companies were distinguished ($I^I(t)$). The set of workers consisted of employed persons ($I^E(t)$) and unemployed persons ($I^U(t)$) who were actively looking for a job. The number of owners of firms equalled the number of firms at the initialisation (at $t = 0$). However, it was not constant over time as was the case in Poledna et al. (2023) and Hommes et al. (2022) (for $t > 0$) as the individuals could change their activity status and new firms and establishments could be created.² There were also mergers and acquisitions within the model, which could lead to job cuts. The set of inactive persons consisted of $I^S(t)$ children under 16 and students as well as $I^{InA}(t)$ inactive adults.

All of the sets $I^E(t)$, $I^U(t)$, $I^I(t)$, $I^S(t)$ and $I^{InA}(t)$ were endogenous because it was assumed that the agents could switch between states with certain probabilities (obtained from Statistics Poland's data).

A firm could operate multiple establishments. Each worker was linked to a single establishment and therefore to the firm that owned it.

The i -th worker ($i = 1, 2, \dots, I^W$) supplied labour to a firm and its establishment(s). If worker i was employed by firm f ($f = 1, 2, \dots, F$) and establishment e ($e = 1, 2, \dots, E$) operating in sector s ($s = 1, 2, \dots, S$), they received an individual wage $w_i(t)$.

An establishment could employ multiple workers. The total wage bill of establishment e was given by:

$$W_e(t) = \sum_{i=1}^{K_e} w_i(t), \quad (C.1)$$

where K_e denotes the number of employees in establishment e . The total wage bill of firm f was the sum of wage bills across all of its establishments:

$$W_f(t) = \sum_{e=1}^{E_f} W_e(t). \quad (C.2)$$

The number of firms, their sectoral distribution and their establishment structure were taken directly from empirical data at $t = 0$. For $t > 0$, the number and structure of firms evolved endogenously during the simulation. Wages were therefore determined at the individual level, while labour costs aggregated bottom-up from workers to establishments and firms, consistent with firm-level heterogeneity that was observed in the microdata.

In addition to wage formation, labour-market dynamics were driven by changes in individuals' activity statuses. The activity statuses were updated several times in the course of the simulation. Individuals could change their status with a certain probability. In addition, the activity statuses were also modified when:

- individuals were hired or fired when the company grew or became smaller
- an individual started a new company
- a firm and the corresponding establishments went bankrupt or ceased to operate in the market or sector

- an individual ceased to be the owner of the company, e.g., due to a merger or acquisition
- an individual decided to run a business that they inherited (with a probability of accepting or rejecting the inheritance)
- an individual ceased to be a student and became unemployed for the first time.

This design ensured that labour market participation and firm ownership dynamics emerged endogenously from both micro-level decisions and macro-economic conditions.

It is also worth emphasising that in our model each of the newly hired employees could obtain a different salary, which was the result of not only the baseline³ also assumed that there are not hiring or firing costs for firms and that dismissed employees started to search for new jobs in the same period that they became unemployed. Both assumptions were changed in the MACROPRU. There are firing and hiring costs and not all of people start looking for a job immediately. searching-matching process but was also a direct consequence of an agent's attributes and the situation on the labour market and the conditions of the economy. The company, of course, also tried to minimise the amount of the remuneration that it paid to employees but the cost criterion was not the only one taken into account (the company also optimised a worker's skills, evaluated their completed education and experience).

If an individual was employed, they did not receive social benefits and their earnings were determined by a wage function dependent on age ($A_i(t)$), gender ($G_i(t)$), the average wage in their sector and an idiosyncratic stochastic component (ε_i).⁴ Therefore, the wage of an individual is given by:

$$w_i(t) = \begin{cases} \frac{\bar{w}_s(t)}{\bar{N}_s^e(t)} (\gamma_1 + \gamma_2 G_i(t)) (\gamma_3 + \gamma_4 A_i(t)) (\gamma_5 \varepsilon_i), & \text{if } i \text{ is an employee,} \\ \gamma_6 (1 - \tau^\Pi) \Pi_f(t-1) \varepsilon_i, & \text{if } i \text{ is a firm owner.} \end{cases} \quad (\text{C.3})$$

where $\bar{w}_s(t)$ is the average wage paid in sector s , $\bar{N}_s^e(t)$ is the average employment per establishment in sector s and $w_i(0)$ is initialised from HFCS microdata (and mapped to sectoral information using the F-01 database). This scaling captured the productivity and size structure of establishments within the sector. The term $\Pi_f(t-1)$ denoted the previous-period profit of firm f , τ^Π was the tax rate on profits and ε_i was an idiosyncratic random shock that captured any unobserved heterogeneity among the individuals.

In practice, the parameters of the wage equation and the transition probabilities between labour market states can be empirically estimated. The wage parameters are calibrated using micro-level labour market data by regressing individual wages on observable worker characteristics (age, gender, sector) and including firm or sector fixed effects. The residual distribution is then used to capture any unobserved heterogeneity. Transition probabilities between employment states are obtained from labour force survey data by constructing empirical transition matrices or estimating multinomial logit/hazard models. Finally, parameters are calibrated to ensure that the model matches key empirical moments such as the distribution of wages, job-finding and separation rates and the sectoral structure of employment.

In the MACROPRU approach, it was not assumed that each firm was owned by one investor, which was the case in Kaszowska-Mojša and Pipień (2020) and Poledna et al. (2023). The mapping of individual entities and companies resulted from the empirical distribution that was obtained from the F-01 database. Then, the number of companies, their owners and shareholders were dynamically updated. Each investor (owner or shareholder) received income in the form of dividends in the event that a firm earned a profit after tax payments, $(1 - \tau^\Pi) \times \Pi_f(t-1)$. Relaxing limited liability and allowing multi-owner structures introduced more realistic wealth dynamics and bankruptcy spillovers. In the case of bankruptcy, the associated losses were partially borne by the investor-inheritor or the buyer and not only by the creditor. The earnings of the owner of a company were only included if the profits were greater than zero and dividends were paid.

Our objective was to extend the modelling framework presented in Poledna et al. (2023) and Hommes et al. (2022). We introduced several modifications in order to better capture empirical labour-market and firm-sector dynamics.

The activity status was updated when the market situation changed and when the characteristics of individual agents changed. In our searching-matching process, the probability of applying for a given position in individual companies was not the same. Similarly, the probability of employing a given person by a company differed depending on the characteristics and skills of the individual agent. The work skills of different agents in the economy reflected their different activity statuses ($\Xi_i(t) = \{2, 3\}$) and the time that had elapsed since the last change in their status on the labour market ($\Psi_i(t)$). This was introduced in order to accommodate the fact that people who are inactive or unemployed for a longer period of time gradually lose their skills. Work skills were also dependent on the age ($A_i(t)$), gender ($G_i(t)$) and the completed education level of an individual ($ED_i(t)$).

$$\Theta_i(t) = \max\{0; \gamma_7 \times \Xi_i(t) + \gamma_8 \times ED_i(t) + \gamma_9 \times G_i(t) + \gamma_{10} \times \Psi_i(t) - \gamma_{11} \times A_i(t)\} \quad (\text{C.4})$$

All of these variables were significant when the econometric model was estimated. The values of the parameters were obtained from this econometric model.

The model also took into account the hiring and firing costs for firms and their establishments (this resulted from documented research on the impact of these costs on the dynamics of the labour market). The employees with the lowest work skills were fired. If the number of employees to be hired was greater than the number of employees to be fired, potential employees were searched for according to their location (using the NUTS codes). The model assumed that employees who lived closer to a firm were beneficial to the company and more willing to work in a particular company.

The introduction of fully heterogeneous agents, i.e. their differentiation in terms of age, gender, experience or qualifications and the diversification of companies in terms of their demand for employees, enabled the non-trivial dynamics on the labour market to be included.

Like in Kaszowska-Mojša and Pipień (2020), Poledna et al. (2023) and Hommes et al. (2022), it was assumed that all unemployed persons received unemployment benefits, which were a fraction of the income that they had received in the last period before they were unemployed. However, we also differentiated between the individuals who were unemployed for a longer period of time and those who had recently become unemployed.

If individuals had just become unemployed, they received unemployment benefits and their earnings from previous employment were equal to zero, see equation 3. However, if individuals had become unemployed more than one quarter ago, then they received lower benefits. This permitted the social benefits that are characteristics to the Polish case to be included.

The model also assumed that not all of the individuals would look for a job immediately (some of them were more likely to become inactive for a period of time, which was dependent on the conditions of the economy).

An economically inactive adult person whose household income was lower than the subsistence level received enough social benefits to cover their basic needs.

If the person was inactive, then the gender and age of the individuals were checked. If individuals that were older than 55 and had become inactive some time ago, they received social benefits until they were eligible for early retirement.

If the individuals were inactive and had become inactive in the current period and their earnings were positive in the past, they could retire early if they were older than 60 in the case of women and

67 in the case of man.

$$sb_i(t) = \begin{cases} l_1 & \text{if } (\Xi_i(t) = 2 \& \Psi_i(t) = 0), \\ l_2 & \text{if } (\Xi_i(t) = 2 \& \Psi_i(t) > 1), \\ l_3 & \text{if } (\Xi_i(t) = 4 \& Y_h(t) < \eta_{SL}), \\ l_4 & \text{if } (\Xi_i(t) = 4 \& A_i(t) > 55), \\ l_5 \times w_i(t-1) & \text{if } (\Xi_i(t) = 4 \& A_i(t) > 60 \& G_i(t) = 0 \\ & \& \Psi_i(t) = 0 \& w_i(t-1) > 0), \\ l_6 \times w_i(t-1) & \text{if } (\Xi_i(t) = 4 \& A_i(t) > 67 \& G_i(t) = 1 \\ & \& \Psi_i(t) = 0 \& w_i(t-1) > 0), \end{cases} \quad (C.5)$$

where $\Xi_i(t)$ was their labour status, $\Psi_i(t)$ was the number of periods since the last change on the labour market, $A_i(t)$ was the age of the individual, $G_i(t)$ was their gender and $w_i(t-1)$ was their wages in the previous period.

Unlike Hommes et al. (2022), we did not assume that investors were a fixed share of the economically inactive population as this was not supported by the empirical data.⁵ Because the age and gender of the agents were taken into account in our study, it was possible to better approximate the social benefits that were paid by governments and their types (and thus the governmental expenditures). In the model, we also differentiated between situations in which someone had only recently become inactive, some time ago, or when an individual was inactive from the beginning of the simulation (this differentiation resulted from the HFCS database).

C.2.4 Consumption, Savings and Consumer Loans

In the model, we assumed that consumption was conducted at the level of the households and not individual agents. On the one hand, this was due to the fact that decisions to purchase goods were made jointly by individuals that lived together, rather than separately by individual agents. On the other hand, this was because the data in the HFCS was used. We could determine the consumption patterns using the household-level data rather than individual-level data. In the model of Poledna et al. (2023), it was assumed that “in a bounded rational setting, consumer’s behaviour follows a rule of thumb (heuristic) where they plan to consume a fraction of their expected dispensable net income including social benefits” (the consumption budget was corrected for the VAT). In their model, “expected disposable net income inclusive of social transfers was determined according to the household’s activity status and the associated income from labour, expected profits or social benefits as well as tax payments, the consumer index price index of the last period and expectations of the rate of inflation that was formed using an AR(1) model”.⁶

Consumers allocated “their consumption budget to purchase different goods from firms. The consumption budget of the h -th household for purchasing the g -th good was $C_h^d g(t) = b_g^{HH} C_h^d(t)$ where b_g^{HH} was the consumption coefficient for the g^{th} product of households”. As is described in the footnote, the authors assumed that households would buy the same set of goods regardless of the amount they spent on consumption. They also assumed that this set of goods varied depending on price changes. In practice, the values of b_g^{HH} were taken from the input-output tables.

While this approach seems to be reasonable, our approach put more emphasis on the role of expectations and the possibility of increasing the funds for consumption as a result of a consumer borrowing money from the banking sector. In practice, in a high-inflation regime that adopts the expectations of the rate of inflation that is formed using an AR (1) model might not be sufficient.

In our model, wages were delayed when the inflation rate in the economy evolved (incomplete indexation). This is of particular importance when an economy with a dynamically changing rate of

inflation is modelled, which we are currently witnessing. Failure to take this into account in the model would lead to a situation in which we would not be able to include the mechanisms of the price-inflation and income-inflation spirals within this framework. Social benefits are partially-inflation indexed. The model also took into account the fact that pensions were not adjusted downwards when there was deflationary pressure. They could be adjusted exceptionally if there was a severe recession. Thus, the most flexible framework that enables us to model different macroeconomic regimes and different scenarios of economic growth and inflation rates were obtained. We also removed the assumptions that the households always buy the same set of goods regardless of the amount spent on consumption and that this set was invariant to price changes.⁷

Our model also took a more realistic approach to the search-and-matching process. In the model of Poledna et al. (2023), a searching-matching process was taken into account, as a result of which as much as needed or less of goods were purchased (depending on the supply of the goods by the companies on the market). We know from the description that in this model all consumers (households, companies and the government) want to buy goods at the lowest possible price. The consumer selects a subsample of companies and purchases from a company with a certain probability (because an exponential distribution was assumed, companies that offered lower prices were chosen with a higher probability). In their approach, the probability was also dependent on the size of the companies (large companies were chosen more often). In practice, this is a fairly strong assumption that applies to public contracts or certain sectors. In a small economy, many processes are decentralised and inputs are purchased from small and medium-sized enterprises. Therefore, we depart from this assumption in the current version of our model. The probability is dependent on the price that is offered and the geographical distance from the supplier in the case of the selected sectors of the economy, e.g. manufacturing. Large companies were more likely to be chosen when the purchase was made by a public entity.

From the description of the model of Poledna et al. (2023) it is unclear whether the algorithm is looking for a company that is able to supply all of the demand or if the consumer buys some of the goods from the first company and then the rest from other companies on the market. The latter solution was adopted in Kaszowska-Mojśa and Pipień (2020) and Hommes et al. (2022) and it was included in the current version of the model.

When preparing the model, we also changed the way the algorithm works regarding involuntary savings. In the Poledna's model, if no supplier was found locally, the consumer saved involuntarily. Thus, in the authors' own words, "realised demand is the endogenous outcome of the model algorithm, which depends mainly on the random-visiting element, that is, whether the agent acting as a customer finds firms to fulfil its demands". In Kaszowska-Mojśa and Pipień (2020) and in our current version of the model, in the search-and-matching algorithm, we assumed that when it was not possible to find a supplier locally, a supplier was searched for globally (although this solution could be expensive and more computationally demanding). This prevented this sub-sample from affecting the final purchase result. Such a solution as adopted by Poledna et al. (2023) is justified only in the case of performing multiple repetitions of the simulation, which in practice extends the waiting time for the result in the absence of any clear substantive benefits from adopting such a solution (even if we discussed whether the reason was the desire to adopt a more realistic-bound rational behaviour).

In the model of Poledna et al. (2023), entities buy as much as they have assumed or as much as the companies are able to offer them. The difference between production and sales accounts for a company's expectation error. The difference is stored as inventories. Certainly, the imperfection of this approach is that it does not take into account the depreciation of the inventory of finished goods.

In addition to the consumption of consumer goods, in the model of Poledna et al. (2021), households also made investments in durable goods and housing. However, there was no stylised housing market in the market and the role of mortgage loans was not analysed, which made the stylised banking sector less meaningful.

In the current version of the model, a different approach to consumption modelling was adopted in which we tried to improve on the approaches of Kaszowska-Mojśa and Pipień (2020) and Poledna

et al. (2023). At the same time, the adopted solution was constrained by the availability of the data and the design of HFCS database, which was the basis for the development of the model.

We assumed that an individual's income was the sum of their wages, social benefits and any interest that was earned on deposits.

$$\underbrace{y_i(t)}_{\text{Individual's income}} = \underbrace{w_i(t)}_{\text{Wages}} + \underbrace{sb_i(t)}_{\text{Social benefits}} + \underbrace{r_b(t) \max\{0, D_i(t)\}}_{\text{Interest earned on deposits}} \quad (\text{C.6})$$

Then, the total income for all of the households (HHs) was computed as the sum of an individual's income, any donations (which included alimony payments) and any profits from renting out the properties.

$$\underbrace{y_h(t)}_{\text{HHs income}} = \underbrace{\sum_{i=1}^{N_h} y_i(t)}_{\text{HH's members incomes}} + \underbrace{\chi_h(t)}_{\text{Donations}} + \underbrace{\Pi_h^{\text{Rent}}(t)}_{\text{Profits from renting}} \quad (\text{C.7})$$

The savings in the current period ($s_h(t)$) were computed taking into account the income after deducting the basic living expenses and its relationship to the minimum acceptable level of income per person in a household (η_{AL}) that had been computed and published by Statistics Poland (it was higher than the subsistence level of income). The basic living expenses included the cost of either renting or repaying the mortgage ($\kappa_h(t)$).

$$y_h^s(t) = y_h(t) - \underbrace{(\eta_{SL} \times N_i^h + \kappa_h(t))}_{\text{Basic living expenses}} \quad (\text{C.8})$$

The computation of savings took into account the fact that the more affluent households were able and willing to save more than the less affluent households.⁸

$$s_h(t) = \begin{cases} \max\{0; \frac{A_i^{\text{eld}}(t)}{\eta_1} \times y_h^s(t)\} & y_h^s(t) \geq N_h \times \eta_{AL} \\ \max\{0; \frac{A_i^{\text{eld}}(t)}{3\eta_1} \times y_h^s(t)\} & N_h \times \eta_{AL} \geq y_h^s(t) \geq 0 \end{cases} \quad (\text{C.9})$$

where η_1 was the minimum cost of living per person, N_h counted the number of people in the household and η_{AL} was the parameter that determined the threshold above which a household could save more.

The savings in the current period ($s_h(t)$) were computed taking into account the income after deducting the basic living expenses and its relationship to the minimum acceptable level of income per person in a household (η_{AL}) that had been computed and published by the Central Statistical Office (it was higher than the subsistence level of income). The basic living expenses included the cost of either renting or repaying the mortgage ($\kappa_h(t)$).

$$y_h^s(t) = y_h(t) - \underbrace{(\eta_{SL} \times N_i^h + \kappa_h(t))}_{\text{Basic living expenses}} \quad (\text{C.10})$$

The computation of savings took into account the fact that the more affluent households were able and willing to save more than the less affluent households.⁹

$$s_h(t) = \begin{cases} \max\{0; \frac{A_i^{\text{eld}}(t)}{\eta_1} \times y_h^s(t)\} & y_h^s(t) \geq N_h \times \eta_{AL} \\ \max\{0; \frac{A_i^{\text{eld}}(t)}{3\eta_1} \times y_h^s(t)\} & N_h \times \eta_{AL} \geq y_h^s(t) \geq 0 \end{cases} \quad (\text{C.11})$$

where η_1 was the minimum cost of living per person, N_h counted the number of people in the household and η_{AL} was the parameter that determined the threshold above which a household could save more.

The positive savings from the current period were added to the financial assets of the individuals that accumulated in their bank account in the form of liquid assets ($LA_i(t)$) (this is a proxy for financial wealth). Note that as the liquid assets accumulated in the bank accounts, they became part of the bank's deposits.

Household savings were redistributed between the accounts of the adult household members. If the household had only a single person, then all of the savings were transferred to their account. If the household was a couple or consisted of more than two adults, then the corresponding parts of the savings were transferred into their bank accounts.

In the course of the simulation, the value of liquid assets was updated for:

- basic needs
- cost of renting or the mortgage on the main residence
- the debt burden of the consumer, investment and housing loans (other than the mortgage on the main residence)
- funds that were obtained from banks in the form of loans
- funds from selling/buying properties
- investments in firms
- earned interest
- deposits inherited after deducting the debt burden of any housing loans if applicable.

In our model, we assumed a situation in which the current household income was negative. In that case, the individuals used their financial wealth (liquid assets) to cover the expenses (this smoothed the consumption within the model). They could also use other less liquid assets, i.e. they could sell any properties that they owned on the housing market. If no buyer was found, the household defaulted and the non-performing loans of the banks increased. The liquid assets were updated in different modules in the course of the simulation. The value of liquid assets was also dependent on the interactions with the other entities on the market as well as the market conditions.

Households purchased goods from individual industries (there were S industries in the model). The household could only consume the basic quantity of goods or the amount could be increased if consumption loans ($\sum_{i=1}^N L_i(t)$) were granted. Thus, the quantity of the goods that were purchased was dependent on how the consumption was financed.

$$Q_h(t) = \begin{cases} \eta_{2,tc,s} \frac{LA_h(t)}{P_s(t)(1 + \tau_s^{VAT})} & (\sum_{i=1}^N L_i(t) = 0), \\ \eta_{2,tc,s} \left(\frac{LA_h(t)}{P_s(t)(1 + \tau_s^{VAT})} + \frac{\sum_{i=1}^N L_i(t)}{M^c P_s(t)(1 + \tau_s^{VAT})} \right) & (\sum_{i=1}^N L_i(t) > 0). \end{cases} \quad (C.12)$$

where $LA_h(t)$ were the liquid assets,¹⁰ P_s was the average price in sector s , τ_s^{VAT} was the tax rate in sector s , $L_i(t)$ was the value of any loans and the parameter value $\eta_{2,tc,s}$ was specific to the industry and customer type. It expressed the percentage of total consumption from a particular industry s by a household with a specific consumer type.

When buying from several industries, we assumed $\sum_{s=1}^S \eta_{2,tc,s} = 1$, where there were $s = 1, 2, \dots, S$ industries in the economy. There were six consumer types in the model, which was dependent on the composition of the households (and thus also on their sources and levels of income and expenditures).

If a supplier was found (see the description of searching-matching process below), then a purchase was made and the value of the liquid assets was reduced by the purchase price (the quantity of the goods times the price of the goods). When a purchase was made, the sales value (in monetary terms) and liquid assets of the establishment increased by the same amount. At the same time, the stock of the final goods of the establishment decreased and the value of (the auxiliary variable) the demand for this good increased by the quantity of the purchased goods. It should therefore be noted that the respective values of the variables were updated in terms of quantity and in monetary terms.

A loan $L_h^C(t)$ could only be granted when the income was higher than the specified amount per individual in the household (N_i^h).

$$Y_h(t) \geq \eta_3 \times N_i^h \quad (\text{C.13})$$

This η_3 was usually equal or greater than α_{AL} , which was specific for the economy under study and was determined by all of the banks in the economy (it was a banking system-wide specific parameter).

The amount of a loan that could be granted is given by:

$$L_h^C(t) = \eta_{4,tc,s} \times (Y_h(t) - DB_h(t)) + \eta_{5,s} \quad (\text{C.14})$$

The parameter value $\alpha_{4,tc,s}$ was specific to the industry and customer type, while $\eta_{5,s}$ was industry-specific.

We used a modified searching-matching process when searching for a financial provider, which was similar to the one that was used in Kaszowska-Mojša and Pipień (2020). With a certain probability, an individual tried to obtain the amount from the bank at which they already had a credit history. If they were not successful, the individual approached other banks. In such cases, the interest rates were compared and the supply side requirements and consumer creditworthiness were checked. It was also determined whether the bank had sufficient funds to supply credit, whether the bank's policy permitted the loan to be granted and whether the regulatory requirements for any sectoral exposures were met. If no bank was willing to provide the funds, the amount of the loan was adjusted using an adaptive algorithm.

Determining the creditworthiness of an individual included monitoring the level of the income per person after deducting any repayments of other loans. The acceptable level of net income was specific to each bank ($\eta_{6,b}$):

$$(Y_h(t) - DB_h(t)) \geq \eta_{6,b} \times N_i^h \quad (\text{C.15})$$

The next conditions relate to the credit history of the household. The probability of the default of members of the household had to be lower than the threshold that was specified by the bank. The maximum number of loans that could be granted to one household was also assumed (in line with the empirical findings). For all of the loans that were granted to individuals, the age and activity status of the applicant were also verified.

Similar to Kaszowska-Mojša and Pipień (2020), it was also possible to activate a variable that calculated the elapsed time since the last change in their status on the labour market. If the individual worked fewer than four quarters and was under 30, it was assumed that they had a fixed-term contract and no creditworthiness, which is a reasonable assumption in the case of Poland. The maturity of a loan depended on the duration of the loan (an empirical distribution was followed).

When a new loan was granted, the value of the debt service was updated taking into account the civil status of the adult household members. The value of the repayment instalments (interest and capital) was recalculated. The supply of the credit and the revenues of the bank in the given period were also updated. The values of the auxiliary parameters that were used to describe the method for granting consumer loans in the modules are presented in the appendix.

There were different establishments-suppliers of inputs and final goods from specific sectors. We assumed that the relationships between suppliers and consumers that already existed were consolidated in the model. If the current stock of goods was sufficient to cover the demand of a household and the ratio of the quality to the price of the goods was higher than the average ratio in the sector, then the household purchased the goods from this supplier.

$$\frac{\alpha_{7,s-sup} \times QL_e(t)}{\alpha_{8,s-sup} P_e(t)} > \frac{\alpha_{7,s-sup} QL_s(t)}{\alpha_{8,s-sup} P_s(t)} \quad (\text{C.16})$$

Otherwise, the household looked for a new supplier from incrementally more distant spatial locations. The requirements for the same spatial codes were loosened sequentially. When a purchase was made, the profits from the sales, demand, stock and liquid assets of suppliers were updated. In addition, the household's liquid assets decreased when the transaction was settled.

C.2.5 Investments on the Housing Market and Mortgages

In Poledna et al. (2023), household investment was only a part of disposable income, i.e. similar logic was adopted as in the case of consumption. The investment demand of household h for product g was determined using fixed weights (from the input-output tables). The searching-matching process was the same as in the case of consumer goods. Investment growth increased household capital and, in the aggregate, the capital in the economy. The total household income was dependent on wages, social benefits or investments as well as the realised inflation. Household savings were the difference between current dispensable income, the consumption expenditures and the realised investment in housing and was used to accumulate financial wealth. The stock of the deposits was corrected by interest rate payments on any overdrafts on a household's deposit account and interest that was received on any deposits in the bank. The same approach was adopted in Hommes et al. (2022).

Our aim was to make the model more realistic. Therefore, households used part of their income to invest in dwellings and other durable goods but also in firms. Unlike the Poledna et al. (2023) model, we did not assume that household investment only occurred according to a fixed rate on the expected dispensable net income. What determined the decision to invest in real estate was primarily wealth not just the current income. We also assumed the existence of the real estate market and its dynamics together with the credit conditions (and interest rates) that determine investments in dwellings in addition to the income, wealth and current debt burden.

Firstly, we explained why households might want to buy a new property. This might be motivated by a decrease in the cost of living or investments in dwellings and also in order to obtain profits from renting. Then, we explained how the purchase of dwellings was financed and what the role of banks was in this process. We also briefly mentioned the consequences of any potential defaults on housing loans for the banking sector.

Based on the HFCS database, the properties and the households that owned them were mapped and the households that rented properties were identified. We assumed that the households that owned more than one property were willing to rent them to other households or to sell them.

The cost of living ($\kappa_h(t)$) in a given property was equal to the cost of the rent or mortgage instalment plus the average cost of servicing the property in a given country (or region).

$$\kappa_h(t) = \begin{cases} \beta_1 \times DB_h^H(t) + \beta_2 \times \frac{P_p(t)}{N_p^{Rent}(t)} & \text{if } p \text{ is rented by HH} \\ \beta_1 \times DB_h^H(t) + \beta_0 & \text{if } p \text{ is owned by HH} \end{cases} \quad (C.17)$$

where parameters β_0 and β_1 adjusted the fixed and the variable parts of accommodation cost, respectively and $DB_h^H(t)$ stood for the debt burden of the housing loans. The debt burden of housing loans was computed as the sum of those instalments.

$$DB_h^H(t) = \sum_{i=1}^N (L_i^{H_q}(t) + R_b^{H_q}(t)) \quad (C.18)$$

where $L_i^{H_q}(t)$ was the capital part and $R_b^{H_q}(t)$ indicated the interest that was to be paid. The cost of renting was calculated as part β_1 of the sum of the liabilities to the bank and part β_2 of the cost of rent, which was calculated as the ratio of the price of the property to the number of households that lived in the property. If the property was owned by the household, the costs were dependent on the debt burden and the amount of the fixed costs.

If the cost of living was too high, a household was willing to change the property. If the household was the owner of property and the living cost was greater than the specified parameter β_2 part of the income $Y_h(t)$, the household would decide to sell the property. If the property was already for sale on the market, then the price had to be decreased.

If a household rented a property and the cost of rent was too high, it searched through the offers for cheaper properties. A household looked for other dwellings considering their activity status and the age of the household members. If all of the adults in the household were working, the property near one of their workplaces was selected (the spatial codes were compared). In addition to the locations, the price of the property from the appropriate price range and whether the real estate was for sale were also taken into account. If more than one property met the criteria, one was selected at random and the spatial codes that attributed the individual to the respective spatial units were updated. If the adults were unemployed or inactive and the difference between the sum of individual deposits and the sum of the individual liabilities of the household members was less than the subsistence level, then the individuals and the household-consumer were removed from the database.

$$(D_h(t) - DB_h(t) + \beta_3 \times \frac{P_p(t)}{R_p(t)}) < \eta_{SL} \quad (C.19)$$

where η_{SL} was the subsistence level. As a result, the inflow of non-performing loans increased and the probability of a default to the bank increased. The exception was a situation in which an adult was under 25 in which case the assumption was made that the individual still lived with their parents.

The mechanism of the searching-matching process between the buyers and sellers of dwellings was introduced into the model. If a household that was willing to sell the property for the indicated price was found, the values of the deposits of the buyers and sellers as well as the ownership of buyer were updated. If a buyer was not found, the price was decreased sequentially.

If an agent had problems with their loan repayment, this could eventually lead to a default and the household would be removed from the database. In that case, the value of the non-performing loans and the probability of a default to the bank increased. The bank became the new temporary owner of the property when a household was removed from the database after a default. The property was once again put up for sale. Once sold, the bank's revenues increased and the probability of default decreased.

Households could also want to buy a property to earn profits from renting the properties. However, the assumption was made that the main residence could not be sublet to another household. If no one lived in the second dwelling, this property was designated for sale. If it had already been put on the market for sale in the past, its price was reduced.

$$P_p(t) = (1 - \beta_4) \times P_p(t - 1) \quad (C.20)$$

While renting, the revenues from renting are updated.

$$\Pi_h^{Rent}(t) = (1 + \beta_5) \times \Pi_h^{Rent}(t - 1) \quad (C.21)$$

There were two ways for funding the purchase of dwellings. Households could finance the purchase of real estate from their own resources or on credit.

If the current funds and savings in the bank account were greater than the price of the cheapest property on the market that had already been put up for sale, it could potentially pay for the property with cash.

$$(D_h(t) - DB_h(t)) > P_p^{min}(t) \quad (C.22)$$

where $D_h(t) = \sum_i^N D_i(t)$ were the deposits of the households. When a household had sufficient funds to buy a property, then deposits decreased by an amount equal to the price of property.

The investment would be funded from their own funds with a certain probability if their net financial assets (after deducting their debt burden) were greater than the price of the property.

$$DB_h(t) = \sum_{i=1}^N \left(\underbrace{L_i^{Cq}(t) + R_i^{Cq}(t)}_{\text{Consumer loans}} + \underbrace{L_i^{Hq}(t) + R_i^{Hq}(t)}_{\text{Mortgages}} \right)$$

$$D_h(t) - DB_h(t) \geq P_p(t)$$

We assumed that a household would buy a property with cash only with a given probability in the model. If a member of the household was an individual who had a high level of entrepreneurial spirit, they would rather invest the funds in their firm (and consequently, the property would not be bought with cash).

A household could also apply for a housing loan with a certain probability. The housing investment could be funded by the banking sector if they did not have enough funds to cover the cost of buying the dwelling or if they would rather use their financial assets for consumption or investments in firms.

Banks calculate the values of prudential ratios (debt service to income, debt to assets, debt to income and loans to value ratio). A potential borrower must meet the conditions for granting a loan. The lender, on the other hand, must have an adequate supply of credit and guarantee that they could generate an appropriate profit on the loan in the form of interest. The borrower would try to obtain a loan at the lowest interest rate but their efforts would also depend on the bank's internal regulations regarding creditworthiness and compliance with the prudential requirements.

The characteristics of properties were also modified in the case of marriages and divorces. A married couple could pay back their housing loans if they sold some of their properties for a profit. If the housing loans that were due to be paid were greater than the revenue from selling the properties, then the amount of housing loans to be paid decreased but the remaining part still had to be paid. If the price for which the properties were sold was greater than the sum of all of the liabilities then the deposits of each adult individual were changed.

In the case of divorce, both adults remain in the same property and hence they both contribute to the rent to cover the accommodation cost. The ex-wife is the owner, while the ex-husband lives there temporarily. If the former marriage had two or more properties, then each partner would stay in one of them and the rest would be put up for sale. For simplicity, children always stayed with the mother in her primary residence. The status of the owner, the variable for the primary residence and the number of households that rented the property were updated. If the property was purchased on credit, then the amount of the loans that were due to be paid by the ex-wife were updated as well. We assumed that the loans to be repaid were assigned to the person who stayed in the property.

C.2.6 Inter-Generational Transfer of Wealth

The inter-generational transfer of wealth was also modelled. When a child died, only the consumer type of the household had to be changed. If an adult died, the heir had to be determined.

If the individual was an entrepreneur and did not have family, the number of employees in the company was determined. If it was a sole proprietorship, then the firm was put up for sale. Otherwise, one of workers in the company who had earned the highest wage in the previous period was selected to be the new owner of the company. If the deceased person was not an entrepreneur, the inheritor was selected at random from the group of working adults.

If the deceased adult person had a family, then two cases had to be differentiated. If they had children, the eldest child in the family was the inheritor and the consumer type did not change. If there were no children, then the spouse was the inheritor and the consumer type changed depending on the age of the spouse.

If the deceased adult was a single parent, then the adoption of a child was considered. The algorithm looked for a new couple or a single individual to be the parent(s) and to calculate the deposits, ownership of the properties and firms. If they owned more than two properties, they were designated for sale.

The savings after the deductions of the housing loans that were due to be paid are given to the inheritor. If these savings were greater than zero, then the deposits of the heir were updated. The parameter τ^{inh} stood for the taxes that had to be paid.

In the model, we assumed that consumer loans were not inherited and hence the inflow of non-performing loans of banks and the probability of default to the bank were updated.

If the individual's debts were greater than their savings, then the variables were updated separately. In this way it was possible for the heir to inherit the debt from any housing loan that had been granted in the past.

As the inflow of non-performing consumer loans increased, the probability of a default to bank increased as well. If the deceased person was not the owner of a firm then only the savings (deposits) were modified.

Otherwise, the inheritor might or might not run the business in the future. The decision on running the business depended on their previous earnings relative to the potential income from the business activity.

If the inheritor decided to run the business, the status of entrepreneur, their labour status and the number of periods since the last change in their labour status were updated. The social benefits ceased. The inheritor was responsible for paying back any investment loans.

If the inheritor decided to sell, the company was put up for sale. The inflow of non-performing loans was increased by the amount of any investment loans that would not be paid. The probability of a default to the bank also increased in that case.

Finally, the impact of the inheritance of properties was analysed. The number of adults who were in the household of deceased person was determined as was whether the deceased person rented or owned the residence.

If the deceased individual rented the residence, then the number of households that rented this property decreased. If the deceased person owned the residence and had no mortgage, then the property was put up for sale. However, if the deceased person had taken out a housing loan to buy the property, the bank received the property and attempted to sell it. The bank looked for any household whose total deposits were greater than the property price. If one was found, then the bank updated the inflow of the non-performing loans and the revenue from selling the property. The new owners of the property proportionally updated the deposits after the purchase. If the bank was not able to sell the property, the price was gradually lowered.

C.3 Sectors, Firms and Establishments in the Model

There were S , ($s = 1, 2, \dots, S$), sectors in the model that represent the NACE-2 industries. Each sector was populated by heterogeneous firms and their establishments. There were F ($f = 1, 2, \dots, F$) firms and E ($e = 1, 2, \dots, E$) establishments in the model. Each establishment produced goods using labour, capital and intermediate goods (inputs) from other establishments-suppliers. One of the main differences with respect to Poledna et al. (2023) and Hommes et al. (2022) was that a firm could operate in more than one sector via different establishments, thereby replicating the empirical data (F-01 data).

In our model, companies primarily created expectations regarding the behaviour of the sectors in which they operated and that were not related to the aggregate economy (we did not use the AR(1) forecasting rule, which was adopted in Poledna et al. (2023)). New establishments were created in those sectors that were characterised by a higher average profitability. Generally, the (expected and realised) average values of the variables for individual industries were the reference point for the activities of the companies and establishments, see Table D.13. These values were dynamically updated as the simulation ran and the agents conducted their economic activity.

The activity in a given sector also affected the method for calculating a company's maximum production. The formulas for the expected demand of an establishment included the relative price and quality of the product with respect to the average price and quality in the sectors in which it operated. The model assumed different dynamics of price changes for sectors, which permitted the analysis of any price and wage spirals. It also enabled us to observe how changes in the prices of the inputs in one sector affected the prices of the final goods in more than one sector and how the price changed in the economy.

The establishments purchased inputs from other establishments/ suppliers from all sectors. The price and quality of the goods that were offered by a supplier had to be at least as good as the average price and quality in that sector.

When establishments applied for a loan, the total exposure to the industry was determined, which could not exceed the regulatory thresholds. The role of the sectors was emphasised when any large exposures of the banks to particular industries were calculated.

C.3.1 Entrepreneurial Spirit

The creation of companies was closely related to the existence of agents with a higher degree of entrepreneurial spirit. Each individual agent in the database could potentially be the owner of a company; in the model no fixed number of companies or company owners was specified as was the case in Poledna et al. (2023) and Hommes et al. (2022). Each individual agent could also change its status on the labour market and cease to be the owner of a company (in certain situations such as closing the company, a merger or acquisition, bankruptcy of the firm etc.).

The entrepreneurial spirit expressed how likely the individual was to become an entrepreneur. It was computed for all of the individuals (for all of the labour statuses (activity statuses)). The HFCS database not only provided data on the labour statuses but also on gender, age, level of education, number of periods since the last change of their status on the labour market and information about whether an individual had been an entrepreneur in the past. All of these variables were statistically significant in the econometric model that was estimated to determine the degree of entrepreneurial spirit.

C.3.2 Firm Demography and Growth

Within the firm demography, the focus was on firm creation in the sectors, mergers and acquisitions and the opening and closure of establishments.

C.3.2.1 Firm Creation in the Sectors

New companies were first created with a certain probability in the most profitable sectors and then in the next sectors according to their profitability. At the same time, the expectations of obtaining above-average profits were not the only factor that was taken into account in the process of creating companies. Each sector was assigned a qualitative variable that defined its entry barriers. In this way, it was easier to start a business in some sectors than in others in the model. This is consistent with the empirical research on entry barriers for firms in Poland.

The size of a firm was drawn from the empirical distribution of firm sizes in Poland. The approximate costs of creating a new firm were dependent on the number of employees (firm size) ($\mathfrak{K}_i(t)$) and the average wages in the sector ($\overline{W}_s(t)$) in which the company was going to be set up as well as on the fixed costs that were sector specific.

$$TC_f(t) = v_1 \times \mathfrak{K}_i(t) \times \overline{W}_s(t) + v_{2,s} \quad (C.23)$$

There were three ways to fund a firm's creation in the model. Some companies, mostly small enterprises, were funded by the funds that the individuals had accumulated in their bank account. Otherwise, it was funded by either debt or equity.

In the case of small open economies such as the one in Poland, bank funding is actually of prime importance. Therefore, banks could grant investment loans that could fund the creation of firms within the model. In the process of applying for a loan, certain conditions had to be met by both the lender and the borrower. The bank had to have sufficient funds to grant the credit and any sector exposures (large exposures) requirements had to be met. The process of determining an investor's creditworthiness included determining the level of leverage, financial risk, the average level of risk of starting a business in a given sector and the investor's credit history.

Firms could also be funded by raising capital through the sale of shares (equity funding). In order to close the model, we assumed that the individuals used their bank deposits to buy shares. If a sufficient number of individuals were willing to invest in the firm, the firm was created and the firm capital increased and the deposits of the individuals decreased accordingly.

C.3.2.2 *Mergers and Acquisitions*

The market value was computed for all of the firms that operated on the market. Firstly, the ratio of profit per employee to the average profitability per employee in the sector was calculated. Then, the ratio of the business risk to the average business risk in the sector was estimated. The market value of the company was changed depending on the number of employees it employed as well as on the values of the aforementioned factors.

Mergers and acquisitions were included in the model in order to ensure the correct dynamics on the market. In both cases, what part of the company's profits was attributable to the profits that would be generated by the company's establishments operating in a given sector (or sectors) was calculated first. The merger or acquisition was conducted with a certain probability by a company in the sector in which it earned more. However, not all of the companies could conduct a merger. Primarily, parameters such as the level of debt relative to the profits that were obtained in the most recent period, the level of debt relative to the liquid assets and capital and a sufficiently high market value were determined. Mergers were also only permitted in a group of companies that had not been identified as companies that were for sale. If these conditions were met, the firm looked for a business partner among a randomly selected relatively small sample of companies from the same sector. For a merger to take place, the sum of the liquid assets and capital of that company had to be lower than the same sum in the company that was seeking a business partner. The same applied to its number of employees, which had to be smaller. The market values of both companies also had to be high enough.

In the case of acquisitions, only the firms for which the financial risk with respect to the average financial risk in the sector was low enough could look for a firm to be acquired in the sample of firms that were indicated for sale. The acquired company also had to be correspondingly smaller (employed fewer employees) and its level of debt had to be reasonable relative to the financial position of the acquiring company (liquid assets and debt). In both cases, mergers and acquisitions, the values of debt, liquid assets, capital and the number of employees were recalculated.

C.3.2.3 *Establishments Opening and Closure*

Individual firms could also open and close individual establishments in different sectors (in those in which they had already operated as well as in new ones).

This was the case in which the financial position of a company was good (for this purpose the financial risk relative to the average risk in the sector and the average profitability of the company per employee relative to the average profitability per employee in the sector were calculated).

If all of the establishments of the firms closed, the corresponding firm had to close as well.

C.3.3 *Production and Sales of Establishments*

In order to calculate the production of a given establishment, its potential (maximum) production had to be determined.

$$Y_e^{max}(t) = \alpha_{1,s}(A_e(t))^{\alpha_{2,s}}(L_e(t) + 1)^{\alpha_{3,s}}(K_e(t))^{\alpha_{4,s}}\left(\frac{Ql_e(t)}{Ql_s(t)}\right)^{\alpha_{5,s}} \quad (C.24)$$

where $Y_e^{max}(t)$ was the maximum production of establishment e at time t ,
 $A_e(t)$ was the know-how of the establishment e ,
 $L_e(t)$ was the total labour force,

$K_e(t)$ was the fixed capital of the establishment e and

$\frac{Ql_e(t)}{\overline{Ql}_s(t)}$ was the relative quality of the product that was produced by establishment e with respect to the average quality in the sector s in which it operated.

When faced with fluctuations in demand, the establishments did not always respond by changing production. Often, they reacted with a price change. If the realised demand was greater than the expected demand for the goods and the previous level of production was greater than the fraction of maximum production, the producer raised the price of the goods. However, if the realised demand was lower than the fraction of maximum production and the production was lower than the fraction of max production, then the price of the product that was produced by the establishment was lowered.

The demand expectations were then recalculated for all of the establishments.

$$Q_e^{de}(t) = \begin{cases} \left\{ \frac{\alpha_{11,s}P_e(t)}{\overline{P}_s(t)} + \frac{\alpha_{12,s}P_e(t-1)}{\overline{P}_s(t-1)} + \frac{\alpha_{13,s}Ql_e(t)}{\overline{Ql}_s(t)} + \frac{\alpha_{14,s}Ql_e(t-1)}{\overline{Ql}_s(t-1)} \right\} [(L_e(t) + 1)\overline{Sl}_s(t)], & \text{if new } e \\ \left\{ \frac{\alpha_{11,s}P_e(t)}{\overline{P}_s(t)} + \frac{\alpha_{12,s}P_e(t-1)}{\overline{P}_s(t-1)} + \frac{\alpha_{13,s}Ql_e(t)}{\overline{Ql}_s(t)} + \frac{\alpha_{14,s}Ql_e(t-1)}{\overline{Ql}_s(t-1)} \right\} Q_e^d(t-1), & \text{if not new } e. \end{cases} \quad (C.25)$$

where $P_e(t)$ and $P_e(t-1)$ were the prices of the goods that were produced by the establishment e in the respective time period t and in the previous period $(t-1)$,

$\overline{P}_s(t)$ and $\overline{P}_s(t-1)$ were the average prices of the goods in the sector s in the respective current and previous periods,

$Ql_e(t)$ and $Ql_e(t-1)$ were the qualities of goods that were produced by the establishment at t and $t-1$ and

$\overline{Ql}_s(t)$ and $\overline{Ql}_s(t-1)$ were the average quality of the goods that were produced by the other establishments in the sector s at t and $t-1$.

Then, the optimal level of the inventories (stock) of the establishment ($Inv_e^{opt}(t)$) was calculated.

$$Inv_e^{opt}(t) = \begin{cases} \max\{0, \alpha_{15} Q_e^{de}(t)\}, & \text{if new } e \\ \max\left\{0, \alpha_{15} Q_e^{de}(t) \frac{\alpha_{16}P_e(t)Q_e^{de}(t)}{TC_e(t)} + \frac{\alpha_{17}Sl_e(t)}{TC_e(t-1)}\right\}, & \text{if not new } e. \end{cases} \quad (C.26)$$

where $TC_e(t)$ and $TC_e(t-1)$ were the total costs of the establishment e at respective t and $t-1$ and $Sl_e(t)$ were the total sales of the establishment e at time t .

The establishment would only produce if the optimal stock was greater than the current stock, the financial risk associated with the production was low and the leverage of the establishment were acceptable.

$$Y_e(t) = \begin{cases} \max\{0; Inv_e^{opt}(t) - Inv_e(t)\} & \text{if fulfilled} \\ 0 & \text{otherwise} \end{cases} \quad (C.27)$$

It is worth noting that the costs that were incurred by the establishment were equal to the sum of the inputs ($IN_e(t)$), taxes ($\tau_e^p(t)$), the average cost of servicing the debt that corresponded to

the establishment of the firm, the fixed costs of production and the wages that were paid by the establishment ($W_e(t)$) plus the fixed costs per employee ($\rho_{3,s}L_e(t)$).

$$TC_e(t) = IN_e(t) + \tau_e^p(t) + \frac{\rho_1 D_f(t)}{\mathfrak{K}_j(t)} + \rho_{2,s}Y_e(t) + W_e(t) + \rho_{3,s}L_e(t) \quad (C.28)$$

Inputs were purchased from other establishments. The demand for goods from consumers was supplemented by the demand from other establishments and the public sector. In the case of establishments, it was also assumed that the already existing relationships between suppliers and consumers were consolidated in the model.

If the current stock of goods was sufficient to cover the demand of households and the ratio of the quality to the price of the goods was higher than the average ratio in the sector, then a household purchased the goods from this supplier.

$$\frac{\alpha_{7,s-sup} \times QL_e(t)}{\alpha_{8,s-sup} P_e(t)} > \frac{\alpha_{7,s-sup} QL_s(t)}{\alpha_{8,s-sup} P_s(t)} \quad (C.29)$$

Otherwise, the establishment looked for a new supplier from incrementally more distant spatial locations.

The requirements for the same spatial codes were loosened sequentially.¹¹

The purchase of the inputs could be financed in whole or in part from a bank loan, which enabled production to be maintained with temporary liquidity problems. This possibility was not taken into account in the models of Poledna et al. (2023) and Hommes et al. (2022). Obtaining a loan was dependent on meeting the credit requirements of the banks.

An establishment could even increase production by obtaining additional funds from a bank even if the establishment did not have liquidity problems and intended to use the liquid funds for other purposes, e.g., changing the structure of the firm or entering more markets (sectors).

The sales value for each establishment was updated when the final goods or inputs were purchased by a household, another establishment or an establishment that makes a public investment (public contracts), respectively.

C.4 Public Sector

The demand from the private sector was complemented by the demand from the public sector. Although large establishments were more likely to sign public contracts, their activity in the model was similar to any other company. For example, the construction of a road or the construction of a hospital (funded from public funds) was performed by an establishment that operated in the construction sector (and the contracted company purchases inputs on the market in exactly the same way as the other establishments in the model).

However, in order to sign a public contract, a number of criteria had to be met. The price that was offered should be lower than the average price of the product in that sector, while the quality had to be above the average in that sector. The stock of the supplier could not be lower than the minimum predetermined fraction of production. After the contract was signed, the stock, demand, liquid assets and the value of sales were updated in both companies accordingly.

Similar to Kaszowska-Mojša and Pipień (2020) and Hommes et al. (2022), there were also other expenditures of the general government such as interest payments on debt, social benefits and other subsidies.

Government revenues were computed in a similar way as in Hommes et al. (2022). However, because we included buying and selling properties on the housing market, we also had to include additional property taxes in the model. We also had inter-generational transfer of wealth (therefore inheritance taxes).

A government's budget is equal to the difference between its expenditures and revenues. As a stock variable, government debt is determined by the year-to-year deficits or surpluses of the public sector. For now, the same assumption was made as the one that was made in Hommes et al. (2022) that for reasons of model parsimony, it was assumed that the government sold its debt contracts to the central bank¹²

C.5 The Banking System in the Model

The model assumes the existence of B banking groups that granted loans to individuals (consumer and mortgage loans) and financed the current and investment activities of companies. In contrast to the model of Poledna et al. (2023), this was a more realistic approach to the money creation process and the other heterogeneous banks activity.

C.5.1 Money Creation and the Role of Commercial Banks Within Our Model

We did not explicitly model a central bank but we did keep the money creation logic in the model. There are common misconceptions about the role of banks and money creation that unfortunately are also present in the state-of-the-art agent-based models. One common misconception is that banks simply act as intermediaries, lending out the deposits that savers place with them. In this view, deposits are typically “created” by the savings decisions of households and banks then “lend out” those existing deposits to borrowers. In fact, savings alone do not increase the funds that are available for banks to lend. This approach ignores the fact that banks are the creators of the money that is deposited. The second misconception is that of the money multiplier approach. In reality, central banks only set the price of reserves, not the quantity of reserves. In our approach, each bank in the model had a stylised balance sheet, income statement and cash flow statement; and individual entries were updated as transactions were settled.

Each bank within the model also decided on how much it would lend depending on profitable lending opportunities. It was also these lending decisions that determined how many bank deposits were created by the banking system. The banks then decided how much they wanted to hold in their reserves (supplied by the central bank) in order to accommodate the withdrawals by the public, meet the regulatory requirements and make payments to other banks.

Banks themselves have limits on how much they can lend. In particular, in our model we focused on:

- the market forces that can constrain lending (individual banks have to be able to lend profitably in a competitive market)
- risk mitigation (banks have to take steps to mitigate the risks that are associated with making additional loans)
- regulatory requirements (to mitigate a build-up of risks that could pose a threat to the stability of the financial system).

C.5.2 Bank Lending and the Deposits

Four types of loans are distinguished in the model.

C.5.2.1 Consumer Loans and Mortgages

Each individual in the database was assigned a bank. No information was available in the HFCS database as to which bank the funds were deposited into by an agent or which bank granted loans to an agent. However, because the banks followed their own strategy on the market and had their own specialisation (not all of them are universal banks, some of them only specialise in mortgages or

consumer loans), we were able to match agents with banks that matched their profiles with a certain probability.

We took into account the information that was provided in the HFCS and F01 (the risk and lending profiles of the agents) and the profile of the banks in order to provide a better approximation.

Matching individuals with banks could be improved if the access to confidential data of individual banks of the central bank was granted.

This matching was of prime importance only in the case of consumer loans. In the case of consumer loans, individual entities were guided by their attachment to a bank. First, they applied for a loan from the institution that was assigned to them in the system. If that institution was not willing to give them a loan, they looked for another bank that had a sufficient amount of funds and had acceptable credit requirements. Institutions that had a lower interest rate on consumer loans were preferred.

In the case of mortgage loans, the lender had to have sufficient resources to grant the loan and meet the requirement of large exposures to the real estate sector. The borrower had to meet the credit conditions. The effect of an attachment to a bank was not assumed; borrowers were primarily guided by the interest rate and credit requirements and the availability of credit.

C.5.2.2 Short Term Loans for Firms

Credits for the purchase of inputs could be granted:

- to companies that were having temporary liquidity problems and were unable to fully finance a purchase, which would force them to decrease the production of final goods
- to companies that would like to expand their production due to expectations of a higher demand (they had enough liquid assets that they would prefer, however, to use to fund further investment or a structural change (mergers or acquisitions)).

C.5.2.3 Investment Loans

Entrepreneurial individuals could obtain loans to set up a business in the model. In this case, interest rates and compliance with regulatory requirements were of particular importance.

C.5.3 Profitability, Solvency and Liquidity of Banks

The simulation enabled us to analyse:

- profitability: the ability to generate income/profit from the allocated capital
- solvency: the credit quality and adequacy of a bank's own resources (indebtedness)
- liquidity: the ability to meet the obligations with liquid funds.

C.5.3.1 Profitability

The return on equity enabled the market value to be approximated as well as the potential for a bank's growth:

$$\text{ROE} = \frac{\Delta \text{Equity}}{\text{Equity}_{t-1}} = \frac{\Delta \text{Net income}}{\text{Equity}_{t-1}} \quad (\text{C.30})$$

C.5.3.2 Non-performing Loans Ratio and Solvency Ratio

With respect to non-performance and solvency measures, the following were computed:

- the non-performing loans ratio for consumer loans ($\text{NPL}_b^C(t)$)

$$\text{NPL}_b^C(t) = \frac{\text{NPL}_b^C(t)}{l^M(t)} \quad (\text{C.31})$$

where $NL_{lc}^b(t)$ were the non-performing consumer loans and $l_b^C(t)$ were all of the consumer loans.

- the non-performing loans ratio for mortgages ($NPL_b^{l^H}(t)$)

$$NPL_b^{l^H}(t) = \frac{NL_b^{l^H}(t)}{l_b^H(t)} \quad (C.32)$$

where $NL_b^{l^H}(t)$ were the non-performing mortgages and $l_b^H(t)$ were all of the mortgages

$$NPL_{lf}^b(t) = \frac{NL_b^{lf}(t)}{l_b^F(t)} \quad (C.33)$$

where $NL_b^{lf}(t)$ were the non-performing short-term loans to firms and $l_b^F(t)$ were all of the short-term loans to firms

- the non-performing loans ratio for investment loans ($NPL_b^{l^I}(t)$)

$$NPL_{li}^b(t) = \frac{NL_{li}^b(t)}{l_b^I(t)} \quad (C.34)$$

where $NL_{li}^b(t)$ were the non-performing investment loans to entrepreneurs and $l_b^I(t)$ were all of the investment loans to entrepreneurs.

- the non-performing loans ratio ($NPL_b(t)$)

$$NPL_b(t) = \frac{NL_b(t)}{TA_b(t)} \quad (C.35)$$

where $NL_b(t)$ were the total non-performing loans and $TA_b(t)$ were the bank's total assets.

The solvency of a lending institution rested on maintaining an adequate buffer of its own funds – regulatory capital – that could absorb potential losses and cover the risks associated with its credit exposures. In practice, this was captured by the solvency ratio, which was defined as the share of capital relative to its risk-weighted assets.

A smaller proportion of own resources relative to the total balance sheet signalled greater financial leverage. While this could enhance returns, it simultaneously reduced the institution's protection against defaults on the loans that were recorded among its assets.

The capital adequacy ratio $CAR_b(t)$ is computed as:

$$CAR_b(t) = \frac{E_b(t)}{RWA_b(t)}, \quad (C.36)$$

where $E_b(t)$ denotes Tier 1 capital and $RWA_b(t)$ represents the bank's risk-weighted assets.

Risk-weighted assets are calculated as the weighted exposure to different loan categories:

$$RWA_b(t) = \sum_{j=1}^J \omega_{j,b}(t) L_{j,b}(t), \quad (C.37)$$

where $L_{j,b}(t)$ is the value of loans of type j held by bank b and $\omega_{j,b}(t)$ is the corresponding regulatory risk weight. The vector of risk weights $\omega_b(t) = [\omega_{1,b}(t), \dots, \omega_{J,b}(t)]$ reflects heterogeneity across loan categories and across banks, consistent with regulatory standards.

The leverage ratio ($LR_b(t)$) is computed as:

$$LR_b(t) = \frac{E_b(t)}{TA_b(t)} \quad (C.38)$$

where $E_b(t)$ was the TIER 1 capital and $TA_b(t)$ were the consolidated total assets. This corresponds to the Basel III definition of the leverage ratio, which does not rely on risk-weighted assets. It was also straightforward to compute the other measures of leverage such as the debt-to-equity ratio or debt-to-capital ratio.

C.5.3.3 Liquidity of Banks

The liquidity coverage ratio (LCR) measures the proportion of high-quality liquid assets held by a financial institution to ensure its ability to meet short-term obligations.

$$LCR_b(t) = \frac{HQLA_b(t)}{TCF_b(t)} \quad (C.39)$$

where $HQLA_b(t)$ denotes high-quality liquid assets and $TCF_b(t)$ represents total net cash outflows. In the model, $HQLA_b(t)$ is approximated as:

$$HQLA_b(t) = Res_b(t) + Cash_b(t) + \min\{0.85 B_b(t), 0.75 \times [Res_b(t) + Cash_b(t)]\} \quad (C.40)$$

where $Res_b(t)$ denotes reserves, $Cash_b(t)$ denotes cash, and $B_b(t)$ represents sovereign bonds.

Total net cash outflows are given by:

$$TCF_b(t) = \mathbb{E}[OUT]_b(t) - \mathbb{E}[IN]_b(t) \quad (C.41)$$

Expected outflows:

$$\mathbb{E}[OUT]_b(t) = \zeta_1 + \zeta_2 d_b(t) + \zeta_3 L_b^{CB}(t) \quad (C.42)$$

where $d_b(t)$ denotes deposits and $L_b^{CB}(t)$ is the liquidity drawn from the central bank.

Expected inflows:

$$\mathbb{E}[IN]_b(t) = \zeta_4 - \zeta_5 + \zeta_6 Cash_b(t) + \zeta_7 B_b(t) + \zeta_8 Res_b(t) \quad (C.43)$$

C.5.3.4 Regulatory Framework

Below we outline how additional regulatory capital buffers could be incorporated into the model. These buffers follow the Basel III and EU CRR/CRD IV & V regulatory framework.

COMBINED BUFFER REQUIREMENT.

$$CBR_b(t) = \beta^{CCoB} + \beta_b^{CCB}(t) + \beta_b^{GSIB} + \beta_b^{OSII} + \beta_b^{SRB}(t) \quad (C.44)$$

Total capital buffer requirement faced by bank b at time t .

$$\frac{CET1_b(t)}{RWA_b(t)} \geq \kappa^{P1} + \kappa_b^{P2}(t) + CBR_b(t) \quad (C.45)$$

Banks must hold sufficient CET1 capital relative to risk-weighted assets.

CAPITAL CONSERVATION BUFFER (CCoB).

$$\beta^{CCoB} > 0 \quad (C.46)$$

A fixed buffer that must always be maintained.

COUNTERCYCLICAL CAPITAL BUFFER (CCB).

$$\beta_b^{CCB}(t) = \sum_c \omega_{b,c}(t) \beta_c^{CCB}(t), \quad \sum_c \omega_{b,c}(t) = 1 \quad (C.47)$$

$$\beta_c^{CCB}(t) = \min\left\{\bar{\beta}^{CCB}, \lambda^{CCB} \max(0, g_c(t) - g_c^*)\right\} \quad (C.48)$$

The bank's CCB is a jurisdiction-weighted average of local CCBs, which respond to credit cycle conditions.

G-SIB BUFFER (GLOBAL SYSTEMICALLY IMPORTANT BANKS).

$$\beta_b^{\text{GSIB}} = \sum_{k=1}^K \beta_k^{\text{G}} \mathbb{I}\{\text{bucket}_b = k\} \quad (\text{C.49})$$

G-SIB buffers depend on the systemic importance bucket assigned to each bank.

O-SII BUFFER (OTHER SYSTEMICALLY IMPORTANT INSTITUTIONS).

$$\beta_b^{\text{OSII}} \in [0, \bar{\beta}^{\text{O}}] \quad (\text{C.50})$$

Additional buffer applied to banks identified as O-SIIs by the national authority.

SYSTEMIC RISK BUFFER (SRB).

$$\beta_b^{\text{SRB}}(t) = \bar{\beta}^{\text{SRB}} \quad \text{or} \quad \beta_b^{\text{SRB}}(t) = \sum_{j=1}^J \sigma_j \frac{L_{j,b}(t)}{\sum_{m=1}^J L_{m,b}(t)} \quad (\text{C.51})$$

SRB may be constant or linked to a bank's asset structure (e.g. higher weights for real estate or corporate lending).

Symbol	Definition
b	Bank index
t	Time period
$\text{CET1}_b(t)$	Common Equity Tier 1 capital of bank b
$\text{RWA}_b(t)$	Risk-weighted assets of bank b
κ^{P1}	Pillar 1 CET1 minimum requirement
$\kappa_b^{\text{P2}}(t)$	Pillar 2 requirement for bank b
β^{CCoB}	Capital Conservation Buffer
$\beta_b^{\text{CCB}}(t)$	Countercyclical buffer for bank b
$\beta_c^{\text{CCB}}(t)$	Countercyclical buffer in jurisdiction c
$\omega_{b,c}(t)$	Share of bank b 's RWA in jurisdiction c
$\bar{\beta}^{\text{CCB}}$	Maximum CCB
λ^{CCB}	Sensitivity of CCB to credit cycle
$g_c(t)$	Credit cycle indicator in jurisdiction c
g_c^*	Activation threshold for CCB
β_b^{GSIB}	G-SIB buffer for bank b
β_k^{G}	G-SIB buffer for bucket k
bucket_b	G-SIB bucket allocation
β_b^{OSII}	O-SII buffer for bank b
$\bar{\beta}^{\text{O}}$	Maximum O-SII buffer
$\beta_b^{\text{SRB}}(t)$	Systemic Risk Buffer
$\bar{\beta}^{\text{SRB}}$	Constant SRB level
σ_j	SRB weight for loan class j
$L_{j,b}(t)$	Loans of type j issued by bank b
J	Number of loan classes

C.5.4 Interest Rates of Banks

There are two options in the model. The first assumed that the proprietary data on the interest rates of the commercial banks that were collected by the central banks could be used. In the second approach, the interest rates that fed the system were

- the average interest rates that were used by commercial banks¹³
- the (Warsaw) Interbank Offered Rate (WIBOR) and the Interbank Offer Bid Rate (WIBID) until 2022
- the (Warsaw) Interest Rate Overnight (WIRON) and (Warsaw) Index for Deposit Market (WIRD) since the beginning of 2023.

WIBOR and WIBID were used by commercial banks as a reference point for calculating interest rates on loans and deposits, respectively, until 2022. WIRON and WIRD replaced WIBOR and WIBID at the beginning of 2023.

The differences between the offered rates of commercial banks and WIBOR (or since 2023 WIRON) were used to approximate the average risk perception indices at $t = 0$.

The risk perception indicators were the mark-ups that banks added to the average rate that was offered on the interbank market (WIBOR/WIRON) that ensured the desired level of profits while assuming an acceptable level of risk.

In practice, however, each transaction on the market could be conducted at a different interest rate. The interest rate that a borrower had to pay depended on their risk profile. A lender wanted to earn a profit at an acceptable level of risk. Risk perception indicators were therefore assigned to individuals and firms in the model at $t = 0$ and the mean values were computed at the end of a given iteration.

At $t > 0$, the values of the indicators were recalculated according to the risk profiles of individuals and firms. For individuals, the variable probability of default (which was estimated taking into account the labour status, income, number of dependents and debt burden) was taken into account. For firms, the probability of going bankrupt, which depended on the level of debt/leverage, return to equity, market value and the riskiness of the sector(s) where the firm operated was considered.

The average values of the risk perception indicators were also corrected for the ratio of the non-performing loans to all of the loans that were granted (of a specific type, e.g. consumer loans, mortgages, investment loans and short-term loans to firms). The average values could be easily compared with the values that were based on the average interest rates that were published by the central bank.

C.5.5 Supply of Credit

Banks evaluated how much revenue they were able to generate from the different types of loans (consumer loans, mortgages and short-term loans to firms and investment firms) and how much they would lose due to non-performing loans of a specific type.

The banks ordered the net revenues and rearranged their strategy to make a profit out of the more profitable sectors, e.g. lending more to firms than to individuals. These changes are never quick or abrupt as there is a great deal of persistence on the market (and many banks specialise in a specific type of lending).

Notes

1. In Poledna et al. (2023) and Hommes et al. (2022) only individuals over 15 years old were included, while in our model, we used the HFCS data in which all ages were included.
2. In contrast to Poledna et al. (2023) and Hommes et al. (2022), the number of inactive people and the number of investors were not constant, in our approach both inactive people and investors could change their labour status (their activity status was not permanently assigned to them for the entire simulation). In Poledna et al. (2023) and Hommes et al. (2022), an agent's employment status could only change from employed to unemployed (and unemployed to employed).
3. In Poledna et al. (2023), "If unemployed, the person looks for a job on the labour market from firms with open vacancies in random order and applies for a job through a search-and-matching process". Person accepts only a job from the first hiring firm in the same industry as their previous employer. This is unrealistic. This implies no industry switching and artificially multiplies vacancies. The authors

4. The stochastic component ε_i is i.i.d. with $\mathbb{E}[\varepsilon_i] = 1$, ensuring that the shock generates cross-sectional heterogeneity in wages without shifting the mean wage level. This specification also prevents persistence or cross-agent correlation in the random component, keeping heterogeneity purely idiosyncratic.
5. Entrepreneurs primarily work for their own companies and do not simply live off shares and dividends.
6. In Hommes et al. (2022) as a robustness check, they allowed households to form their expectation of the inflation rate based on CPI inflation instead of the GDP deflator inflation and they claim that the differences were negligible.
7. In Hommes et al. (2022) in their considerations, they introduced the relative average price of the goods in the previous period to the consumer price index in the previous period.
8. In Poledna et al. (2023) and Hommes et al. (2022), these effects were not taken into account. They also assumed that interest rates and receipts did not enter into the household's consumption decisions and thus generated no wealth effects on consumption. We took these effects into account.
9. In Poledna et al. (2023) and Hommes et al. (2022), these effects were not taken into account. They also assumed that interest rates and receipts did not enter into the household's consumption decisions and thus generated no wealth effects on consumption. We took these effects into account.
10. Liquid assets are the current state of deposits after adding savings and subtracting the debt burden before adjusting for other positions, e.g., selling/buying properties.
11. In appendix, the values of the parameters that describe the supplier searching for and matching in the model are presented.
12. We do not model the central bank balance sheet and strategy but we can assume that there is a variable called bonds which is updated in the model as if the central bank was buying them. This assumption, however, can easily be changed in the future. It can be assumed that individuals can use their deposits not only to invest in shares but also to purchase governmental bonds (this solution, however, has not yet been implemented in the code). Moreover, also firms could invest in bonds using liquid assets.
13. This data is published by the Bank of Poland.

D Tables and Figures

D.1 Variables in the Model

Table D.1 Individuals.

Variable	Explanation	Source of data	Type	Restr.	Note
$i \in N$	N — set of individuals. Each individual i is characterised by an identifier (ID).	HFCS ID created based on the identifier from the "P" dataset for individuals.	Int.	≥ 0	1*
$h \in H$	H — set of households. Each individual i is mapped to a household h .	HFCS HID created by matching IDs from "P" and "H" datasets.	Int.	≥ 0	1*
$A_i(t)$	Age of individual i at time t .	HFCS "RA0300" from "P" dataset. Imputation of 12 records.	Double	$\in (0, 100]$	2*
$ED_i(t)$	Education level of individual i at time t .	HFCS "PA0200" from "P" dataset. For 2330 children, imputed as 1. 1 — Early childhood/no education/primary; 2 — Lower secondary; 3 — Upper secondary/post-sec.; 4 — Short-cycle tertiary; 5 — Bachelor/Master/Doctoral. Computed using $ED_i(t)$ and $A_i(t)$.	Int.	$\in \{1, 2, 3, 4, 5\}$	2*
$PE_i(t)$	Number of quarters of education completed.		Int.	≥ 0	2*
G_i	Gender of individual i .	HFCS "RA0200". Mapping: HFCS 2 $\rightarrow$ 0 (female), 1 otherwise.	Boolean	$\in \{0, 1\}$	2*
$M_i(t)$	Civil status of individual i .	HFCS "PA0100". 1 single; 2 married/union; 3 widow(er); 4 divorced.	Int.	$\in \{1, 2, 3, 4\}$	2*
$\Xi_i(t)$	Labour-market status.	HFCS "PE0100a" & "PE0100b". Mapping: 4 $\rightarrow$ child/student (1); 1,2,7 $\rightarrow$ employed (3); 3 $\rightarrow$ unemployed (2); 5,6,8,9 $\rightarrow$ inactive (4). Entrepreneur (5) if "HD0200"=1 OR "HD0210">0.	Int.	$\in \{1, 2, 3, 4, 5\}$	3*
$\Psi_i(t)$	Quarters since last labour-market status change.	HFCS "PE0700" for employees only; 0 otherwise.	Int.	≥ 0	3*
$\Theta_i(t)$	Skills of worker.	Estimated from HFCS (logit model).	Double	$\in [0, 1]$	3*

1* — Individual & household mapping.

2* — Demographic characteristics.

3* — Labour-market characteristics.

Table D.2 Individuals – continuation.

Variable	Explanation	Source of data	Type	Restr.	Note
$E_i(t)$	The variable that determined whether an individual was an entrepreneur at time t	HFCS If ("HD0200"=1 "HD0210">0) from "H" database for households and then for each adult in the household, the value 1 is assigned at $t = 0$	Boolean	$\in \{0, 1\}$	4*
$Z_i(t)$	The variable that determined whether an individual was an entrepreneur in the past	1 if $E_i(t) = 1$ at least once during the simulation. At $t = 0$, if $E_i(t) = 1$ then $Z_i(t) = 1$, zero otherwise.	Boolean	$\in \{0, 1\}$	4*
$P_i(t)$	The probability of becoming an entrepreneur in the future (expectations)	Values from the logit model estimated on the HFCS data.	Double	$\in (0, 1)$	4*
$j \in J$	Identification code of the establishment in which the individual worked	For each entrepreneur, an establishment and firm were created (IDs). Individuals with $\Xi_i(t) = 3$ $\Xi_i(t) = 5$ matched with establishments. "NULL" for $\Xi_i(t) \in \{1, 2, 4\}$. Establishment assigned randomly for employees; Monte Carlo checks performed.	Int.	≥ 0	4*
$I_i(t)$	Income of individual i at time t	HFCS Sum of "PG0110", "PG0210", "PG0310", "PG0410" from "P" + "HG0410", "HG0510", "HG0610" from "H" divided by the number of adults in the household	Double	–	5*
$W_i(t)$	Wage of individual i at time t	HFCS "PG0110" + "PG0210" from "P"	Double	≥ 0	5*
$PA_i(t)$	Public assistance for individual i at time t	HFCS "PG0510" from "P"	Double	≥ 0	5*
$\psi_i(t)$	Shares of individual i in large and medium-sized firms	HFCS "HD1010" from "H" divided by adults in household	Double	≥ 0	5*
$A_i(t)$	Assets of individual i at time t	HFCS "DA3001" - ("DA1140"+"DA2105"+"DA2104") from "D"	Double	≥ 0	5*
$PD_i(t)$	Probability of default of individual i at time t	Logit model on HFCS data	Double	$\in (0, 1)$	6*

4* – Entrepreneur and establishment assignment

5* – Income and welfare-related variables

6* – Individual PD used by banks

Table D.3 Individuals – continuation.

Variable	Explanation	Source of data	Type	Restr.	Note
$b_i^d(t) \in B$	Bank matched to the individual where deposits (savings) were held at time t . B is the set of banks in the model.	Randomly matched. Robustness checks performed.	Int.	≥ 0	7*
$b_i^c(t) \in B$	First-choice bank for a consumer loan at time t .	Randomly matched; robustness checks as above.	Int.	≥ 0	7*
$b_i^h(t) \in B$	First-choice bank for a housing loan at time t .	Randomly matched; robustness checks as above.	Int.	≥ 0	7*
$b_i^l(t) \in B$	First-choice bank for an investment loan at time t .	Randomly matched; robustness checks as above.	Int.	≥ 0	7*
$D_i^C(t)$	Total outstanding consumer-loan liabilities of individual i at time t .	HFCS "DL1200" from the "D" (derived) dataset, divided by number of adults in household at $t = 0$. Drawn from $\text{Unif}\{1, 20\}$ due to missing values in Polish HFCS.	Double	≥ 0	8*
M_i^C	Consumer-loan maturity in quarters.		Int.	≥ 0	8*
$D_i^{Cq}(t)$	Quarterly principal repayment on consumer loans at time t .	Computed from $D_i^C(t)$, M_i^C , and the interest rate.	Double	≥ 0	8*
$R_i^C(t)$	Total interest due on consumer loans of i at time t .	Computed.	Double	≥ 0	8*
$R_i^{Cq}(t)$	Quarterly interest on consumer loans of i .	Computed.	Double	≥ 0	8*
$N_i^C(t)$	Number of consumer loans.	Indicator: 1 if $D_i^C(t) > 0$, 0 otherwise.	Boolean	$\in \{0, 1\}$	8*
$D_i^{KE}(t)$	Total outstanding mortgage liabilities of i at t .	HFCS "DL1100" divided by adults in household at $t = 0$.	Double	≥ 0	9*
M_i^{RE}	Mortgage maturity in quarters.	Computed from loan value, instalments, and interest rate.	Int.	≥ 0	9*
$D_i^{REq}(t)$	Quarterly mortgage principal repayment at t .	HFCS "DL2100" divided by adults in household at $t = 0$.	Double	≥ 0	9*
$R_i^{RE}(t)$	Total interest due on mortgages of i at t .	Computed.	Double	≥ 0	9*
$R_i^{REq}(t)$	Quarterly mortgage interest of i .	Computed.	Double	≥ 0	9*

7* – Matching individuals with banks.

8* – Consumer loans.

9* – Mortgages.

Table D.4 Individuals – continuation.

Variable	Explanation	Source of data	Type	Restr.	Note
$D_i^l(t)$	Outstanding investment-loan liabilities of i at time t	Approximation based on Statics Poland (GUS) / National Bank of Poland (NBP) data (to be refined)	Double	≥ 0	10*
M_i^l	Maturity of investment loans (quarters)	Approximation based on GUS / NBP data (to be refined)	Int.	≥ 0	10*
$D_i^{lq}(t)$	Quarterly principal repayment of investment loans at t	Computed based on $D_i^l(t)$, M_i^l and interest rate	Double	≥ 0	10*
$R_i^l(t)$	Total interest due on investment loans of i at t	Computed (approximation to be refined)	Double	≥ 0	10*
$R_i^{lq}(t)$	Quarterly interest on investment loans of i	Computed	Double	≥ 0	10*
$\vartheta_i^1(t)$	Spatial code (NUTS1)	Drawn from $\text{Unif}\{1, 7\}$ (not available in HFCS; Monte Carlo performed)	Int.	$\in \{1, \dots, 7\}$	11*
$\vartheta_i^2(t)$	Spatial code (NUTS2)	Drawn from $\text{Unif}\{1, 17\}$	Int.	$\in \{1, \dots, 17\}$	11*
$\vartheta_i^3(t)$	Spatial code (NUTS3)	Drawn from $\text{Unif}\{1, 73\}$	Int.	$\in \{1, \dots, 73\}$	11*
$\zeta_i^{ON}(t)$	Perceived risk indicator (overnight market)	If $= 0 \rightarrow$ reference interest rate (initial period) is used	Double	$\in (0, 1)$	12*
$\zeta_i^{SW}(t)$	Perceived risk indicator (SW)	If $= 0 \rightarrow$ reference interest rate used	Double	$\in (0, 1)$	12*
$\zeta_i^{1M}(t)$	Perceived risk indicator (1-month)	If $= 0 \rightarrow$ reference interest rate used	Double	$\in (0, 1)$	12*
$\zeta_i^{3M}(t)$	Perceived risk indicator (3-month)	If $= 0 \rightarrow$ reference interest rate used	Double	$\in (0, 1)$	12*
$\zeta_i(t)$	Perceived uncertainty indicator	If $= 0 \rightarrow$ reference interest rate used	Double	$\in (0, 1)$	12*

10* – Investment loans.

11* – Geolocation (NUTS levels, Monte Carlo assignment).

12* – Perceived risk and uncertainty (expectations).

Table D.5 Households.

Variable	Explanation	Source of data	Type	Restr.	Note
$h \in H$	H – set of households. Each household h has a household identifier (HID).	HID created by matching IDs from the "P" and "H" HFCS datasets.	Int.	≥ 0	1*
$O_h(t)$	Ownership status at time t (homeowner indicator)	HFCS 1 if "DA1110i" = 1 $\vee$ "DA1120i" = 1; 0 otherwise	Boolean	$\in \{0, 1\}$	1*
$p_h^1(t)$	Primary property ID (main residence)	Generated IDs; matched to households (owners/renters)	Int.	≥ 0	1*
$p_h^2(t)$	Secondary property ID (rental or vacant for sale)	HFCS "HB2410" (number and value of other properties)	Int.	≥ 0	1*
$\kappa_h(t)$	Housing cost (mortgage or rent)	HFCS "HB0410" from the "H" dataset (converted to quarterly)	Double	≥ 0	1*
$I_h(t)$	Household income at time t	HFCS "DI2000" from the "D" derived dataset at $t = 0$	Double	≥ 0	2*
$I_h^{RE}(t)$	Rental income	HFCS "DI1300" from the "D" derived dataset at $t = 0$	Double	≥ 0	2*
$\chi_h(t)$	Donations (including alimony)	HFCS "HNH0800" from the "HN" dataset	Double	≥ 0	3*
$DSTI_h(t)$	Debt service–to–income ratio	HFCS "DODSTOTALp" from the "D" derived dataset	Double	≥ 0	4*
$DTA_h(t)$	Debt–to–assets ratio	HFCS "DODARATIO" from the "D" derived dataset	Double	≥ 0	4*
$DTI_h(t)$	Debt–to–income ratio	HFCS "DODIRATIO" from the "D" derived dataset	Double	≥ 0	4*
$LTV_h(t)$	Loan–to–value ratio	HFCS "DOLTVRATIO" from the "D" derived dataset	Double	≥ 0	4*

1* – Matching households with properties.

2* – Household income.

3* – Transfers / donations.

4* – Household prudential ratios.

Table D.6 Consumers.

Variable	Explanation	Source of data	Type	Restr.	Note
$h_c \in H^C$	H^C – set of consumer agents. Each household h consumes from S sectors, so $ H^C = H \times S $. Each household–sector pair forms one consumer h_c .	Constructed in the model by combining household IDs with sector codes	Int.	≥ 0	1*
$h \in H$	Household identifier to which consumer h_c belongs	HFCS Matched IDs from "P" and "H" datasets	Int.	≥ 0	1*
$s \in S$	Sector code for consumer h_c	Model (sectoral classification)	Int.	≥ 0	1*
$j_s \in J$	Establishment (supplier) serving consumer h_c in sector s	Model (firm–establishment structure)	Int.	≥ 0	1*
$CT_c(t)$	Consumer type: 1 – single ≥ 67 ; 2 – single < 67 ; 3 – couple w/ ≥ 1 adult ≥ 67 ; 4 – couple both < 67 ; 5 – household w/ children; 6 – extended (> 2 adults).	HFCS Derived from household structure	Int.	$\in \{1, \dots, 6\}$	2*
N_h^{ad}	Number of adults in household h	HFCS	Int.	≥ 0	2*
N_h^{ch}	Number of children in household h	HFCS	Int.	≥ 0	2*
$\bar{A}_h$	Mean age of adults in household h (elderly threshold proxy)	HFCS	Double	$\in (0, 100]$	2*
I_h	Indicator whether household has a member ≥ 67	Derived from A_i	Boolean	$\in \{0, 1\}$	2*
$Q^{hc}(t)$	Quantity of goods purchased by consumer h_c in sector s at time t	Model (demand function based on income and type)	Double	≥ 0	3*
$\omega_{hc,s}$	Sector–specific consumption weight for consumer type CT_c	Calibrated using HFCS budget shares / survey data	Double	$\in [0, 1]$	3*

1* – Mapping households into consumer–sector units.

2* – Assigning consumer types from HFCS composition.

3* – Demand per sector via consumer type and budget shares.

Table D.7 Properties.

Variable	Explanation	Source of data	Type	Restr.	Note
$p \in P$	P – set of properties. Each property p has a property identifier (PID).	HFCS PID created based on the number of properties owned by households. A property is created when "DA1110i" = 1 (or when "HB2410" > 0 for an additional property).	Int.	≥ 0	1*
$h \in H$	H – set of households. Each household h has a household identifier (HID).	HFCS HID created by matching IDs from the "P" (individuals) and "H" (households) datasets.	Int.	≥ 0	1*
$\mathbb{R}_{p_h}(t)$	Number of households renting property p_h owned by h at time t	Model (auxiliary variable); at $t = 0$, set to 1 if rented, 0 otherwise	Int.	≥ 0	2*
$p_h^{HMR}(t)$	Main residence indicator for household h	HFCS 1 if "DA1110i" = 1, 0 otherwise	Boolean	$\in \{0, 1\}$	2*
$\Xi_{p_h}(t)$	Property value (price)	HFCS "HB0900" for main residence; "HB280x" for other properties. For Poland: "HB0100" $\times$ avg. market price per m ² . Model: 1 if property is empty (potential to sell), 0 otherwise	Double	≥ 0	2*
$PS(t)$	For-sale indicator		Boolean	$\in \{0, 1\}$	2*
$\vartheta_p^1(t)$	Spatial code (NUTS 1)	Not available in HFCS. Assigned via Monte Carlo draws from Unif{1, 7}	Int.	$\in \{1, \dots, 7\}$	3*
$\vartheta_p^2(t)$	Spatial code (NUTS 2)	Not available in HFCS. Assigned via Unif{1, 17}	Int.	$\in \{1, \dots, 17\}$	3*
$\vartheta_p^3(t)$	Spatial code (NUTS 3)	Not available in HFCS. Assigned via Unif{1, 73}	Int.	$\in \{1, \dots, 73\}$	3*

1* – Identification of properties and household linkage.

2* – Rental status, residence indicator, and valuation.

3* – Geolocation (NUTS levels assigned via Monte Carlo).

Table D.8 Property owners.

Variable	Explanation	Source of data	Type	Restr.	Note
$p \in P$	P – set of properties. Each property p has a property identifier (PID).	HFCS PID created based on the number of properties reported by households in the HFCS dataset.	Int.	≥ 0	1*
$h \in H$	H – set of households. Each household h has a household identifier (HID).	HFCS HID created by matching IDs from the "P" and "H" datasets.	Int.	≥ 0	1*

1* – Mapping HFCS households to owned real-estate units (properties).

Table D.9 Firms.

Variable	Explanation	Source of data	Type	Restr.	Note
$f \in F$	F – set of firms. Each firm f has a firm identifier (FID).	GUS F-01 ID created from firms' IDs in F-01.	Int.	≥ 0	1*
$s \in S$	Sector in which the firm's establishments operate.	Auxiliary to GUS F-01 PKD 2007 (NACE Rev. 2) code.	Int.	≥ 0	1*
$\aleph_j(t)$	Number of establishments of a firm across sectors.	Auxiliary to GUS F-01 Same FID with different NACE codes.	Int.	≥ 0	2*
$\aleph_i(t)$	Number of employees in the firm.	GUS F-01 (76) Avg. full-time employees; (77) employees.	Int.	≥ 0	2*
$\aleph_T(t)$	Number of periods the firm has operated.	Model variable; initialised as 1 at $t = 0$.	Int.	≥ 0	2*
$MV_f(t)$	Monetary value of the firm.	Computed in the simulation.	Double	≥ 0	3*
$\Pi_f(t)$	Profits generated by the firm.	GUS F-01 (58) Gross profit – (63) other mandatory reductions.	Double	≥ 0	3*
$\tau_{\pi_f}(t)$	Taxes on profits.	GUS F-01 (60) Taxes (or (61) current part, excl. deferred).	Double	≥ 0	3*
$D_f(t)$	Firm debt (losses).	GUS F-01 (58) Gross loss + (63) mandatory loss increase.	Double	≥ 0	3*
$K_f(t)$	Firm fixed capital.	GUS F-01 (18) Shares + (19) contributions to share capital.	Double	≥ 0	3*
$LA_f(t)$	Firm liquid assets.	GUS F-01 (04) Liquid assets.	Double	≥ 0	3*
$FS_f(t)$	Firm marked for sale.	GUS F-01 Based on market value, debt, profitability ratios.	Boolean	$\in \{0, 1\}$	4*
$FR_f(t)$	Financial risk indicator.	GUS F-01 Based on key financial ratios.	Double	$\in (0, 1)$	4*
$PD_f(t)$	Probability of default.	Credit registry (confidential) or econometric PD estimate.	Double	$\in (0, 1)$	4*

1* – Firm and sector identifiers (HFCS mapping equivalent)

2* – Firm size and activity characteristics

3* – Firm balance sheet and performance variables

4* – Firm risk, sale flag and probability of default

Table D.10 Firms' owners.

Variable	Explanation	Source of data	Type	Restr.	Note
$f \in F$	Set of firms. Each firm f has a unique FID.	GUS F-01 Firm identifiers constructed from F-01 database.	Int.	≥ 0	1*
$i \in N$	Set of individuals linked as firm owners/shareholders.	HFCS Individuals classified as entrepreneurs/ shareholders.	Int.	≥ 0	1*

1* – Mapping HFCS individuals to GUS F-01 firms to identify owners/shareholders.

Table D.11 Establishments.

Variable	Explanation	Source of data	Type	Restr.	Note
$e \in E$	E – set of establishments; at $t = 0$ one per firm, $t > 0$ firms may open multiple establishments across sectors.	GUS F-01 Derived from firm IDs.	Int.	≥ 0	1*
$f \in F$	Firm identifier to which establishment e belongs.	GUS F-01	Int.	≥ 0	1*
$b_e^{ST} \in B$	Bank providing short-term financing.	Random matching (alternative: NBP NB300).	Int.	≥ 0	2*
$TC_e(t)$	Total costs at t .	GUS F-01 (cost side)	Double	≥ 0	2*
$TC_e(t-1)$	Total costs at $t-1$.	GUS F-01 (adjusted)	Double	≥ 0	2*
$PD_e(t)$	Probability of default.	Model / F-01 calibration	Double	$\in \langle 0, 1 \rangle$	2*
$Q_e^d(t)$	Demand for goods/services.	Approx. at $t = 0$, endogenous later	Double	≥ 0	2*
$E(Q_e^d(t))$	Expected demand.	Model-generated	Double	≥ 0	2*
$IN_e(t)$	Monetary inputs required for production.	Computed in the model	Double	≥ 0	2*
$Y_e(t)$	Output.	Production function	Double	≥ 0	2*
$EL_e(t)$	Export/import status.	GUS F-01	Int.	$\in \{0, 1, 2, 3\}$	3*
$K_e(t)$	Fixed assets.	GUS F-01	Double	≥ 0	3*
$LA_e(t)$	Liquid assets.	GUS F-01	Double	≥ 0	3*
$A_e(t)$	Technology / know-how proxy.	GUS F-01	Double	≥ 0	3*
$EN_e(t)$	New establishment indicator.	Model	Boolean	$\in \{0, 1\}$	3*
$\varsigma_e(t)$	Perceived risk indicator.	Random draw / future estimation	Double	$\in \langle 0, 1 \rangle$	4*
$\zeta_e(t)$	Perceived uncertainty.	Random draw / future estimation	Double	$\in \langle 0, 1 \rangle$	4*
$P_e(t)$	Price at t .	Set to 1 at $t = 0$	Double	≥ 0	4*
$P_e(t-1)$	Price at $t-1$.	Set to 1 at $t = 0$	Double	≥ 0	4*

1* – Identification of establishments and assignment to firms.

2* – Cost structure, demand and production variables.

3* – Trade status and asset structure.

4* – Expectations: risk, uncertainty and pricing.

Table D.12 Establishments.

Variable	Explanation	Source of data	Type	Restr.	Note
$e \in E$	E – set of establishments; at $t = 0$ one per firm, $t > 0$ firms may open multiple establishments across sectors.	GUS F-01 Derived from firm IDs.	Int.	≥ 0	1*
$f \in F$	Firm identifier to which establishment e belongs.	GUS F-01	Int.	≥ 0	1*
$b_e^{ST} \in B$	Bank providing short-term financing.	Random matching (alternative: NBP NB300).	Int.	≥ 0	2*
$TC_e(t)$	Total costs at t .	GUS F-01 (cost side)	Double	≥ 0	2*
$TC_e(t-1)$	Total costs at $t-1$.	GUS F-01 (adjusted)	Double	≥ 0	2*
$PD_e(t)$	Probability of default.	Model / F-01 calibration	Double	$\in \langle 0, 1 \rangle$	2*
$Q_e^d(t)$	Demand for goods/services.	Approx. at $t = 0$, endogenous later	Double	≥ 0	2*
$E(Q_e^d(t))$	Expected demand.	Model-generated	Double	≥ 0	2*
$IN_e(t)$	Monetary inputs required for production.	Computed in the model	Double	≥ 0	2*
$Y_e(t)$	Output.	Production function	Double	≥ 0	2*
$EL_e(t)$	Export/import status.	GUS F-01	Int.	$\in \{0, 1, 2, 3\}$	3*
$K_e(t)$	Fixed assets.	GUS F-01	Double	≥ 0	3*
$LA_e(t)$	Liquid assets.	GUS F-01	Double	≥ 0	3*
$A_e(t)$	Technology / know-how proxy.	GUS F-01	Double	≥ 0	3*
$EN_e(t)$	New establishment indicator.	Model	Boolean	$\in \{0, 1\}$	3*
$\varsigma_e(t)$	Perceived risk indicator.	Random draw / future estimation	Double	$\in \langle 0, 1 \rangle$	4*
$\zeta_e(t)$	Perceived uncertainty.	Random draw / future estimation	Double	$\in \langle 0, 1 \rangle$	4*
$P_e(t)$	Price at t .	Set to 1 at $t = 0$	Double	≥ 0	4*
$P_e(t-1)$	Price at $t-1$.	Set to 1 at $t = 0$	Double	≥ 0	4*

1* – Identification of establishments and assignment to firms.

2* – Cost structure, demand and production variables.

3* – Trade status and asset structure.

4* – Expectations: risk, uncertainty and pricing.

Table D.13 Sectors (Industries).

Variable	Explanation	Source of data	Type	Restr.	Note
Id_s	Sector identifier (NACE section code)	NACE Rev. 2 / PKD 2007 classification	Int.	≥ 0	
$\bar{\pi}_s(t)$	Avg. profitability of firms in sector s	CSO F-01 & Input-Output Tables Based on firms' profits (also at $t = 0$)	Double	≥ 0	1*
$\overline{Risk}_s(t)$	Avg. financial risk of industry s	CSO F-01 Based on firms' financial risk (also at $t = 0$)	Double	$\in (0, 1)$	1*
$\overline{Sl}_s(t)$	Avg. sales of firms in sector s	CSO F-01 Based on sales of firms with same NACE code	Double	≥ 0	1*
$\Pi_s(t)$	Total profit of establishments in sector s	CSO F-01 Based on sector profits	Double	≥ 0	1*
$\bar{L}_s(t)$	Avg. workforce of establishments in sector s	CSO F-01 Based on workforce (also at $t = 0$)	Double	≥ 0	2*
$SD_s(t)$	Std. deviation of firm sizes in sector s	CSO data Official statistics	Double	≥ 0	2*
$N_s^f(t)$	Number of firms in sector s	CSO F-01 Based on NACE codes in F-01	Int.	≥ 0	2*
$\overline{W}_s(t)$	Avg. wage in sector s	CSO F-01 Based on wages (also at $t = 0$)	Double	≥ 0	2*
$\%Exp_s(t)$	% of establishments that import	CSO F-01 Based on non-zero entries (70.+71.) Imports	Double	≥ 0	3*
$\%Imp_s(t)$	% of establishments that export	CSO F-01 Based on non-zero entries (07.) Exports	Double	≥ 0	3*
$\overline{Ql}_s(t)$	Avg. quality of goods/services in current period	Based on all firms' products in sector	Double	≥ 0	3*
$\bar{P}_s(t)$	Avg. price of goods/services in sector s at t	By design 1 at $t = 1$, then recalculated	Double	≥ 0	4*
$\bar{P}_s(t-1)$	Avg. price of goods/services in sector s at $t-1$	By design 1 at $t = 1$, then recalculated	Double	≥ 0	4*
t^{VAT}	Value added tax rate	Legal regulations for each sector	Double	≥ 0	5*

1* – Profitability & financial risk aggregates by sector.

2* – Labour market structure by industry.

3* – External trade orientation (imports/exports).

4* – Sector price index and inflation dynamics.

5* – Sectoral VAT based on Polish tax schedule.

Table D.14 Suppliers.

Variable	Explanation	Source of data	Type	Restr.	Note
$e \in E$	Establishment ID acting as supplier	Created to identify establishments as suppliers	Int.	≥ 0	
$s \in S$	Sector (industry) identifier	NACE Rev. 2 / PKD 2007 mapping	Int.	≥ 0	
$Q_e^{sup}(t)$	Quantity of goods/services supplied by establishment e at t	Computed within the simulation (supply to firms and households)	Double	≥ 0	1*
$Id_{e \rightarrow j}(t)$	ID of selected supplier establishment e for buyer j at t	Endogenous — matching algorithm based on location, price, quality	Int.	≥ 0	2*

1* – Total output supplied to all buyers and sectors.

2* – Supplier selection driven by model matching mechanism.

Table D.15 Banks.

Variable	Explanation	Source of data	Type	Restr.	
$b \in B$	Bank identifier	Constructed bank groups based on Polish banking structure	Int.	≥ 0	1*
$B_b(t)$	Bonds held	NBP data (approx.)	Double	≥ 0	2*
$CT_b(t)$	Operating costs	NBP at $t = 0$, then persistent with noise	Double	≥ 0	2*
$PD_b(t)$	Probability of bank default	Derived from NPL ratio (NBP supervisory data)	Double	$\in \{0, 0.5, 1\}$	3*
$d_b(t)$	Deposits	NBP at $t = 0$, then updated endogenously	Double	≥ 0	2*
$Rev_b(t)$	Total revenues	Sum of revenues from all loan portfolios	Double	≥ 0	4*
$AvC_b(t)$	Average operating cost level	NBP at $t = 0$, recalculated in simulation	Double	≥ 0	2*
$SdC_b(t)$	Dispersion in bank costs	NBP at $t = 0$, recalculated	Double	≥ 0	2*
$E_b(t)$	Regulatory capital (Tier 1)	NBP at $t = 0$, then updated endogenously	Double	≥ 0	5*
$i_b^C(t)$	Interest rate on consumer loans	NBP rates at $t = 0$, dynamic later	Double	≥ 0	2*
$i_b^D(t)$	Interest rate on deposits	NBP rates at $t = 0$, dynamic later	Double	≥ 0	2*
$i_b^I(t)$	Interest rate on investment loans	NBP rates at $t = 0$, dynamic later	Double	≥ 0	2*
$i_b^{ST}(t)$	Interest rate on short-term loans	NBP data at $t = 0$, dynamic later	Double	≥ 0	2*
$i_b^H(t)$	Interest rate on mortgages	NBP rates at $t = 0$, dynamic later	Double	≥ 0	2*
$DEF_b(t)$	Defaults among bank borrowers	Simulation; credit registry aggregates at $t = 0$	Double	≥ 0	4*
$NPL_b^C(t)$	Net NPL inflow — consumer loans	Simulation	Double	$\in (0, 1)$	4*
$NPL_b^H(t)$	Net NPL inflow — mortgages	Simulation	Double	$\in (0, 1)$	4*
$NPL_b^{ST}(t)$	Net NPL inflow — short-term loans	Simulation	Double	$\in (0, 1)$	4*
$NPL_b^I(t)$	Net NPL inflow — investment loans	Simulation	Double	$\in (0, 1)$	4*
$Rev_b^H(t)$	Revenues from mortgages	Simulation	Double	≥ 0	4*
$Rev_b^C(t)$	Revenues from consumer loans	Simulation	Double	≥ 0	4*
$Rev_b^{ST}(t)$	Revenues from short-term loans	Simulation	Double	≥ 0	4*
$Rev_b^I(t)$	Revenues from investment loans	Simulation	Double	≥ 0	4*

1* – Bank identifiers (groups based on Polish banking structure).

2* – Initial values from NBP; later endogenously updated.

3* – Supervisory default indicator based on NPL ratios.

4* – Endogenous simulation outputs.

5* – Regulatory capital (Tier 1 per CRR/CRD IV&V).

Table D.16 Banks – continuation.

Variable	Explanation	Source of data	Type	Restr.	Note
$S_b^C(t)$	Supply of consumer loans	NBP loan volumes at $t = 0$, scaled to HFCS; endogenously updated	Double	≥ 0	1*
$S_b^I(t)$	Supply of investment loans (firms)	NBP loan volumes at $t = 0$, scaled to F-01; endogenously updated	Double	≥ 0	1*
$S_b^{ST}(t)$	Supply of short-term loans (firms)	NBP loan volumes at $t = 0$, scaled to HFCS; endogenously updated	Double	≥ 0	1*
$S_b^H(t)$	Supply of mortgages	NBP loan volumes at $t = 0$, scaled to HFCS; endogenously updated	Double	≥ 0	1*
$i^{BID}(t)$	Interbank bid rate (WIBID/WIRD)	Market data (NBP, GPW Benchmark)	Double	≥ 0	2*
$i^{OFFER}(t)$	Interbank offered rate (WIBOR/WIRON)	Market data (NBP, GPW Benchmark)	Double	≥ 0	2*

1* – Loan supply initialised from NBP aggregates and scaled to micro data; updated endogenously.

2* – Market benchmark interest rates: WIBID/WIBOR (pre-2022) and WIRD/WIRON (post-2023).

D.2 Sequential Updating of States in the Model

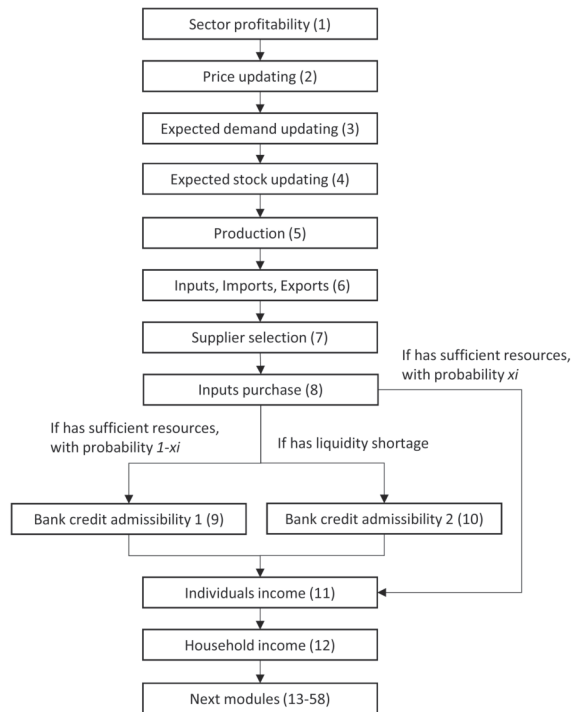


Figure D.1 Sequential updating of states in the model (modules 1–12). The functioning scheme of the model is based on Kaszowska-Mojša & Pipień (2020).

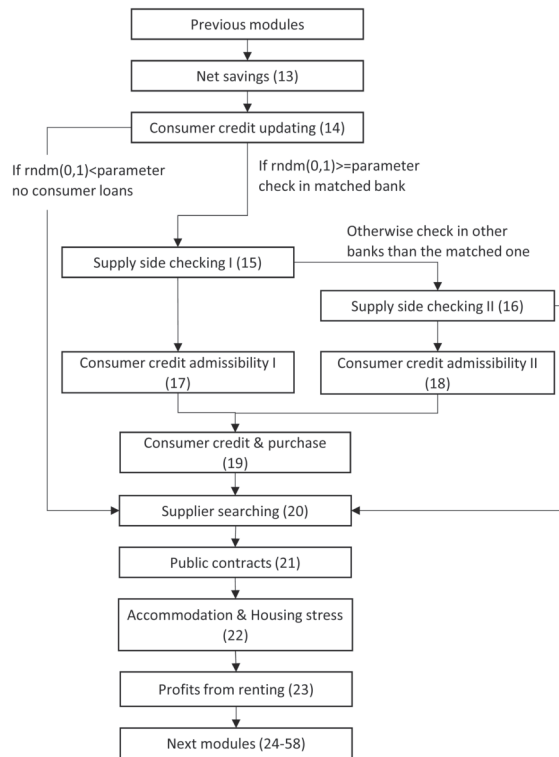


Figure D.2 Sequential updating of states in the model (modules 13–23).

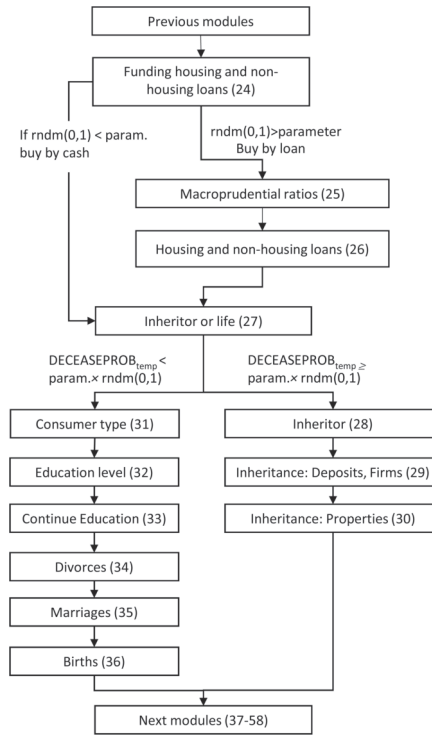


Figure D.3 Sequential updating of states in the model (modules 24–36).

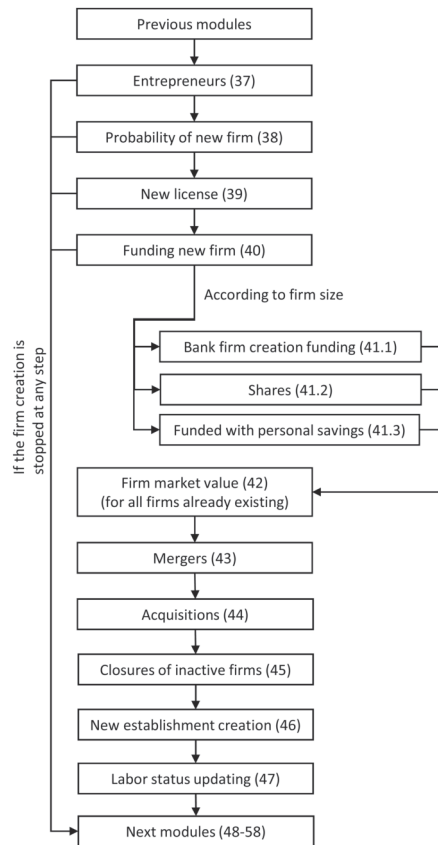


Figure D.4 Sequential updating of states in the model (modules 37–47).

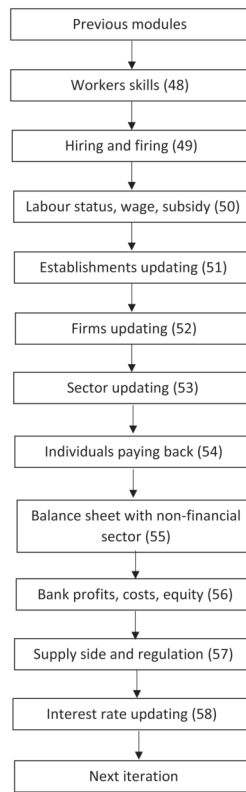


Figure D.5 Sequential updating of states in the model (48–58).

Bibliography

- ABA (2017). The Volcker Rule: Islands of Permission in a Sea of Prohibition. Technical report, American Bankers Association. ABA White Paper.
- Abad, J., Aldasoro, I., Aymanns, C., D'Errico, M., Fache Rousová, L., Hoffmann, P., Langfield, S., Neychev, M., and Roukny, T. (2016). Shedding light on dark markets: First insights from the new EU-wide OTC derivatives dataset. Technical Report 11, European Systemic Risk Board.
- Abreu, D., Félix, S., Oliveira, V., and Silva, F. (2024). The Impact of a Macroprudential Borrower-based Measure on Households' Leverage and Housing Choices. *Journal of Housing Economics*, 64: 11–14.
- Acemoglu, D., Ozdaglar, A., and Tahbaz-Salehi, A. (2015). Systemic Risk and Stability in Financial Networks. *American Economic Review*, 105(2):564–608.
- Aceña, P. M. (2005). La conformación histórica de la industria bancaria española. *Mediterráneo Económico*, pages 21–44.
- Acharya, V., Pedersen, L. H., Philippon, T., and Richardson, M. (2017). Measuring Systemic Risk. *Review of Financial Studies*, 30(1):2–47.
- Acharya, V. V. (2009). Some Steps in the Right Direction: A Critical Assessment of the de Larosière Report. Accessed: 2025-02-14.
- Acharya, V. V. and Richardson, M. (2012). Implications of the Dodd–Frank Act. *Annual Review of Financial Economics*, 4:1–31.
- Acharya, V. V. and Steffen, S. (2012). Analyzing Systemic Risk of the European Banking Sector. In Fouque, J.-P. and Langsam, J. A., editors, *Handbook on Systemic Risk*, pages 247–285. Cambridge University Press, Cambridge.
- Adamus, M., Janus, J., and Kaszowska, J. (2015). Nierównowaga bilansów obrotów bieżących państw Unii Europejskiej w latach 2000–2012 jako zagrożenie dla pełnej europejskiej integracji gospodarczej. In Tendera-Właszczuk, H., editor, *Nowe państwa członkowskie w Unii Europejskiej. Diagnoza i perspektywy*, chapter 8. Difin, Warszawa.
- Admati, A. R., DeMarzo, P. M., Hellwig, M. F., and Pfleiderer, P. (2010). Fallacies, Irrelevant Facts, and Myths in the Discussion of Capital Regulation: Why Bank Equity is *Not* Expensive. Technical Report 2010/42, Max Planck Institute for Research on Collective Goods, Bonn.
- Adrian, T. and Boyarchenko, N. (2018). Liquidity policies and systemic risk. *Journal of Financial Intermediation*, 35. Part B:45–60.

- Adrian, T. and Brunnermeier, M. K. (2008). CoVaR. Staff Report 348, Federal Reserve Bank of New York.
- Adrian, T. and Shin, H. S. (2010). Liquidity and Leverage. *Journal of Financial Intermediation*, 19(3):418–437.
- Afonso, G., Kovner, A., and Schoar, A. (2011). Stressed, Not Frozen: The Federal Funds Market in the Financial Crisis. *The Journal of Finance*, 66:1109–1139.
- Aitken, A. and Aitken, S. (2011). *Mortgage Freedom: Retire House Rich and Cash Rich*. Insomniac Press, Ontario, Canada.
- Akerlof, G. A. and Shiller, R. J. (2009). *Animal Spirits: How Human Psychology Drives the Economy and Why It Matters for Global Capitalism*. Princeton University Press, Princeton, NJ.
- Alam, Z., Alter, A., Eiseman, J., Kang, H., Nier, E., and Wang, N. (2019). Digging deeper: Evidence on the effects of macroprudential policies from a new database. *IMF Working Paper*, (19/66).
- Alegre, J. M. R. (2008). El papel del modelo de “originar para distribuir” en la crisis financiera de 2007. *Estabilidad Financiera*, (15):9–20.
- Aleksiejuk, A., Hołyst, J. A., and Kossinets, G. (2002). Self-Organized Criticality in a Model of Collective Bank Bankruptcies. *International Journal of Modern Physics C*, 13(03):333–341.
- Allen, F., Carletti, E., Goldstein, I., and Leonello, A. (2015). Moral Hazard and Government Guarantees in the Banking Industry. *Journal of Financial Regulation*, 1(1):1–21.
- Allen, F. and Gale, D. (2007). *Understanding Financial Crises*. Clarendon Lectures in Finance. Oxford University Press, Oxford.
- Álvarez Martínez, M. T. (2021). *La política fiscal en España y en la Unión Europea*. Ediciones Alfara S.A, Madrid. In Spanish.
- Anderson, E. W., Ghysels, E., and Juergens, J. L. (2009). The Impact of Risk and Uncertainty on Expected Returns. *Journal of Financial Economics*, 94(2):233–263.
- Anderson, R. G. (2009). Resolving a Banking Crisis, the Nordic Way. *Economic Synopses*, (10):1–2.
- Angeloni, I. and Faia, E. (2013). Capital regulation and monetary policy with fragile banks. *Journal of Monetary Economics*, 60:311–324.
- Anguren Martín, R. (2011). Credit Cycles: Evidence Based on a Non Linear Model for Developed Countries. Working Paper 1113, Banco de España.
- Anguren Martín, R. (2017). Identificación y evolución de los ciclos de crédito en las economías avanzadas. *Banco de España. Estabilidad Financiera*, (22):125–139.
- Anscombe, F. J. and Aumann, R. J. (1963). A Definition of Subjective Probability. *Annals of Mathematical Statistics*, 34(1):199–205.
- Antoniades, A. (2013). At the Eye of the Cyclone: The Greek Crisis in Global Media. In Sklias, P. and Tzifakis, N., editors, *Greece’s Horizons*, The Konstantinos Karamanlis Institute for Democracy Series on European and International Affairs. Springer, Berlin, Heidelberg.
- Arjani, N. (2009). Procyclicality and Bank Capital. *Bank of Canada Financial Stability Review*, pages 33–39.

- Arrow, K. J. (1951). An Extension of the Basic Theorems of Classical Welfare Economics. In Neyman, J., editor, *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, pages 507–532. University of California Press, Berkeley.
- Arrow, K. J. and Debreu, G. (1954). Existence of an Equilibrium for a Competitive Economy. *Econometrica*, 22(3):265–290.
- Atoyan, R., Manning, J., and Rahman, J. (2013). Rebalancing: Evidence from Current Account Adjustment in Europe. *IMF Working Paper WP/13/74*, pages 1–34.
- Auclert, A. (2020). Monetary Policy and the Redistribution Channel. *American Economic Review*, 109(6):2337–2369.
- Aumann, R. J. (1962). Utility Theory without the Completeness Axiom. *Econometrica*, 30(3):445–462.
- Aumann, R. J. (1964). Utility Theory without the Completeness Axiom: A Correction. *Econometrica*, 32(1-2):210–212.
- Austin, L. S. and J. G. Ritter, II (2008). Effects of Emergency Economic Stabilization Act of 2008 on Executive Compensation. Hunton & Williams Client Alert.
- Avery, R. B., Calem, P. S., and Canner, G. B. (2003). The Effects of the Community Reinvestment Act on Local Communities. Technical report, Board of Governors of the Federal Reserve System, Washington, D.C.
- Axtell, R. L. and Farmer, J. D. (2025). Agent-Based Modeling in Economics and Finance: Past, Present, and Future. *Journal of Economic Literature*, 63(1):197–287. ISSN 0022-0515 (Print), ISSN 2328-8175 (Online).
- BaFin (2025). Countercyclical Capital Buffer (CCyB) – Germany.
- Bahena, A. (2010). What Role Did Credit Agencies Play in the Credit Crisis? <https://paperzz.com/doc/8965348/1-what-role-did-credit-rating-agencies-play-in-the-credit...> pp. 1–23.
- Baily, M. N., Holmes, S. E., and Bekker, W. (2015). The Big Four Banks: The Evolution of the Financial Sector. Part I. Technical report, Economic Studies at Brookings.
- Baily, M. N., Klein, A., and Schardin, J. (2017). The Impact of the Dodd-Frank Act on Financial Stability and Economic Growth. *RSF: The Russell Sage Foundation Journal of the Social Sciences*, 3(1):20–47.
- Bak, P., Tang, C., and Wiesenfeld, K. (1987). Self-Organized Criticality: An Explanation of the $1/f$ Noise. *Physical Review Letters*, 59(4):381–384.
- Baker, D. (2015). From Recession to Collapse: The Bush Administration and the Over-Valued Dollar. Technical Report 2015-08, Center for Economic and Policy Research (CEPR).
- Balla, E. and McKenna, A. (2009). Dynamic Provisioning: A Countercyclical Tool for Loan Loss Reserves. *Federal Reserve Bank of Richmond Economic Quarterly*, 95(4):383–418.
- Bańbuła, P. (2013). Polityka makroostrożnościowa: przesłanki, cele, instrumenty i wyzwania. Technical Report 298, Narodowy Bank Polski, Warsaw.
- Banco de Portugal (2022). Amended recommendation on new credit agreements for consumers: Limits on loan maturity linked to borrower age. Web page / PDF. Accessed: 2025-09-24.

- Bank for International Settlements (2008). Addressing Financial System Procyclicality: A Possible Framework. Technical report, Bank for International Settlements, Basel.
- Banking Act (1933). Banking Act of 1933. Public Law 73-66, 48 Stat. 162. Also known as the Glass–Steagall Act.
- Banking Law (1997). Act of 29 August 1997 – Banking Law. Dz.U. 1997 No. 140, item 939.
- Bao, J., O’Hara, M., and Zhou, A. (2016). The Volcker Rule and Market-Making in Times of Stress. Finance and Economics Discussion Series 2016-102, Board of Governors of the Federal Reserve System, Washington, D.C.
- Baptista, R., Farmer, J. D., Hinterschweiger, M., Low, K., Tang, D., and Uluc, A. (2016). Macroprudential policy in an agent-based model of the UK housing market. Staff Working Paper 619, Bank of England.
- Barabási, A.-L. and Albert, R. (1999). Emergence of scaling in random networks. *Science*, 286(5439):509–512.
- Baradaran, M. (2012). Reconsidering the Separation of Banking and Commerce. *Georgetown Law Journal*, 80:385–441.
- Barberis, N. and Thaler, R. (2003). Chapter 18 A survey of behavioral finance. In *Financial Markets and Asset Pricing*, volume 1 of *Handbook of the Economics of Finance*, pages 1053–1128. Elsevier.
- Barnett-Hart, A. K. (2009). The Story of the CDO Market Meltdown: An Empirical Analysis. M-RCBG Associate Working Paper Series No. 4, Mossavar-Rahmani Center for Business and Government, Harvard University, Cambridge, MA. Also originally submitted as Undergraduate Honors Thesis in Economics, Harvard University.
- Bartke, R. W. (1972). Home Financing at the Crossroads – A Study of the Federal Home Loan Mortgage Corporation. *Indiana Law Journal*, 48(1):1–42.
- Bartlett, G. A. (1969). The Housing and Urban Development Act of 1968: Private Enterprise and Low-Income Housing. *William & Mary Law Review*, 10:936–956.
- Basel Committee on Banking Supervision (2006). International Convergence of Capital Measurement and Capital Standards: A Revised Framework (Comprehensive Version). Technical report, Bank for International Settlements.
- Batra, R. (2005). *Greenspan’s Fraud: How Two Decades of His Policies Have Undermined the Global Economy*. St. Martin’s Press, New York, NY.
- Battiston, S., Farmer, J. D., Flache, A., Garlaschelli, D., Haldane, A. G., Heesterbeek, H., Hommes, C., Jaeger, C., May, R., and Scheffer, M. (2016). Complexity theory and financial regulation. *Science*, 351(6275):818–819.
- Battiston, S., Puliga, M., Kaushik, R., Tasca, P., and Caldarelli, G. (2012). DebtRank: Too central to fail? Financial networks, the FED and systemic risk. *Scientific Reports*, 2(541).
- BBVA Research (2014). Securitization in Spain: Past Developments and Expected Future Trends. Economic watch report, Banco Bilbao Vizcaya Argentaria (BBVA).
- BCBS (2010). Guidance for national authorities operating the countercyclical capital buffer. Technical report BCBS 187, Bank for International Settlements, Basel, Switzerland.
- BCBS (2025). Countercyclical capital buffer (CCyB), CCyB decisions.

- BdE (2012). Circular 2/2012, de 29 de febrero, del Banco de España, a entidades de crédito, sobre requisitos de información financiera pública y reservada, y modelos de estados financieros. Technical report, Banco de España, Madrid. Modifies Annex IX of Circular 4/2004; introduces changes to loan classification and provisioning rules.
- BdE (2015). Note on the Use of the Countercyclical Capital Buffer. Published 28 December 2015.
- BdE (2016a). Briefing note: Identification of global systemically important institutions (G-SIIs) and buffer requirements. Briefing note.
- BdE (2016b). Circular 4/2016, de 27 de abril, del banco de españa, a entidades de crédito, sobre normas de información financiera pública y reservada, y modelos de estados financieros. Technical report, Banco de España, Madrid. Amends Circular 4/2004; advances transition toward expected loss provisioning consistent with IFRS 9.
- BdE (2017a). Countercyclical Capital Buffer Decision, March 2017. Accessed: 2025-09-23.
- BdE (2017b). Financial stability report, 2017. Financial Stability Report, November 2017.
- BdE (2017c). Informe sobre la crisis financiera y bancaria en España 2008–2014. Technical report, Banco de España.
- BdE (2020). Financial stability report, autumn 2020. Technical report, Banco de España. Accessed: 2025-09-24.
- BdE (2024). The banco de españa approves the new framework for setting the countercyclical capital buffer and sets the buffer rate for 2024 q4 at 0.5%. Press release. Accessed: 2025-09-23.
- BdE (2025). Systemically important institutions (O-SIIs and G-SIIs) - macroprudential tools. Web page. Accessed: 2025-09-23.
- BdI (2016a). Decision not to reciprocate a macroprudential measure applied by Belgium concerning bank exposures to its real estate market. Press release.
- BdI (2016b). Decision not to reciprocate a macroprudential measure applied by Eesti Pank. Press release.
- BdI (2018). Identification of the unicredit, intesa sanpaolo and banco bpm banking groups as other systemically important institutions (O-SIIs) and phased buffer schedule (2018–2022). Technical report, Banca d'Italia.
- BdI (2019). Implementation of the capital conservation buffer. Web page.
- BdI (2022). Identification of unicredit, intesa sanpaolo, banco bpm and monte dei paschi di siena banking groups as other systemically important institutions (O-SIIs). Technical report, Banca d'Italia.
- BdI (2024a). Decision on the countercyclical capital buffer rate for the second quarter of 2024. Technical report, Banca d'Italia.
- BdI (2024b). Introduction of a Systemic Risk Buffer (SyRB). Technical report, Banca d'Italia.
- BdP (2015). Macroprudential Policy Strategy. Technical report, Banco de Portugal.
- BdP (2016). Notice of Banco de Portugal No 6/2016 – capital conservation buffer. Accessed: 2025-09-24.

- BdP (2018). Recommendation of the Banco de Portugal on new credit agreements for consumers – limits on LTV, DSTI and loan maturities. Web page/PDF. Accessed: 2025-09-24.
- BdP (2023). Amendment to the recommendation on new credit agreements for consumers — DSTI interest-rate stress and maturity rules. PDF. Accessed: 2025-09-24.
- BdP (2025a). Countercyclical capital buffer – background document, quarter 4 2025. Web page/PDF. Accessed: 2025-09-24.
- BdP (2025b). Macroprudential measures in Portugal – progress report (March 2025). Web page. Accessed: 2025-09-24.
- BdP (2025c). Other systemically important institutions (O-SIIs) — capital buffer. Web page. Accessed: 2025-09-24.
- Behn, M., Detken, C., Peltonen, T. A., and Schudel, W. (2013). Setting Countercyclical Capital Buffers Based on Early Warning Models: Would it Work? ECB Working Paper Series 1604, European Central Bank.
- Bellod Redondo, J. F. (2008). *La Burbuja Inmobiliaria*. Lulu Press.
- Belongia, M. T. and Ireland, P. N. (2016). The Evolution of U.S. Monetary Policy: 2000–2007. NBER Working Paper 22693, National Bureau of Economic Research, Cambridge, MA.
- Beltran, D. O. and Thomas, C. P. (2010). Could Asymmetric Information Alone Have Caused the Collapse of Private-Label Securitization? Technical Report 1010, Board of Governors of the Federal Reserve System.
- Ben-Gad, M., Pearlman, J., and Sabuga, I. (2022). An analysis of monetary and macroprudential policies in a DSGE model with reserve requirements and mortgage lending. *Economic Modelling*, 116:105966.
- Benigno, G., Chen, H., Otrok, C., Rebucci, A., and Young, E. R. (2013). Financial crises and macro-prudential policies. *Journal of International Economics*, 89(2):453–470.
- Benston, G. J. (1990). *The Separation of Commercial and Investment Banking*. Palgrave Macmillan, London.
- Berger, A. N., Demsetz, R. S., and Strahan, P. E. (1999). The Consolidation of the financial services industry: Causes, consequences, and implications for the future. *Journal of Banking & Finance*, 23:135–194.
- Berger, A. N., Kashyap, A. K., and Scalise, J. M. (1995). The Transformation of the U.S. Banking Industry: What a Long, Strange Trip It's Been. *Brookings Papers on Economic Activity*, 1995(2):55–218.
- Berger, A. N. and Udell, G. F. (2004). The institutional memory hypothesis and the procyclicality of bank lending behaviour. *Journal of Financial Intermediation*, 13(4):458–495.
- Bernanke, B. (2012). Some Reflections on the Crisis and the Policy Response. Speech at the Russell Sage Foundation and The Century Foundation Conference *Rethinking Finance*, New York. Available at: <https://www.federalreserve.gov/newsevents/speech/bernanke20120413a.htm> [Accessed 18 October 2025].
- Bernanke, B. S. (2005). The Global Saving Glut and the U.S. Current Account Deficit. Sandridge lecture, Virginia association of economists, Board of Governors of the Federal Reserve System, Richmond, VA.

- Bernanke, B. S. (2007). Global Imbalances: Recent Developments and Prospects. Bundesbank Lecture.
- Bernanke, B. S. (2010). Testimony before the Financial Crisis Inquiry Commission. Board of Governors of the Federal Reserve System. Available at: <https://www.federalreserve.gov/newsevents/testimony/bernanke20100902a.htm> [Accessed 18 October 2025].
- Bernanke, B. S. and Gertler, M. (1989). Agency Costs, Net Worth, and Business Fluctuations. *American Economic Review*, 79(1):14–31.
- Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In Taylor, J. B. and Woodford, M., editors, *Handbook of Macroeconomics*, volume 1, pages 1341–1393. Elsevier.
- Bewley, T. F. (1986). Knightian Decision Theory: Part I. Cowles Foundation Discussion Paper 807, Cowles Foundation for Research in Economics, Yale University, New Haven, CT. Later published in *Decision Making Under Uncertainty: Papers in Honor of Jacob Marschak*, Academic Press, New York, 1986, pp. 283–300.
- Bhattacharya, S., Chabakauri, G., and Nyborg, K. G. (2012). Securitized Banking, Asymmetric Information, and Financial Crisis: Regulating Systemic Risk Away. Technical Report AXA Working Paper No. 10; FMG Discussion Paper 704, AXA Working Paper Series/Financial Markets Group, London School of Economics.
- Biais, B., Rochet, J.-C., and Woolley, P. (2009). Asymmetric Information, Risk & Regulation in the Financial Sector. Presentation for the Future of Finance Group, London School of Economics. Slides 1–28.
- Bianchi, J. (2011). Overborrowing and Systemic Externalities in the Business Cycle. *American Economic Review*, 101(7):3400–3426.
- Bianco, K. (2010). A Retrospective of the Troubled Asset Relief Program.
- Billio, M., Getmansky, M., Lo, A. W., and Pelizzon, L. (2012). Econometric measures of connectedness and systemic risk in the finance and insurance sectors. *Journal of Financial Economics*, 104:535–559.
- BIS (2010). Macroprudential Instruments and Frameworks: A Stocktaking of Issues and Experiences. Technical Report CGFS Papers No. 38, Bank for International Settlements, Basel. Committee on the Global Financial System.
- Bisias, D., Flood, M., Lo, A. W., and Valavanis, S. (2012). A Survey of Systemic Risk Analytics. Technical Report Working Paper No. 0001, Office of Financial Research, U.S. Department of the Treasury.
- Blecker, R. A., editor (1996). *U.S. Trade Policy and Global Growth: New Directions in the International Economy*. An Institute for International Economics Policy Series. M. E. Sharpe, Armonk, NY; London, England.
- Blecker, R. A. (1997). NAFTA and the Peso Collapse: Not Just a Coincidence. EPI Briefing Paper Briefing Paper #66, Economic Policy Institute.
- Blinder, A. S. (2014). Federal Reserve Policy Before, During, and After the Fall. In Baily, M. N. and Taylor, J. B., editors, *Across the Great Divide: New Perspectives on the Financial Crisis*, chapter 5, pages 89–102. Hoover Institution Press, Stanford, CA.

- Bliss, R. R. and Kaufman, G. G. (2011). Resolving Insolvent Large Complex Financial Institutions: A Better Way. *The Banking Law Journal*, 128(4):339–363.
- BNB (2017). Bulgaria: Financial Sector Assessment Program – Update 2017.
- Board of Governors of the Federal Reserve System (2023). Frequently Asked Questions on Regulation K (Legal Interpretations). <https://www.federalreserve.gov/supervisionreg/legalinterpretations/reg-k-frequently-asked-questions.htm>.
- BOE (2012). Real decreto-ley 2/2012, de 3 de febrero, de saneamiento del sector financiero. Technical report, Government of Spain, Madrid. Financial sector clean-up decree; reinforces provisioning requirements and prudential measures.
- BoE (2013). Quarterly Bulletin 2013 Q1 Macroprudential Policy at the Bank of England.
- BoE (2014). Policy statement ps9/14 implementing the financial policy committee’s recommendation on loan to income ratios in mortgage lending.
- BoE (2015). Royal Decree 84/2015 of 13 February Implementing Law 10/2014 on the Regulation, Supervision and Solvency of Credit Institutions. Boletín Oficial del Estado (BOE), No. 41, 17 February 2015. Accessed: 2025-09-23.
- BoE (2016). The financial policy committee’s approach to setting the countercyclical capital buffer.
- BoE (2017). Financial policy committee 21 June 2017 meeting record.
- BoE (2025). Financial Policy Committee (FPC).
- BoF (2021). Annual report 2021 financial stability: Development of regulation supported financial stability. <https://annualreport.bankoffinland.fi/2021/annual-report/financial-stability/>.
- BoG (2014). *The Chronicle of the Great Crisis: The Bank of Greece 2008-2013 — Public Interventions and Institutional Actions to Safeguard Financial Stability and Overcome the Crisis*. Bank of Greece, Centre for Culture, Research and Documentation, Athens. Documents 10911.
- BoG (2017). Macroprudential policy framework in Greece. Web page. Accessed June 15 2025.
- BoG (2024). O-SII buffer: Identification of other systemically important institutions and buffer rates in Greece. Web page. Accessed November 2025.
- BoG (2025). Countercyclical capital buffer – framework and decisions in Greece. Web page / PDF document. Accessed 1 November 2025.
- BoL (2011). Responsible lending regulations (resolution no. 03 144 of 1 September 2011).
- BoL (2015). The Bank of Lithuania begins applying a new macroprudential policy instrument: countercyclical capital buffer.
- BoL (2015). Responsible lending regulations: strengthening the resilience of borrowers to adverse interest changes.
- BoL (2019). Banks to accumulate two-times higher countercyclical capital buffer.
- BoL (2020). Bank of Lithuania releases the countercyclical capital buffer requirement amid COVID-19 disruptions.
- BoL (2025). Financial stability instruments, Buffer of other systemically important institutions.

- BoL (2025). Role of the Bank of Lithuania in maintaining financial stability.
- Bond, P., Edmans, A., and Goldstein, I. (2011). The Real Effects of Financial Markets. NBER Working Paper 17719, National Bureau of Economic Research.
- Bookstaber, R. (2017). *The End of Theory: Financial Crises, the Failure of Economics, and the Sweep of Human Interaction*. Princeton University Press, Princeton, NJ.
- Bordo, M. D. (2005). Historical Perspective on Global Imbalances. NBER Working Paper 11383, National Bureau of Economic Research (NBER).
- Borio, C. and Drehmann, M. (2009a). Assessing the Risk of Banking Crises. *BIS Quarterly Review*, pages 29–46.
- Borio, C. and Drehmann, M. (2009b). Towards an Operational Framework for Financial Stability: Fuzzy Measurement and its Consequences. BIS Working Papers 284, Bank for International Settlements.
- Borsos, A., Carro, A., Glielmo, A., Hinterschweiger, M., Kaszowska-Mojša, J., and Uluc, A. (2025). Agent-based Modeling at Central Banks: Recent Developments and New Challenges. Technical Report Staff Working Paper No. 1,122, Bank of England. Published 28 February 2025.
- Bosworth, B. P. (2012). Economic Consequences of the Great Recession: Evidence from the Panel Study of Income Dynamics. Working Paper 2012-4, Center for Retirement Research at Boston College.
- Bowen III, R. M. (2010). Testimony before the Financial Crisis Inquiry Commission. Technical report, Financial Crisis Inquiry Commission, Washington, D.C. Hearing on Subprime Lending and Securitization and Government-Sponsored Enterprises.
- Bradford, C. I. and Linn, J. F. (2010). The April 2009 London G-20 Summit in Retrospect.
- Brass, C. T., Jackson, P. J., Lake, J. E., Spar, K., and Vincent, C. H. (2009). American Recovery and Reinvestment Act of 2009 (P.L. 111-5): Summary and Legislative History. Technical Report R40537, Congressional Research Service, Library of Congress. Referenced Legislation: H.R. 1; P.L. 111-5.
- Bricker, J., Bucks, B. K., Kennickell, A. B., Mach, T. L., and Moore, K. B. (2011). Surveying the Aftermath of the Storm: Changes in Family Finances from 2007 to 2009. Technical Report 2011-17, Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board.
- Brown, E. (2013). Will the Federal Insurance Office Improve Insurance Regulation? *University of Cincinnati Law Review*, 81(2):551–600.
- Brunnermeier, M., Gorton, G., and Krishnamurthy, A. (2014). Liquidity Mismatch Measurement. In *Risk Topography: Systemic Risk and Macro Modeling*. University of Chicago Press.
- Brunnermeier, M. K., Gorton, G., and Krishnamurthy, A. (2012). Risk Topography. In Acemoglu, D. and Woodford, M., editors, *NBER Macroeconomics Annual 2011*, volume 26, pages 149–176. University of Chicago Press.
- Brunnermeier, M. K. and Pedersen, L. H. (2005). Predatory Trading. *The Journal of Finance*, 60(4):1825–1863.
- Brunnermeier, M. K. and Pedersen, L. H. (2009). Market Liquidity and Funding Liquidity. *The Review of Financial Studies*, 22(6):2201–2238.

- Brunnermeier, M. K. and Sannikov, Y. (2014). A Macroeconomic Model with a Financial Sector. *American Economic Review*, 104:379–421.
- Bruno, V., Shim, I., and Shin, H. S. (2017). Comparative assessment of macroprudential policies. *Journal of Financial Stability*, 28:183–202.
- Brzozowski, M. (2014). CRD IV, CRR – instrumenty makroostrożnościowe. Technical report, Narodowy Bank Polski.
- Bullard, J., Neely, C. J., and Wheelock, D. C. (2009). Systemic Risk and the Financial Crisis: A Primer. *Federal Reserve Bank of St. Louis Review*, 91(5):403–418. Part 1.
- Bunch, W. (2010). *Tear Down This Myth: The Right-Wing Distortion of the Reagan Legacy*. Free Press, New York.
- Burns, A. F. and Mitchell, W. C. (1946). *Measuring Business Cycles*. National Bureau of Economic Research.
- Caballero, R. J. (2010). Macroeconomics after the crisis: Time to deal with the pretense-of-knowledge syndrome. *Journal of Economic Perspectives*, 24(4):85–102.
- Caballero, R. J. and Krishnamurthy, A. (2001). International and domestic collateral constraints in a model of emerging market crises. *Journal of Monetary Economics*, 48(3):513–548.
- Caliendo, L. and Parro, F. (2015). Estimates of the Trade and Welfare Effects of NAFTA. *The Review of Economic Studies*, 82(1):1–44.
- Calomiris, C. W. (2000). *U.S. Bank Deregulation in Historical Perspective*. Cambridge University Press, Cambridge.
- Calomiris, C. W. (2008). The Subprime Turmoil: What’s Old, What’s New, and What’s Next. Technical report, International Monetary Fund, Washington, D.C. Paper presented at the IMF Jacques Polak Annual Research Conference, November 13–14, 2008.
- Campbell, J. Y. and Cochrane, J. H. (1999). By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior. *Journal of Political Economy*, 107(2):205–251.
- Campbell, J. Y., Lettau, M., Malkiel, B. G., and Xu, Y. (2001). Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk. *The Journal of Finance*, 56(1):1–43.
- Campiglio, L. (2017). European Recession and the Emerging Two-Speed Europe. In Magatti, M., editor, *The Crisis Conundrum: How to Reconcile Economy and Society*, pages 65–92. Springer.
- Carlstrom, C. T. and Fuerst, T. S. (1997). Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. *American Economic Review*, 87(5):893–910.
- Carow, K. A. (2001). Citicorp–Travelers Group Merger: Challenging Barriers Between Banking and Insurance. *Journal of Banking & Finance*, 25(8):1553–1571.
- Carpantier, J.-F., Olivera, J., and van Kerm, P. (2018). Macroprudential policy and household wealth inequality. *Journal of International Money and Finance*, 85:262–277.
- Carpenter, D. H., Murphy, E. V., and Murphy, M. M. (2016). The Glass-Steagall Act: A Legal and Policy Analysis. Technical Report R44349, Congressional Research Service, Library of Congress. Available at: <https://www.congress.gov/crs-product/R44349> [Accessed 18 September 2025].

- Carro, A. (2023). Could Spain be less different? Exploring the effects of macroprudential policy on the house price cycle. Working Paper 2230, Banco de España.
- Carson, C. S. and Ingves, S. (2003). Financial Soundness Indicators. IMF board paper, International Monetary Fund.
- Castellano, C., Fortunato, S., and Loreto, V. (2009). Statistical physics of social dynamics. *Reviews of Modern Physics*, 81:591–646.
- Catapano, G., Franceschi, F., Loberto, M., and Michelangeli, V. (2021). Macroprudential Policy Analysis via an Agent Based Model of the Real Estate Sector. Temi di discussione (Working Paper) 1338, Bank of Italy.
- Cavallo, M. (2005). Understanding the Twin Deficits: New Approaches, New Results. *FRBSF Economic Letter*, (2005-16):1–3.
- CBC (2017a). Other Systemically Important Institutions (O-SII) and Level of the Additional O-SII Capital Buffer O-SII Cyprus Investment Firms. https://www.centralbank.cy/images/media/redirectfile/0-SII_institutions_%20and_0-SII_buffer_CIFs%20-%202017.pdf.
- CBC (2017b). Publication of the list of Cyprus investment firms that have been exempted by the CBC from the requirement to maintain an institution specific countercyclical capital buffer for 2017. Announcement on the website of the Central Bank of Cyprus.
- CBC (2021). Designation of credit institutions as other systemically important institutions (o-sii) buffer levels for 1 January 2022. <https://www.centralbank.cy/en/announcements/designation-of-credit-institutions-as-other-systemically-important-institutions-29-11-2021>.
- CBI (2014). Implementation of competent authority discretions and options in CRD IV and CRR (updated May 2014). Technical report, Central Bank of Ireland. Accessed November 2025.
- CBI (2017). FAQ – new regulations on residential mortgage lending. PDF document. Accessed 1 November 2025.
- CBI (2019). Countercyclical capital buffer rate announcement. PDF. CCyB rate set at 1.
- CBI (2020). The central bank cuts capital buffer from 1 per cent to 0 per cent to free bank funds to fight COVID-19 effects. Web article.
- CBI (2022). Mortgage measures framework review – public engagement. Web page. Accessed 1 November 2025.
- CBI (2024a). Countercyclical capital buffer (CCyB) – policy framework. Web page. Accessed: 2025-09-24.
- CBI (2024b). Other systemically important institutions buffer: Identified o-siis and associated buffer rates. Technical report, Central Bank of Ireland. Accessed 1 November 2025.
- CBM (2013). Directive no. 11 on macro-prudential policy. PDF document. Accessed November 2025.
- CBM (2016). Statement of decision on the reciprocity of the systemic risk buffer of Estonia. Policy Document.

- CBM (2025). Countercyclical capital buffer (ccyb) – macro-prudential tool. Web page. Accessed 1 November 2025.
- Central Statistical Office (GUS) (2014). European Union Statistics on Income and Living Conditions (EU-SILC) in 2013. <http://stat.gov.pl/obszary-tematyczne/warunki-zycia/docho dy-wydatki-i-warunki-zycia-ludnosci/europejskie-badanie-dochodow-i-warun kow-zycia-eu-silc-w-2013-r-,7,5.html>.
- Central Statistical Office (GUS) (2015). Household budget survey. <https://stat.gov.pl/en/t opics/living-conditions/>. Information on the 2014 household budget survey in Poland.
- Cerutti, E., Claessens, S., and Laeven, L. (2017). The Use and Effectiveness of Macroprudential Policies: New Evidence. *Journal of Financial Stability*, 28:203–224.
- Chakraborti, A., Toke, I. M., Patriarca, M., and Abergel, F. (2011). Econophysics Review: II. Agent-Based Models. *Quantitative Finance*, 11(7):1013–1041.
- Chawwa, T. (2021). Impact of reserve requirement and Liquidity Coverage Ratio: A DSGE model for Indonesia. *Economic Analysis and Policy*, 71:321–341.
- Chen, J. M. (2016). Gini’s Crossbow. Presented at the 81st International Atlantic Economic Society Conference, Lisbon, Portugal.
- Chen, J. M. (2017). *Econophysics and Capital Asset Pricing: Splitting the Atom of Systematic Risk*. Palgrave Macmillan Cham. eBook ISBN 978-3-319-63465-4.
- Chinn, M. D., Eichengreen, B., and Ito, H. (2012). Rebalancing Global Growth. In Canuto, O. and Leipziger, D., editors, *Ascent After Descent: Regrowing Economic Growth after the Great Recession*, pages 35–86. World Bank, Washington, D.C. Chapter 2.
- Chinn, M. D. and Ito, H. (2008). Global Current Account Imbalances: American Fiscal Policy versus East Asian Savings. *Review of International Economics*, 16(3):479–498.
- Cincotti, S., Raberto, M., and Teglio, A. (2012). Macroprudential Policies in an Agent-Based Artificial Economy. *Revue de l’OFCE*, 124(5):205–234.
- Claessens, S., Evanoff, D., Kaufman, G. G., and Kodres, L. E., editors (2012). *Macroprudential Regulatory Policies: A New Road to Financial Stability?* Number 17 in World Scientific Studies in International Economics. World Scientific Publishing Co. Pte. Ltd., Hackensack, NJ.
- Claessens, S. and Forbes, K. J. (2001). *International Financial Contagion*. Springer New York, NY, New York.
- Claessens, S. and van Horen, N. (2014). The Impact of the Global Financial Crisis on Banking Globalization. IMF Working Paper WP/14/197, International Monetary Fund.
- Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suárez, J., and Vardoulakis, A. P. (2015a). Capital Regulation in a Macroeconomic Model with Three Layers of Default. ECB Working Paper 1827, European Central Bank.
- Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suárez, J., and Vardoulakis, A. P. (2015b). Capital Regulation in a Macroeconomic Model with Three Layers of Default. *International Journal of Central Banking*, 11(3):9–63.
- CNB (2015). The CNB sets the countercyclical capital buffer rate at 0.5%. Press release, Czech National Bank.

- CNB (2017). CNB increases countercyclical capital buffer to 1%. Domestic financial sector remains stable and resilient. Press release, Czech National Bank.
- CNB (2018). CNB introduces new mortgage limits. Press release, Czech National Bank.
- CNB (2019). Official Information: Recommendation on the management of risks associated with retail loans secured by residential property. Official Information Bulletin, Czech National Bank.
- CNB (2020). CNB partially relaxes mortgage limits and lowers countercyclical capital buffer rate. Press release, Czech National Bank.
- CNB (2022a). Cnb increases countercyclical capital buffer rate to 2.5%. Press release, Czech National Bank.
- CNB (2022b). Notification by the Czech National Bank on LTV, DSTI and DTI limits. European Systemic Risk Board Notification Document.
- CNB (2024a). List of other systemically important institutions. Website of the Czech National Bank.
- CNB (2024b). Requirements for LTV, DSTI and DTI limits. Website of the Czech National Bank.
- CNB (2024c). The capital conservation buffer. Website of the Czech National Bank.
- CNB (2024d). The Czech National Bank leaves the countercyclical capital buffer rate at 1.25%. Press release, Czech National Bank.
- CNB (2024e). The mandate of the Czech National Bank. Website of the Czech National Bank.
- CNSM (2025). The National Committee for Macroprudential Oversight (CNSM) – Institutional Arrangements.
- Code of Federal Regulations (2023). 12 C.F.R. § 211.5 – Edge and Agreement Corporations. <https://www.ecfr.gov/current/title-12/chapter-II/subchapter-A/part-211/subpart-A/section-211.5>.
- Cokayne, G. (2019). The Effects of Macroprudential Policies on House Price Cycles in an Agent-Based Model of the Danish Housing Market. Working Paper 138, Danmarks Nationalbank.
- Colander, D., Föllmer, H., Haas, A., Goldberg, M., Kirman, A., Juselius, K., Lux, T., and Sloth, B. (2009). The Financial Crisis and the Systemic Failure of Academic Economics. *Kiel Working Paper*, (1489):1–14.
- Collard, K. (2015). Advantages of a Co-Regulatory OTC Derivatives Regime. *Georgetown Journal of International Law*, 46:879–912.
- Colón, H. (2016). The Role of Derivatives in the Financial Crisis. Issue Brief 187, National Center for Policy Analysis (NCPA), Dallas, TX. Published January 26, 2016.
- Cornett, M. M. and Tehranian, H. (1990). An Examination of the Impact of the Garn–St. Germain Depository Institutions Act of 1982 on Commercial Banks and Savings and Loans. *The Journal of Finance*, 45(1):95–111.
- Council of the EU (2025). Bank resolution: Council and parliament strike deal to strengthen the EU crisis management framework. Press release — Council & Parliament political agreement on CMDI reform, including access to the Single Resolution Board/Single Resolution Fund for failing banks.

- Council Reg. 1024 (2013). Council regulation (EU) no 1024/2013 conferring specific tasks on the European Central Bank concerning policies relating to the prudential supervision of credit institutions. OJ L 287, 29.10.2013, pp. 63–89.
- Coval, J. D., Jurek, J. W., and Stafford, E. (2009). The Economics of Structured Finance. *Journal of Economic Perspectives*, 23(1):3–35.
- Covas, F. and Fujita, S. (2010). Procyclicality of Capital Requirements in a General Equilibrium Model of Liquidity Dependence. *International Journal of Central Banking*, 6(4):138–173.
- CRD IV (2013). Directive 2013/36/EU of the European Parliament and of the Council of 26 June 2013 on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms, amending Directive 2002/87/EC and repealing Directives 2006/48/EC and 2006/49/EC (CRD IV). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013L0036>. *Official Journal of the European Union*, L 176, 27.6.2013, pp. 338–436.
- Crowe, C., Dell’Ariccia, G., Igan, D., and Rabanal, P. (2013). How to Deal with Real Estate Booms: Lessons from Country Experiences. *Journal of Financial Stability*, 9(3):300–319.
- Cuervo García, A. (1988). *La crisis bancaria en España, 1977–1985: Causas, sistemas de tratamiento y coste*. Ariel, Barcelona.
- Czapiński, J. and Panek, T. (2015). Social diagnosis 2015: Objective and subjective quality of life in Poland. *Contemporary Economics*, 9:13–526. Accessed on 8 January 2020.
- Czerwińska, T. and Jajuga, K., editors (2016). *Ryzyko instytucji finansowych – współczesne trendy i wyzwania*. C.H. Beck, Warszawa.
- Da Silva, M. A. and Lima, G. T. (2017). Combining monetary policy and prudential regulation: an agent-based modeling approach. *Journal of Economic Interaction and Coordination*, 15(2):385–411. Published online 11 Dec 2017.
- Damgaard, C. and Weiner, J. (2000). Describing inequality in plant size or fecundity. *Ecology. Ecological Society of America*, 81:1139–1142.
- Danielsson, J. and Shin, H. S. (2003). Endogenous Risk. In Field, P., editor, *Modern Risk Management: A History*, pages 297–314. Risk Books, London. Also available at the LSE Research Online repository: <http://eprints.lse.ac.uk/id/eprint/10208>.
- Danielsson, J., Shin, H. S., and Zigrand, J.-P. (2013). Endogenous and Systemic Risk. In Haubrich, J. G. and Lo, A. W., editors, *Quantifying Systemic Risk*, pages 73–112. University of Chicago Press, Chicago.
- Davidoff Solomon, S. and Zaring, D. (2015). Regulation by Deal: The Government’s Response to the Financial Crisis. *Berkley University Law Review*, 275:271–425.
- Davis, E. P. and Karim, D. (2008). Comparing early warning systems for banking crises. *Journal of Financial Stability*, 4:89–120.
- De Brandt, O. and Hartmann, P. (2000). Systemic Risk: A Survey. ECB Working Paper Series 35, European Central Bank.
- De Jonghe, O. (2010). Back to the Basics in Banking? A Micro-Analysis of Banking System Stability. *Journal of Financial Intermediation*, 19(3):387–417.
- Debreu, G. (1951). The Coefficient of Resource Utilization. *Econometrica*, 19(3):273–292.

- Deffuant, G., Neau, D., Amblard, F., and Weisbuch, G. (2000). Mixing beliefs among interacting agents. *Advances in Complex Systems*, 03(01n04):87–98.
- Deissenberg, C., van der Hoog, S., and Dawid, H. (2008). EURACE: A Massively Parallel Agent-Based Model of the European Economy. *Applied Mathematics and Computation*, 204:541–552.
- Demirgüç-Kunt, A. and Detragiache, E. (1998). The Determinants of Banking Crises: Evidence from Developing and Developed Countries. *IMF Economic Review*, 45:81–109.
- Demirgüç-Kunt, A. and Detragiache, E. (2005). Cross-Country Empirical Survey of Systemic Banking Distress: A Survey. IMF Working Paper 05/96, International Monetary Fund.
- Der Kiureghian, A. and Ditlevsen, O. (2009). Aleatory or Epistemic? Does It Matter? *Structural Safety*, 31(2):105–112.
- D’Errico, M. and Roukny, T. (2017). Compressing Over-the-Counter Markets. Technical Report 44, European Systemic Risk Board.
- DeYoung, R. and Roland, K. P. (2001). Product Mix and Earnings Volatility at Commercial Banks: Evidence from a Degree of Total Leverage Model. *Journal of Financial Intermediation*, 10(1):54–84.
- Diamond, D. W. and Dybvig, P. H. (1983). Bank Runs, Deposit Insurance, and Liquidity. *Journal of Political Economy*, 91(3).
- Diamond, D. W. and Rajan, R. G. (2001). Banks, short-term debt and financial crises: theory, policy implications and applications. *Carnegie-Rochester Conference Series on Public Policy*, 54(1):37–71.
- Dimitrov, V., Palia, D., and Tang, L. (2015). Impact of the Dodd–Frank Act on Credit Ratings. *Journal of Financial Economics*, 115:505–520.
- Dimova, D., Kongsamut, P., and Vandenbussche, J. (2016). Macroprudential Policies in Southeastern Europe. IMF Working Paper WP/16/29, International Monetary Fund.
- Dir. 1174 (2024). Directive (eu) no 2024/1174 of the European parliament and of the council of 11 April 2024 amending directive 2014/59/EU and regulation (EU) no 806/2014 as regards certain aspects of the minimum requirement for own funds and eligible liabilities (mrel). OJ L, 22.4.2024.
- Dir. 14 (2013). Directive 2013/14/eu of the European parliament and of the council of 21 May 2013 amending directive 2009/65/EC and directive 2011/61/EU as regards certain aspects of credit rating agencies. OJ L 146, 22.5.2013, pp. 1–12.
- Dir. 17 (2014). Directive 2014/17/EU of the European Parliament and of the Council of 4 February 2014 on credit agreements for consumers relating to residential immovable property and amending Directives 2008/48/EC and 2013/36/EU and Regulation (EU) No 1093/2010. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0017>. *Official Journal of the European Union*, L 60, 28.2.2014, pp. 34–85.
- Dir. 39 (2004). Directive 2004/39/EC of the European parliament and of the council of 21 April 2004 on markets in financial instruments, amending council directives 85/611/EEC and 93/6/EEC and directive 2000/12/EC of the European parliament and of the council, and repealing council directive 93/22/EEC. OJ L 145, 30.4.2004, pp. 1–44.
- Dir. 48 (2006). Directive 2006/48/EC of the European parliament and of the council of 14 June 2006 relating to the taking up and pursuit of the business of credit institutions (recast). OJ L 177, 30.6.2006, pp. 1–200.

- Dir. 49 (2006). Directive 2006/49/EC of the European parliament and of the council of 14 June 2006 on the capital adequacy of investment firms and credit institutions (recast). OJ L 177, 30.6.2006, pp. 201–255.
- Dir. 49 (2014). Directive 2014/49/EU of the European parliament and of the council of 16 April 2014 on deposit guarantee schemes (recast). OJ L 173, 12.6.2014, pp. 149–178.
- Dir. 59 (2014). Directive 2014/59/EU of the European parliament and of the council of 15 May 2014 establishing a framework for the recovery and resolution of credit institutions and investment firms. OJ L 173, 12.6.2014, pp. 190–348.
- Dir. 61 (2011a). Directive 2011/61/EU of the European parliament and of the council of 8 June 2011 on alternative investment fund managers and amending directives 2003/41/EC and 2009/65/EC and regulations (EC) no 1060/2009 and (EU) no 1095/2010. OJ L 174, 1.7.2011, pp. 1–73.
- Dir. 61 (2011b). Directive (EU) no 2011/61/eu of the European parliament and of the council of 8 June 2011 on alternative investment fund managers and amending directives 2003/41/EC and 2009/65/EC and regulations (EC) no 1060/2009 and (EU) no 1095/2010. OJ L 174, 1.7.2011, pp. 1–73.
- Dir. 65 (2009a). Directive 2009/65/EC of the european parliament and of the council of 13 july 2009 on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS). OJ L 302, 17.11.2009, pp. 32–96.
- Dir. 65 (2009b). Directive (EC) No 2009/65/EC of the European Parliament and of the Council of 13 July 2009 on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS). <https://eur-lex.europa.eu/eli/dir/2009/65/oj/eng>. Official Journal of the European Union, L 302, 17.11.2009, pp. 32–96.
- Dir. 78 (1998). Directive 98/78/ec of the European parliament and of the council of 27 October 1998 on the supplementary supervision of insurance undertakings in an insurance group. OJ L 330, 5.12.1998, pp. 1–17.
- Dir. 78 (2010). Directive 2010/78/eu of the European parliament and of the council of 24 November 2010 amending directives 98/26/EC, 2002/87/EC, 2003/6/EC, 2003/41/EC, 2003/71/EC, 2004/39/EC, 2004/109/EC, 2005/60/EC, 2006/48/ec, 2006/49/EC and 2009/65/EC in respect of the powers of the European supervisory authorities. OJ L 331, 15.12.2010, pp. 120–161.
- Dir. 87 (2002). Directive 2002/87/ec of the European parliament and of the council of 16 December 2002 on the supplementary supervision of credit institutions, insurance undertakings and investment firms in a financial conglomerate. OJ L 35, 11.2.2003, pp. 1–27.
- Dir. 878 (2019). Directive (EU) 2019/878 of the European Parliament and of the Council of 20 May 2019 amending Directive 2013/36/EU as regards exempted entities, financial holding companies, mixed financial holding companies, remuneration, supervisory measures and powers and capital conservation measures (CRD V). <https://eur-lex.europa.eu/legal-content/EN/TEXT/?uri=CELEX:32019L0878>. Official Journal of the European Union, L 150, 7.6.2019, pp. 253–295.
- Dir. 879 (2019). Directive (EU) no 2019/879 of the European parliament and of the council of 20 May 2019 amending directive 2014/59/EU as regards the loss-absorbing and recapitalisation capacity of credit institutions and investment firms (BRRD ii). OJ L 150, 7.6.2019, pp. 1–44.

- Dir. 89 (2011). Directive 2011/89/EU of the European parliament and of the council of 16 November 2011 amending directives 98/78/EC, 2002/87/EC, 2006/48/EC and 2009/138/EC as regards the supplementary supervision of financial entities in a financial conglomerate. OJ L 326, 8.12.2011, pp. 113–141.
- Dir. 91 (2014a). Directive 2014/91/eu of the European parliament and of the council of 23 July 2014 amending directive 2009/65/EC on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS) as regards depositary functions, remuneration policies and sanctions. OJ L 257, 28.8.2014, pp. 186–213.
- Dir. 91 (2014b). Directive 2014/91/EU of the European Parliament and of the Council of 23 July 2014 amending Directive 2009/65/EC on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS) as regards depositary functions, remuneration policies and sanctions (UCITS V). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0091>. Official Journal of the European Union, L 257, 28.8.2014, pp. 186–214.
- Dir. 927 (2024). Directive (EU) 2024/927 of the European parliament and of the council of 13 March 2024 amending directives 2011/61/EU and 2009/65/EC as regards delegation arrangements, liquidity risk management, supervisory reporting, the provision of depositary and custody services and loan origination by alternative investment funds. <https://eur-lex.europa.eu/eli/dir/2024/927/oj>.
- DiVenti, T. R. (2009). Fannie Mae and Freddie Mac: Past, Present, and Future. *Cityscape: A Journal of Policy Development and Research*, 11(3):231–242. Policy Brief, U.S. Department of Housing and Urban Development, Office of Policy Development and Research.
- Dobos, N., Barry, C., and Pogge, T., editors (2011). *Global Financial Crisis: The Ethical Issues*. Palgrave Macmillan, London.
- Dobrzańska, A. (2014). Polityka makroostrożnościowa – zagadnienia instytucjonalne. Teoria i dotychczasowe doświadczenia w Unii Europejskiej. *Materiały i Studia*, (307):1–70.
- Dooley, M. P., Folkerts-Landau, D., and Garber, P. (2003). An Essay on the Revived Bretton Woods System. NBER Working Paper 9971, National Bureau of Economic Research.
- D’Orazio, P. (2019). Income inequality, consumer debt, and prudential regulation: An agent-based approach to study the emergence of crises and financial instability. *Economic Modelling*, 82:308–331.
- Dornbusch, R., Park, Y. C., and Claessens, S. (2000). Contagion: Understanding How It Spreads. *The World Bank Research Observer*, 15(2):177–197.
- Drehmann, M., Borio, C., Gambacorta, L., Jimenez, G., and Trucharte, C. (2010). Countercyclical Capital Buffers: Exploring Options. BIS Working Paper 317, Bank for International Settlements.
- Drehmann, M., Borio, C., and Tsatsaronis, K. (2011). Anchoring countercyclical capital buffers: the role of credit aggregates. BIS Working Papers 355, Bank for International Settlements.
- Drehmann, M., Patton, A. J., and Sørensen, S. (2007). Non-linearities and Stress Testing. In *Risk Measurement and Systemic Risk: Proceedings of the Fourth Joint Central Bank Research Conference*, pages 283–308. European Central Bank.
- Drehmann, M. and Tarashev, N. A. (2011). Measuring the Systemic Importance of Interconnected Banks. Technical Report 342, Bank for International Settlements.

- Drzyzga, K. and Drzyzga, J. (2015). Zmiany w systemie nadzoru finansowego w odpowiedzi na kryzys finansowy poprzez pryzmat pakietu CRDIV/CRR oraz Unii Bankowej. Praca dyplomowa – Studia Podyplomowe: Mechanizmy Funkcjonowania Strefy Euro.
- Dudley, W. C. (2012). Solving the Too Big to Fail Problem. Speech at the Federal Reserve Bank of New York. Remarks at the Clearing House’s Second Annual Business Meeting and Conference, New York City.
- Duffie, D. (2011). Systemic Risk Exposures: A 10-by-10-by-10 Approach. Technical Report 17281, National Bureau of Economic Research.
- Duffie, D. (2012). Market Making Under the Proposed Volcker Rule. Working Paper 3118, Stanford Graduate School of Business.
- Duffie, D. (2016). Financial Regulatory Reform After the Crisis: An Assessment. Technical report, Graduate School of Business, Stanford University. Post-conference version, 2016 ECB Forum on Central Banking.
- Durbin, D. (2010). The Durbin Amendment. Section 1075 of the Dodd–Frank Act.
- Dz.Urz. NBP (2004). Uchwała nr 4/2004 Komisji Nadzoru Bankowego z dnia 8 września 2004 r. w sprawie zakresu i szczegółowych zasad wyznaczania wymogów kapitałowych z tytułu poszczególnych rodzajów ryzyka oraz zakresu stosowania metod statystycznych i warunków, których spełnienie umożliwia uzyskanie zgody na ich stosowanie, sposobu i szczegółowych zasad obliczania współczynnika wypłacalności banku, zakresu i sposobu uwzględniania działania banków w holdingach w obliczaniu wymogów kapitałowych i współczynnika wypłacalności oraz określenia dodatkowych pozycji bilansu banku ujmowanych łącznie z funduszami własnymi w rachunku adekwatności kapitałowej oraz zakresu, sposobu i warunków ich wyznaczania.
- Dz.Urz. NBP (2011). Uchwała nr 5/2001 Komisji Nadzoru Bankowego z dnia 12 grudnia 2001 r. w sprawie zakresu i szczegółowych zasad wyznaczania wymogów kapitałowych z tytułu poszczególnych rodzajów ryzyka, w tym z tytułu przekroczenia limitów koncentracji wierzytelności, sposobu i szczegółowych zasad obliczania współczynnika wypłacalności banku, z uwzględnieniem powiązań banków z innymi podmiotami zależnymi lub działającymi w tym samym holdingu oraz określenia dodatkowych pozycji bilansu banku ujmowanych łącznie z funduszami własnymi w rachunku adekwatności kapitałowej oraz zakresu i sposobu ich wyznaczania.
- EBA (2016). Final draft regulatory technical standards on the identification of global systemically important institutions (G-SIIs) (eba-rts-2016-01). Technical report, European Banking Authority. Accessed: 2025-09-23.
- EBA (2020). Final report – draft regulatory technical standards on the methodology for global systemically important institutions (G-SIIs) (eba/rts/2020/08). Technical report, European Banking Authority. Accessed: 2025-09-23.
- EC (2010). European system of financial supervision. Overview page linking to ESRB, EBA, EIOPA, ESMA and related legal acts.
- EC Com. (2012). Green Paper – Shadow Banking /* COM/2012/0102 final */. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012DC0102>. European Commission, Brussels, 2012.
- EC Com. (2013). Shadow Banking: Addressing New Sources of Risk in the Financial Sector /* COM/2013/0614 final */. <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0614:FIN:EN:PDF>. European Commission, Brussels, 2013.

- EC SRM (2025). Single resolution mechanism. European Commission, Directorate-General for Financial Stability, Financial Services and Capital Markets Union.
- ECB (2010). The economic recovery in the central and eastern European EU countries. *ECB Monthly Bulletin*, December 2010.
- ECB (2023a). Household Finance and Consumption Survey (HFCS) Microdata Access. https://www.ecb.europa.eu/stats/ecb_surveys/hfcs/html/index.en.html. Information on access to anonymised HFCS microdata for researchers.
- ECB (2023b). The household finance and consumption survey: Methodological report for the 2021 wave. Statistics Paper Series 45, European Central Bank. Details on survey design, data collection, and comparability across countries.
- ECB (2023c). The household finance and consumption survey: Results from the 2021 wave. Statistics Paper Series 46, European Central Bank. Presents results from the fourth wave (2020-2021) of the HFCS.
- Edwards, S. (2005). Is the U.S. Current Account Deficit Sustainable? If Not, How Costly Is Adjustment Likely to Be? *Brookings Papers on Economic Activity*, 2005(1):211–288.
- Eesti Pank (2014). Eesti Pank is setting requirements for housing loans from March 2015.
- Eesti Pank (2023). Countercyclical Capital Buffer.
- Eesti Pank (2024). Financial stability review 1/2024. Technical report, Eesti Pank.
- Eesti Pank (2025). Macroprudential policy - Organisation of macroprudential supervision.
- EFRAG-EFF Joint Working Group (2009). Impairment of Financial Assets: The Expected Loss Model. European Financial Reporting Advisory Group (EFRAG).
- Eggertsson, G. B. and Krugman, P. (2012). Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach. *The Quarterly Journal of Economics*, 127(3):1469–1513.
- Eichengreen, B. (2002). *Financial Crises and What to Do About Them*. Oxford University Press, Oxford.
- Elliott, D., Feldberg, G., and Lehnert, A. (2013). The History of Cyclical Macroprudential Policy in the United States. Technical Report 2013-29, Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board, Washington, D.C.
- Elliott, L. (2011). Global Financial Crisis: Five Key Stages 2007–2011. *The Guardian*.
- Elwell, C. K. (2013). Economic Recovery: Sustaining U.S. Economic Growth in a Post-Crisis Economy. Technical Report R41332, Congressional Research Service.
- Enguñados, A. M. (2012). Banco de España vs NIC 39. *Consejeros*, pages 12–17.
- EP Legislative Train Schedule (2025). Amendments to the single resolution mechanism regulation (srmr). Overview of legislative train on SRMR amendments.
- Epstein, L. G. and Schneider, M. (2007). Learning under Ambiguity. *Review of Economic Studies*, 74(4):1275–1303.
- Epstein, L. G. and Schneider, M. (2008). Ambiguity, Information Quality, and Asset Pricing. *The Journal of Finance*, 63(1):197–228.

- Epstein, L. G. and Wang, T. (1994). Intertemporal Asset Pricing under Knightian Uncertainty. *Econometrica*, 62(2):283–322.
- ESMA (2015). Advice to the European Parliament, the Council and the Commission on the application of the AIFMD passport to non-EU AIFMs and AIFs.
- ESMA (2025). Final Report: Technical Advice on the review of the UCITS Eligible Assets Directive (EAD). https://www.esma.europa.eu/sites/default/files/2025-06/ESMA34-20877_85638-1548_Final_report_on_the_Technical_Advice_on_the_review_of_the_UCITS_EAD.pdf.
- ESRB (2014a). The ESRB handbook on operationalising macro-prudential policy in the banking sector. Technical report, European Systemic Risk Board. Updated February 2018; instrument-specific guidance for macroprudential authorities in the banking sector.
- ESRB (2014b). Flagship report on macroprudential policy in the banking sector. Technical report, European Systemic Risk Board.
- ESRB (2015). The ESRB handbook on operationalising macroprudential policy in the banking sector: Addendum – macroprudential leverage ratios. Technical report, European Systemic Risk Board, Frankfurt am Main. Addendum to the ESRB Handbook on Operationalising Macroprudential Policy in the Banking Sector.
- ESRB (2017). A Review of Macroprudential Policy in the EU in 2016. European Systemic Risk Board.
- ESRB (2017). Notification by Finland maximum loan-to-value ratio for new housing loans. https://www.esrb.europa.eu/pub/pdf/other/esrb.notification_other170627_Finland_en.pdf.
- ESRB (2018). Handbook on Operationalising Macroprudential Policy in the Banking Sector.
- ESRB (2019a). Finland 15 per cent risk weight floor for mortgage loans (expired 01 January 2021). https://www.esrb.europa.eu/national_policy/reciprocation/html/finland_mortgage.es.html.
- ESRB (2019b). List of national macroprudential authorities and national designated authorities in eea member states.
- ESRB (2019c). Notification on other systemically important institutions in latvia. Technical report, ESRB.
- ESRB (2019d). Other Systemically Important Institutions (O-SII) in Estonia. Technical report, ESRB.
- ESRB (2021). Notification from the haut conseil de la stabilité financière to the esrb of 8 december 2021 on borrower-based measures (DSTI and maturity limits) for new housing loans in France. Technical Report ESRB Notification 2021/12/08, European Systemic Risk Board.
- ESRB (2023). Notification to the European systemic risk board of the o-sii buffer rates for cypriot credit institutions. https://www.esrb.europa.eu/pub/pdf/other/Esrb.notification_230702_OSII_CY~e12ebff84b.en.pdf.
- ESRB (2024). Notification by Central Bank of Malta and Malta financial services authority on other systemically important institutions (O-SII) buffer resetting. PDF document. Accessed November 2025.

- European Central Bank (2009). Financial Stability Review. Technical report, European Central Bank, Frankfurt am Main.
- Faia, E., Hackethal, A., Haliassos, M., and Langenbucher, K., editors (2015). *Financial Regulation: A Transatlantic Perspective*. Cambridge University Press, Cambridge.
- Falagiarda, M. and Saia, A. (2017). Credit, endogenous collateral and risky assets: A DSGE model. *International Review of Economics & Finance*, 49:125–148.
- Farhi, E. and Werning, I. (2012). Dealing with the Trilemma: Optimal Capital Controls with Fixed Exchange Rates. NBER Working Paper 18199, National Bureau of Economic Research, Cambridge, MA.
- Farhi, E. and Werning, I. (2016). A Theory of Macroprudential Policies in the Presence of Nominal Rigidities. *Econometrica*, 84(5):1645–1704.
- Farmer, J. D. and Foley, D. (2009a). The economy needs agent-based modelling. *Nature*, 460:685–686.
- Farmer, J. D. and Foley, D. K. (2009b). The Economy Needs Agent-Based Modelling. *Nature*, 460:685–686.
- Farmer, J. D., Kleinnijenhuis, A., Schuermann, T., and Wetzer, T., editors (2022). *Handbook of Financial Stress Testing*. Cambridge University Press, Cambridge. ISBN 9781108903011.
- Fedorowicz, M. (2011). Regulacja nadzoru nad rynkiem finansowym w UE – integracja czy dezintegracja prawnych instrumentów antykrzysowych. *Ekonomia i Prawo*, 7:287–303.
- Fedorowicz, M. (2014). W sprawie przyszłej organizacji nadzoru makroostrożnościowego w Polsce. *Bezpieczny Bank*, (4(57)):83–100.
- Feito, J. L. (2006). Reflexiones sobre el déficit exterior. *Cuadernos del pensamiento político*, July–September:113–133.
- Fernández de Lis, S. and García-Herrero, A. (2009). The Spanish Approach: Dynamic Provisioning and Other Tools. Working Paper 09/03, BBVA Economic Research Department.
- Fernández-Ordóñez, M. (2011). Intervención en el XVIII Encuentro del Sector Financiero. Deloitte–ABC. Speech.
- FHFA OIG (2017). A Brief History of the Housing Government-Sponsored Enterprises. Technical report, Federal Housing Finance Agency Office of Inspector General, Washington, D.C. pp. 1–9.
- FI (2010). Beslutspromemoria: Allmänna råd om begränsning av lån mot säkerhet i bostad. https://www.fi.se/contentassets/3239c506b3ca4196ac89ceb811d10605/beslutspromemoria_bolan-fs1002.pdf.
- FI (2013). Risk weight floor for Swedish mortgages. <https://www.fi.se/contentassets/bf9750a907a14f9aac761bb28f0975db/riskviktsgolv-svenska-bolan-12-11920-21maj2014-eng.pdf>.
- FI (2015). Decision, countercyclical buffer rate (16 March 2015), activate at 1 per cent. <https://www.fi.se/contentassets/8be9239f4ea248339867228a6b7f7adc/decision-ccb-sweden-2015-03-16.pdf>.

- FI (2017). A stricter amortisation requirement for households with high loan-to-income ratios, decision memorandum. <https://www.fi.se/contentassets/217df9e983fb49db930d4d564d9f0ddc/amorteringskrav-beslutspm-eng.pdf>. Decision memo on the 1 mortgages with loan-to-income above 4.5 times income (effective 1 March 2018). Accessed 2025-11-03.
- FI (2018a). Decision memorandum: Changed method for the application of the risk-weight floor for Swedish mortgages. https://www.fi.se/contentassets/85100a98bf914e219f4f39bb0a58741d/art458_beslutspm_2018-08-22_eng.pdf.
- FI (2018b). Liquidity coverage ratio requirements in individual currencies. https://www.fi.se/contentassets/7a7909b95b954f80af93f0817e63f57a/pm_lcr_20190306_eng_ny.pdf.
- FI (2020). Decision: Countercyclical buffer rate (16 March 2020), lowering from 2.5 per cent to 0 per cent. <https://www.fi.se/contentassets/846d9b6c9b8e4641bde29440684b49d9/kontracyklisk-kapitalbuffert-2020-kv4-eng.pdf>.
- FI (2023). The mortgage market in Sweden, October 2023. https://www.financesweden.se/media/5655/1407-sbf-rapport-bolaanemarknad-2023_en04.pdf.
- FI (2024). Capital requirements for Swedish banks, FI maintains level of systemic risk buffer for major banks. <https://www.fi.se/en/financial-stability/kapitalkrav-for-svenska-banker/capital-requirements-for-swedish-banks/?catid=16&catid=24&catid=61&catid=80&page=6>.
- Filardo, A. J. and Rungcharoenkitkul, P. (2016). The Quantitative Case for Leaning Against the Wind. BIS Working Paper 594, Bank for International Settlements. Accessed 19 Oct. 2025.
- FIN-FSA (2015). Board decision on designation of other systemically important institutions (O-SIIs) and additional capital buffer requirements. https://www.esrb.europa.eu/pub/pdf/other/150706_ESRB_notification_financial_supervisory_authority_Finland.pdf.
- FIN-FSA (2017). Macroprudential decision: A minimum risk weight level of 15% on mortgage loans. <https://www.finanssivalvonta.fi/en/publications-and-press-releases/Press-release/2017/macroprudential-decision-a-minimum-risk-weight-level-of-15-on-mortgage-loans-no-changes-to-the-loan-cap-no-countercyclical-capital-buffer-requirement2/>.
- FIN-FSA (2023). Macroprudential decision: Systemic risk buffer set for banks. <https://www.sttinfo.fi/announcement/4357?lang=en&publisherId=69817444>.
- FIN-FSA (2025). Macroprudential decision: National buffer requirements for banks and the housing loan-cap to remain unchanged. <https://www.finanssivalvonta.fi/en/publications-and-press-releases/Press-release/2025/macroprudential-decision-national-buffer-requirements-for-banks-and-the-housing-loan-cap-to-remain-unchanged/>.
- Financial Supervisory Authority (FIN-FSA), F. (2025). Macroprudential decision: Housing loan cap and countercyclical capital buffer requirement for banks to remain unchanged. <https://www.finanssivalvonta.fi/en/publications-and-press-releases/Press-release/2025/macroprudential-decision-housing-loan-cap-and-countercyclical-capital-buffer-requirement-for-banks-to-remain-unchanged/>.
- Firlej, K. A. (2011). Źródło i przebieg kryzysu finansowego w Stanach Zjednoczonych i Europie Zachodniej. *Roczniki Ekonomiczne Kujawsko-Pomorskiej Szkoły Wyższej w Bydgoszczy*, (4):179–191.

- Fischer, S. (2015). Macroprudential Policy in the U.S. Economy. Speech at the “Macroprudential Monetary Policy” Conference, 59th Economic Conference of the Federal Reserve Bank of Boston, Boston, MA.
- Fitzpatrick IV, T. J., Greenlee, M., and Thomson, J. (2011). Resolving Large, Complex Financial Firms. *Federal Reserve Bank of Cleveland, Economic Commentary*, (2011-16).
- Fitzpatrick IV, T. J. and Thomson, J. (2011a). An End to Too Big to Let Fail? The Dodd-Frank Act’s Orderly Liquidation Authority. *Federal Reserve Bank of Cleveland, Economic Commentary*, (2011-01).
- Fitzpatrick IV, T. J. and Thomson, J. (2011b). How Well Does Bankruptcy Work When Large Financial Firms Fail? Some Lessons from Lehman Brothers. *Federal Reserve Bank of Cleveland, Economic Commentary*, (2011-23).
- Flannery, M. J., Hirtle, B., and Kovner, A. (2016). Evaluating the Information in the Federal Reserve Stress Tests. Staff Report 744, Federal Reserve Bank of New York.
- Fligstein, N. and Rucks-Ahidiana, Z. (2015). The Rich Got Richer: The Effects of the Financial Crisis on Households’ Well-Being, 2007–2009. IRLE Working Paper 121-15, Institute for Research on Labor and Employment, University of California, Berkeley.
- Focarelli, D., Marqués-Ibañez, D., and Pozzolo, A. F. (2011). Are Universal Banks Better Underwriters? Evidence from the Last Days of the Glass–Steagall Act. ECB Working Paper Series 1287, European Central Bank, Frankfurt am Main.
- Freixas, X., Lóránth, G., and Morrison, A. D. (2007). Regulating financial conglomerates. *Journal of Financial Intermediation*, 16:479–514.
- Froot, K. A. and Dabora, E. M. (1999). How are stock prices affected by the location of trade? *Journal of Financial Economics*, 53(2):189–216.
- Frost, J. and van Stralen, R. (2018). Macroprudential policy and income inequality. *Journal of International Money and Finance*, 85:278–290.
- FSB (2014). 2014 update of list of global systemically important banks (g-sibs). Technical report, Financial Stability Board. Accessed: 2025-09-23.
- FSB, IMF, BIS (2011). Macroprudential policy tools and frameworks: Update to g20 finance ministers and central bank governors. Technical report, Financial Stability Board. Joint update by FSB/IMF/BIS to the G20 Finance Ministers and Central Bank Governors, 14 February 2011.
- Fuentes Quintana, E. (1998). España ante el examen de convergencia de 1998. In *Anales de la Real Academia de Ciencias Morales y Políticas*, volume 75.
- G20 (2009a). Leaders’ statement: The Pittsburgh summit. https://g20.org/wp-content/uploads/2024/10/G20_EUA_2009_communique-1.pdf. Accessed 22 September 2025.
- G20 (2009b). London Summit G20 Leaders’ Statement. Online.
- Gadancz, B. and Jayaram, K. (2015). Measures of financial stability – a review. In *BIS IFC Bulletin*, number 31, pages 365–380. Bank for International Settlements.
- Gai, P. (2013). *Systemic Risk: The Dynamics of Modern Financial Systems*. Oxford University Press, Oxford.

- Galam, S. (2008). Sociophysics: A Review of Galam Models. *International Journal of Modern Physics C*, 19(03):409–440.
- Galati, G. and Moessner, R. (2011a). Macroprudential policy – a literature review. BIS Working Papers 337, Bank for International Settlements.
- Galati, G. and Moessner, R. (2011b). Macroprudential Policy: A Literature Review. BIS Working Paper 337, Bank for International Settlements.
- Galati, G. and Moessner, R. (2014). What Do We Know About the Effects of Macroprudential Policy? *Economica*, 85(340):735–770.
- Garslian, L. (2016). Towards a Universal Model Regulatory Framework for Derivatives: Post-Crisis Conclusions from the United States and the European Union. *University of Pennsylvania Journal of International Law*, 37(3):941–1028.
- Gattuso, J. (2008). Deregulation and the Financial Crisis. *Heritage Foundation Backgrounder*, (2191):1–8.
- Geanakoplos, J. (2011). What’s Missing from Macroeconomics: Endogenous Leverage and Default. Cowles Foundation Paper 1332, Cowles Foundation for Research in Economics, Yale University, New Haven, CT.
- Geanakoplos, J., Axtell, R., Farmer, J. D., Howitt, P., Conlee, B., Goldstein, J., Hendrey, M., Palmer, N. M., and Yang, C.-Y. (2012). Getting at Systemic Risk via an Agent-Based Model of the Housing Market. *American Economic Review: Papers & Proceedings*, 102(3):53–58.
- Geanakoplos, J., Magill, M., Quinzii, M., and Drèze, J. (1990). Generic inefficiency of stock market equilibrium when markets are incomplete. *Journal of Mathematical Economics*, 19(1):113–151.
- Geanakoplos, J. and Polemarchakis, H. (1986). Existence, Regularity, and Constrained Suboptimization of Competitive Allocations when Markets are Incomplete. In Heller, W. P., Starr, R. M., and Starrett, D. A., editors, *Uncertainty, Information and Communication: Essays in Honor of Kenneth J. Arrow*, volume 3, pages 65–96. Cambridge University Press, Cambridge.
- Geithner, T. F. (2014). *Stress Test: Reflections on Financial Crises*. Crown Publishers, New York. Memoir by former U.S. Treasury Secretary.
- Gelain, P., Lansing, K. J., and Mendicino, C. (2013). House Prices, Credit Growth, and Excess Volatility: Implications for Monetary and Macroprudential Policy. *International Journal of Central Banking*, 9(2):219–276.
- Georgescu, O.-M. and Vila Martin, D. (2021). Do macroprudential measures increase inequality? Evidence from the euro area household survey. ECB Working Paper Series 2567, European Central Bank.
- Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking*, 42(s1):107–141.
- Gersbach, H. and Rochet, J.-C. (2012). Aggregate Investment Externalities and Macroprudential Regulation. *Journal of Money, Credit and Banking*, 44. Supplement 2:73–109.
- Gilbert, R. A. (1986). Requiem for Regulation Q: What It Did and Why It Passed Away. *Federal Reserve Bank of St. Louis Review*, 68:22–37.
- Gini, C. (1909). Concentration and dependency ratios. *Rivista di Politica Economica*, 87:769–789.

- Giordana, G. A. and Schumacher, I. (2017). An Empirical Study on the Impact of Basel III Standards on Banks' Default Risk: The Case of Luxembourg. *Journal of Risk and Financial Management*, 10(8):1–21.
- Gissler, S. and Narajabad, B. (2017). The Increased Role of the Federal Home Loan Bank System in Funding Markets, Part 1: Background. FEDS notes, Board of Governors of the Federal Reserve System, Washington, D.C. FEDS Notes, October 18, 2017.
- GLB (1999). Gramm–Leach–Bliley Act of 1999. Public Law 106-102, 113 Stat. 1338. Also known as the Financial Services Modernization Act.
- Golyk, V. A. (2012). Self-organized Criticality. <http://www.mit.edu/~8.334/grades/projects/projects12/V.%20A.%20Golyk.pdf>. MIT Online Project Report.
- Goodhart, C., Kashyap, A. K., Tsomocos, D. P., and Vardoulakis, A. P. (2012). Financial Regulation in General Equilibrium. Working Paper 17909, National Bureau of Economic Research (NBER).
- Goodhart, C. A. E. (2008). The regulatory response to the financial crisis. *Journal of Financial Stability*, 4(4):351–358.
- Goodman, L., Parrott, J., and Zhu, J. (2015). The Impact of Early Efforts to Clarify Mortgage Repurchases: Evidence from Freddie Mac and Fannie Mae's Newest Data. Technical report, Urban Institute, Washington, D.C. Housing Finance Policy Center.
- Gorton, G. (2009). The Subprime Panic. *European Financial Management*, 15(1):10–46. Published by Wiley Online Library.
- Gourio, F., Kashyap, A. K., and Sim, J. W. (2018). The Trade Offs in Leaning Against the Wind. *IMF Economic Review*, 66(1):70–115.
- GPO-FCIC (2011). The Financial Crisis Inquiry Report: Final Report of the National Commission on the Causes of the Financial and Economic Crisis in the United States. Government report, U.S. Government Publishing Office, Washington, D.C.
- Granja, J. and Leuz, C. (2020). The Death of a Regulator: Strict Supervision, Bank Lending and Business Activity. LawFin Working Paper 4, Goethe University, Center for Advanced Studies on the Foundations of Law and Finance (LawFin), Frankfurt am Main.
- Gray, D. F., Merton, R. C., and Bodie, Z. (2006). A New Framework for Analyzing and Managing Macrofinancial Risks of an Economy. Working paper, Harvard Business School, Cambridge, MA.
- Greenwald, B. and Stiglitz, J. E. (1986). Externalities in Economies with Imperfect Information and Incomplete Markets. *The Quarterly Journal of Economics*, 101(2):229–264.
- Grejcz, K. and Żółkiewski, Z. (2017). Household wealth in Poland: the results of a new survey of household finance. *Bank i Kredyt*, 48:295–326.
- Grinstein-Weiss, M., Key, C., Guo, S., Yeo, Y.-H., and Holub, K. (2013). Homeownership and Wealth among Low- and Moderate-Income Households. *Housing Policy Debate*, 23:259–279.
- Grzywacz, J. and Jabłońska, A. (2012). Normy ostrożnościowe w działalności banków. *Zeszyty Naukowe Państwowej Wyższej Szkoły Zawodowej w Płocku. Nauki Ekonomiczne. Tom 15*, (13):7–21.
- Guerrero, O. A. (2020). Decentralized markets and the emergence of housing wealth inequality. *Computers, Environment and Urban Systems*, 84:101541.

- Guerrieri, V. and Lorenzoni, G. (2017). Credit Crises, Precautionary Savings, and the Liquidity Trap. *The Quarterly Journal of Economics*, 132(3):1427–1467.
- Guillén, M. F. (2015). The Global Economic & Financial Crisis: A Timeline. https://lauder.warton.upenn.edu/wp-content/uploads/2015/06/Chronology_Economic_Financial_Crisis.pdf.
- Gupta, V., Mittal, R. K., and Bhalla, V. (2010). Role of the Credit Rating Agencies in the Financial Market Crisis. *Journal of Development and Agricultural Economics*, 2(7):268–276.
- Guth, M. A. S. (1994). *Speculative Behavior and the Operation of Competitive Markets Under Uncertainty*. Avebury, Aldershot. ISBN-10 1856289850, ISBN-13 978-1856289856.
- Haldane, A. G. and May, R. M. (2011). Systemic risk in banking ecosystems. *Nature*, 469:351–355.
- Hallaron, M. (2009). Systemic Risks and the Bear Stearns Crisis. In Ciorciari, J. and Taylor, J., editors, *The Road Ahead for the Fed*, number 574, pages 151–170. Hoover Institution Press.
- Haltom, R. (2011). Foreign Housing Finance: America’s Unique Mortgage Finance System Is Facing Renovation. *Econ Focus* (“Region Focus” cover story), *Federal Reserve Bank of Richmond*, 15(2):6–17.
- Hanc, G. (2004). The Future of Banking in America: Summary and Conclusions. *FDIC Banking Review*, 16(1):1–8. FDIC Banking Review Series.
- Hand, D. J. (1993). Statistical Reasoning with Imprecise Probabilities. By P. Walley. *Journal of the Royal Statistical Society. Series C: Applied Statistics*, 42(1):237–238.
- Hanson, S. G., Kashyap, A. K., and Stein, J. C. (2011). A Macroprudential Approach to Financial Regulation. *Journal of Economic Perspectives*, 25(1):3–28.
- Hartman-Glaser, B., Stanton, R., and Wallace, N. (2014). Mortgage Underwriting Standards in the Wake of Quantitative Easing. Technical report, University of California, Los Angeles (UCLA) / University of California, Berkeley, Los Angeles / Berkeley, CA. Working Paper, December 11 2014.
- Hartmann, P., Straetmans, S., and de Vries, C. G. (2005). Banking System Stability: A Cross-Atlantic Perspective. ECB Working Paper 527, European Central Bank, Frankfurt am Main.
- Harun, C. A. and Gunadi, I. (2022). Financial Stability and Systemic Risk. In Warjiyo, P. and Juhro, S. M., editors, *Central Bank Policy Mix: Issues, Challenges, and Policy Responses*, pages 73–89. Springer.
- Hałaj, G. (2007). *Modelowanie ryzyka systemowego na rynku międzybankowym*. PhD thesis, Szkoła Główna Handlowa w Warszawie. Doctoral dissertation, in Polish.
- He, Z. and Krishnamurthy, A. (2013). Intermediary Asset Pricing. *American Economic Review*, 103(2):732–770.
- Hillier, A. E. (2003). Redlining and the Home Owners’ Loan Corporation. *Journal of Urban History*, 29(4):394–420.
- Hirschleifer, D. (2001). Investor Psychology and Asset Pricing. *The Journal of Finance*, 56:1533–1597.
- HNB (2014). Financial Stability Council.

- Hodula, M., Szabo, M., Pfeifer, L., and Melecký, M. (2022). Based Limits on New Mortgage Lending. Technical Report CNB WP-2022-03, Czech National Bank.
- Holinski, N., Kool, C., and Muysken, J. (2012). Persistent Macroeconomic Imbalances in the Euro Area: Causes and Consequences. *Federal Reserve Bank of St. Louis Review*, 94(1):1–20.
- Holmström, B. and Tirole, J. (1997). Financial Intermediation, Loanable Funds, and the Real Sector. *The Quarterly Journal of Economics*, 112(3):663–691.
- Holmström, B. and Tirole, J. (1998). Private and Public Supply of Liquidity. *Journal of Political Economy*, 106(1):1–40.
- Hommes, C., He, M., Poledna, S., Siqueira, M., and Zhang, Y. (2022). CANVAS A Canadian Behavioral Agent-Based Model. Staff Working Paper 2022-51, Bank of Canada.
- Hommes, C. and Wagener, F. (2009). CHAPTER 4 - Complex Evolutionary Systems in Behavioral Finance. In Hens, T. and Schenk-Hoppé, K. R., editors, *Handbook of Financial Markets: Dynamics and Evolution*, Handbooks in Finance, pages 217–276. North-Holland, San Diego.
- Honkapohja, S. (2009). The 1990's Financial Crises in Nordic Countries. Bank of Finland Research Discussion Paper 5/2009, Bank of Finland.
- Hu, G. X., Pan, J., and Wang, J. (2013). Noise as Information for Illiquidity. *The Journal of Finance*, 68(6):2341–2382.
- Huang, X., Zhou, H., and Zhu, H. (2009a). A Framework for Assessing the Systemic Risk of Major Financial Institutions. *BIS Working Papers*, (281).
- Huang, X., Zhou, H., and Zhu, H. (2009b). A Framework for Assessing the Systemic Risk of Major Financial Institutions. *Journal of Banking & Finance*, 33(11):2036–2049.
- HUD (1996). Privatization of Fannie Mae and Freddie Mac: Desirability and Feasibility. Technical report, U.S. Department of Housing and Urban Development, Washington, D.C.
- Hurd, M. D. and Rohwedder, S. (2010). Effects of the Financial Crisis and Great Recession on American Households. NBER Working Paper 16407, National Bureau of Economic Research, Cambridge, MA.
- Hurley, C. K. (2010). Paying the Price for Too Big to Fail. *Ohio State Entrepreneurial Business Law Journal* 3, 4:351–389.
- Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. *American Economic Review*, 95(3):739–764.
- Igan, D., Mishra, P., and Tressel, T. (2009). A Fistful of Dollars: Lobbying and the Financial Crisis. Technical Report WP/09/287, International Monetary Fund, Washington, D.C. IMF Working Paper.
- Ilut, C. L. and Schneider, M. (2014). Ambiguous Business Cycles. *American Economic Review*, 104(8):2368–2399.
- IME (1998). Informe de convergencia. Informe requerido por el Artículo 109 J del Tratado constitutivo de la Comunidad Europea. Technical report, Instituto Monetario Europeo.
- IMF (2010). Greece: Staff Report on Request for Stand-By Arrangement. Technical Report 10/110, International Monetary Fund, Washington, D.C.

- IMF (2013a). Key Aspects of Macroprudential Policy. Technical report, International Monetary Fund.
- IMF (2013b). Republic of Slovenia: Financial System Stability Assessment. Technical Report IMF Country Report No. 12/325, International Monetary Fund.
- IMF (2021). 2021 Comprehensive Surveillance Review — Background Paper on Systemic Risk and Macroprudential Policy Advice in Article IV Consultations. Policy Paper 2021/033, International Monetary Fund.
- IMF (2021). Republic of Latvia: 2021 article iv consultation, staff report. Technical Report 2021/194, International Monetary Fund.
- IMF (2024). Kingdom of the Netherlands: Financial System Stability Assessment. IMF Country Report 24/171, International Monetary Fund.
- Immergluck, D. (2009). *Foreclosed: High-Risk Lending, Deregulation, and the Undermining of America's Mortgage Market*. Cornell University Press.
- Iwanicz-Drozdowska, M., Lepczyński, B., and Wierzbą, R. (2004). Nowa Umowa Kapitałowa Bazylejskiego Komitetu Nadzoru Bankowego: konsekwencje dla gospodarki i sektora bankowego w Polsce. *Transformacja Gospodarki*, (111).
- Javarone, M. A. and Armano, G. (2013). Perception of Similarity: A Model for Social Network Dynamics. *Journal of Physics A: Mathematical and Theoretical*, 46(45):455102.
- Jeanne, O. and Korinek, A. (2010). Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach. *American Economic Review*, 100(2):403–407.
- Jensen, H., Ravn, S. H., and Santoro, E. (2018). Changing credit limits, changing business cycles. *European Economic Review*, 102:211–239.
- Jiménez, G., Ongena, S., Peydró, J.-L., and Saurina, J. (2017a). Macroprudential Policy, Countercyclical Bank Capital Buffers, and Credit Supply: Evidence from the Spanish Dynamic Provisioning Experiments. *Journal of Political Economy*, 125(6).
- Jiménez, G., Ongena, S., Peydró, J.-L., and Saurina, J. (2017b). Macroprudential Policy, Countercyclical Capital Buffers and Credit Supply. *Journal of Political Economy*, 125(6).
- Johnson, Jr., C. J. and McLaughlin, J. (2013). *Corporate Finance and the Securities Laws*. Wolters Kluwer Law & Business, New York, NY.
- Jones, K. D. and Critchfield, T. S. (2005). Consolidation in the U.S. Banking Industry: Is the “Long, Strange Trip” About to End? *FDIC Banking Review*, 17(4):31–56.
- Jonung, L. (2011). Lessons from the Nordic Financial Crisis. In *AEA Annual Meeting*, Chicago, IL.
- Jurkowska-Zeidler, A. (2009). *Bezpieczeństwo rynku finansowego w świetle prawa Unii Europejskiej*. Wolters Kluwer, Warsaw.
- Kaminsky, G. and Reinhart, C. (1999). The Twin Crises: The Causes of Banking and Balance-of-Payments Problems. *American Economic Review*, 89(3):473–500.
- Kaminsky, G. L. and Reinhart, C. M. (2000). On Crises, Contagion, and Confusion. *Journal of International Economics*, 51(1):145–168.
- Kannai, Y. (1963). Existence of a Utility in Infinite Dimensional Partially Ordered Spaces. *Israel Journal of Mathematics*, 1(4):229–234.

- Kapadia, S., Drehmann, M., Elliott, J., and Sterne, G. (2013). Liquidity Risk, Cash Flow Constraints, and Systemic Feedbacks. In Haubrich, J. G. and Lo, A. W., editors, *Quantifying Systemic Risk*, pages 29–72. University of Chicago Press.
- Kaplan, G., Moll, B., and Violante, G. L. (2018). Monetary Policy According to HANK. *American Economic Review*, 108(3):697–743.
- Karkowska, R. (2015). *Ryzyko systemowe. Charakter i źródła indywidualizacji w sektorze bankowym*. Oficyna, Wydawnictwo Wolters Kluwer.
- Karni, E. (2005). A New Approach to Modeling Decision-Making under Uncertainty and Defining Subjective Probabilities. Economics Working Paper 519, Johns Hopkins University, Department of Economics.
- Kashyap, A. K., Tsomocos, D. P., and Vardoulakis, A. P. (2014). How does macroprudential regulation change bank credit supply? Working Paper 20165, National Bureau of Economic Research (NBER).
- Kaszowska, J. and Santos, J. L. (2014). The Role of Risk Perception in The Systemic Risk Generation and Amplification: An Agent-Based Approach. *ACRN Journal of Finance and Risk Perspectives*, 3(4):146–170.
- Kaszowska-Mojša, J. (2023). Investigating new policies for financial stability that do not create inequality (macropru). EU Horizon 2020 Marie Skłodowska-Curie Individual Fellowships, Grant Agreement 101023445. Project start: 1 Oct 2021; end: 30 Sep 2023.
- Kaszowska-Mojša, J. and Pipień, M. (2020). Macroprudential Policy in a Heterogeneous Environment—An Application of Agent-Based Approach in Systemic Risk Modelling. *Entropy*, 22(2):129.
- Kaufman, G. G. (2013). Too Big to Fail in Banking: What Does It Mean? Technical Report 222, LSE Financial Markets Group, London School of Economics. LSE Financial Markets Group Special Paper No. 222.
- Kennard, F. and Hanne, A. (2015). *Boom & Bust: A Look at Economic Bubbles*. Lulu Enterprises Incorporated.
- Kennedy, P. (2013). *The Spanish Socialist Party and the Modernisation of Spain*. Manchester University Press, Manchester.
- Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248.
- KNF (2008). Uchwała nr 382/2008 Komisji Nadzoru Finansowego z dnia 17 grudnia 2008 r. w sprawie szczegółowych zasad i warunków uwzględniania zaangażowań przy ustalaniu przestrzegania limitu koncentracji zaangażowań i limitu dużych zaangażowań, określenia zaangażowań, wobec których nie stosuje się przepisów dotyczących limitów koncentracji zaangażowań i dużych zaangażowań oraz warunków, jakie muszą one spełniać, określenia zaangażowań, wobec których wymagane jest uzyskanie zgody knf na niestosowanie przepisów dotyczących limitów koncentracji zaangażowań i dużych zaangażowań oraz zakresu i sposobu uwzględniania działania banków w holdingach w obliczaniu limitów koncentracji zaangażowań.
- KNF (2011a). Uchwała nr 153/2011 Komisji Nadzoru Finansowego z dnia 7 czerwca 2011 r. zmieniająca uchwałę nr 76/2010 knf w sprawie zakresu i szczegółowych zasad wyznaczania wymogów kapitałowych z tytułu poszczególnych rodzajów ryzyka.

- KNF (2011b). Uchwała nr 208/2011 Komisji Nadzoru Finansowego z dnia 22 sierpnia 2011 r. w sprawie szczegółowych zasad i warunków uwzględniania zaangażowań przy ustalaniu przestrzegania limitu koncentracji zaangażowań.
- Knight, F. H. (1921). *Risk, Uncertainty and profit*. Houghton Mifflin Company, Boston, New York.
- Koleśnik, J. (2013). Europejska unia bankowa – nowy wymiar ryzyka systemowego. *Problemy Zarządzania*, 11(2(42)):91–110.
- Konstantinou, P., Rizos, A., and Stratopoulou, A. (2022). Macroprudential policies and income inequality in former transition economies. *Economic Change and Restructuring*, 55(2):1005–1062.
- Korinek, A. (2011). Systemic Risk-Taking: Amplification Effects, Externalities, and Regulatory Responses. *ECB Working Paper*, (1345):1–41.
- Kotz, S., Johnson, N. L., and Read, C. B. (1983). *Encyclopedia of Statistical Sciences*. John Wiley & Sons, Inc., Hoboken, NJ, USA.
- Kowalczyk, D. (2015). Zmiany w europejskim nadzorze bankowym po kryzysie finansowym. *Zarządzanie i Finanse (Journal of Management and Finance)*, 3:33–45.
- Kowalik, M. (2011). Countercyclical capital regulation: should bank regulators use rules or discretion. *Economic Review*, pages 59–80. Issue Q II.
- Kozak, S. (2013). Consolidation of the Banking Sector in Poland in 1989–2013 in Comparison with the Structural Changes of the Banking Sector in the USA and the EU. Working Paper 166, Narodowy Bank Polski.
- KPMG (2013). AIFMD: Transposition Status. Technical report, KPMG International.
- Kraft, E. and Galac, T. (2011). Macroprudential Regulation of Credit Booms and Busts: The Case of Croatia. Policy Research Working Paper WPS5772, World Bank, Washington, D.C.
- Krawiec, K. and Liu, G. (2015). The Volcker Rule: A Brief Political History. *Capital Markets Law Journal*, 10:507–522.
- Kroszner, R. S. and Rajan, R. G. (1994). Is the Glass–Steagall Act Justified?: A Study of the U.S. Experience with Universal Banking before 1933. *American Economic Review*, 84(4):810–832.
- Krugman, P. R. (2007). Will There Be a Dollar Crisis? *Economic Policy*, 22:436–467.
- Krugman, P. R. (2009). *The Return of Depression Economics and the Crisis of 2008*. W. W. Norton & Company, New York.
- Krugman, P. R. (2011). Inequality and Crises: Coincidence or Causation? Luxembourg Income Study (LIS) Presentation & Discussion.
- Kukk, M., Levenko, N., and Reigl, N. (2023). Measuring the effects of borrower-based policies on new housing loans in Estonia. Technical Report 4/2023, Eesti Pank.
- Kupiec, P. H. (2017). Is Systemic Risk a Dodd-Frank Fallacy? *American Banker*.
- Labonte, M. and Makinen, G. (2008). Monetary Policy and the Federal Reserve: Current Policy and Conditions. CRS Report RL30354, Congressional Research Service, Washington, D.C.
- Laliotis, D., Buesa, A., Leber, M., and Población, J. (2020). An Agent-based Model for the Assessment of LTV Caps. *Quantitative Finance*, 20(10):1721–1748.

- Lambertini, L., Mendicino, C., and Punzi, M. T. (2013). Leaning against boom-bust cycles in credit and housing prices. *Journal of Economic Dynamics and Control*, 37(8):1500–1522.
- Lamont, O. A. and Thaler, R. H. (2003). Can the Market Add and Subtract? Mispricing in Tech Stock Carve-Outs. *Journal of Political Economy*, 111(2):227–268.
- Landau, J.-P. (2009). Procyclicality – what it means and what could be done. *BIS Review*, (94):1–6. Remarks by Mr Jean-Pierre Landau, Deputy Governor of the Bank of France, at the Bank of Spain’s conference on Procyclicality and the Role of Financial Regulation; Madrid, 4 May 2009.
- Lannoo, K. (2009). The Road Ahead after de Larosi  re. CEPS Policy Brief 195/7, Centre for European Policy Studies (CEPS), Brussels.
- Larcker, D. F. and Tayan, B. (2010). Lehman Brothers: Peeking under the Board Facade. *Stanford Closer Look Series*, pages 1–3.
- Larosi  re Report (2009). Report of the High-Level Group on Financial Supervision in the EU. https://ec.europa.eu/economy_finance/publications/pages/publication14527_en.pdf. Published 25 February 2009. Group members included Leszek Balcerowicz; Otmar Issing; Rainer Masera; Callum McCarthy; Lars Nyberg; Jos   P  rez; Onno Ruding; Jacques de Larosi  re (Chair).
- Law 426 (2014). Law 4261/2014 “access to the activity of credit institutions and prudential supervision of credit institutions and investment firms (transposition of directive 2013/36/eu)”. Government Gazette A 107, Greece, 5 May 2014. Accessed 1 November 2025.
- Law of 1 April 2015 (2015). Law of 1 April 2015 establishing a systemic risk committee. https://www.cssf.lu/wp-content/uploads/L_010415_SRC.pdf.
- LB (2022). Countercyclical capital buffer.
- LB (2025). Macroprudential measures introduced in Latvia: O-SII buffer.
- LeBaron, B. and Tesfatsion, L. (2008). Modeling Macroeconomies as Open-Ended Dynamic Systems of Interacting Agents. *American Economic Review: Papers & Proceedings*, 98(2):246–250. ISSN 0002-8282 (Print), ISSN 1944-7981 (Online).
- Leduc, M. V., Poledna, S., and Thurner, S. (2017). Systemic Risk Management in Financial Networks with Credit Default Swaps. *Journal of Network Theory in Finance*, 3(3):19–39.
- Lee, J., Rabanal, P., and Sandri, D. (2010). US Consumption after the 2008 Crisis. IMF Staff Position Note SPN/10/01, International Monetary Fund.
- Lehar, A. (2005). Measuring Systemic Risk: A Risk Management Approach. *Journal of Banking & Finance*, 29(10):2577–2603.
- Lenart, L. (2013). Non-Parametric Frequency Identification and Estimation in Mean Function for Almost Periodically Correlated Time Series. *Journal of Multivariate Analysis*, 115:252–269.
- Lenart, L. and Pipie  n, M. (2013). Almost Periodically Correlated Time Series in Business Fluctuations Analysis. *Acta Physica Polonica A*, 123:567–583.
- Lenart, L. and Pipie  n, M. (2015). Empirical Properties of the Credit and Equity Cycle within Almost Periodically Correlated Stochastic Processes: The Case of Poland, UK and USA. *Central European Journal of Economic Modelling and Econometrics*, 7(3):169–186.
- Lenart, L. and Pipie  n, M. (2017). Non-Parametric Test for the Existence of the Common Deterministic Cycle: The Case of the Selected European Countries. *Central European Journal of Economic Modelling and Econometrics*, 9(3):201–241.

- Lenart, L. and Pipień, M. (2018). Cyclical Properties of the Credit and Production in Selected European Countries - A Comparison of Deterministic and Stochastic Cycle Approach. *Acta Physica Polonica A*, 133:1371–1387.
- Lewellen, J. and Shanken, J. (2002). Learning, Asset-Price Tests, and Market Efficiency. *The Journal of Finance*, 57(3):1113–1145.
- Lim, C. H., Columba, F., Costa, A., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T., and Wu, X. (2011). Macroprudential Policy: What Instruments and How to Use Them? Lessons from Country Experiences. IMF Working Paper WP/11/238, International Monetary Fund.
- Lim, E.-G. (2006). The Euro’s Challenge to the Dollar: Different Views from Economists and Evidence from COFER (Currency Composition of Foreign Exchange Reserves) and Other Data. IMF Working Paper WP/06/153, International Monetary Fund.
- Lin, C. Y.-Y., Edvinsson, L., Chen, J., and Beding, T. (2014). Impact of the 2008 Global Financial Crisis. In Lin, C. Y.-Y., Edvinsson, L., Chen, J., and Beding, T., editors, *National Intellectual Capital and the Financial Crisis in Denmark, Finland, Iceland, Norway, and Sweden*, SpringerBriefs in Economics, pages 7–19. Springer, New York.
- Lo Duca, M. and Stracca, L. (2014). The Effects of G20 Summits on Global Financial Markets.
- Lo Schiavo, G. (2014). From National Banking Supervision to a Centralized Model of Prudential Supervision in Europe?: The Stability Function of the Single Supervisory Mechanism: The Stability Function of the Single Supervisory Mechanism. *Maastricht Journal of European and Comparative Law*, 21(1):110–140.
- Lorenz, M. O. (1905). Methods of measuring the concentration of wealth. *Publications of the American Statistical Association*, 9(70):209–219.
- Lorenzoni, G. (2007). Inefficient Credit Booms. NBER Working Paper 13639, National Bureau of Economic Research, Cambridge, MA.
- LSE (2014). Systemic Risk Centre. <http://www.systemicrisk.ac.uk/systemic-risk>. Accessed: 17 Oct 2025.
- Lucas, D. and Torregrosa, D. (2010). Fannie Mae, Freddie Mac, and the Federal Role in the Secondary Mortgage Market. Technical Report Pub. No. 4021, Congressional Budget Office, Washington, D.C. Published 22 December 2010.
- Luckhurst, J. (2016). *G20 Since the Global Crisis*. Palgrave Macmillan, New York.
- Ludwig, E. A. (2012). Assessment of Dodd–Frank Financial Regulatory Reform: Strengths, Challenges, and Opportunities for a Stronger Regulatory System. *Yale Journal on Regulation*, 29(1):181–199.
- López-Espinosa, G., Moreno, A., Rubia, A., and Valderrama, L. (2015). Systemic risk and asymmetric responses in the financial industry. *Journal of Banking & Finance*, 58:471–485.
- Mahoney, P. G. (2018). Deregulation and the Subprime Crisis. *Virginia Law Review*, 104(2):235–300.
- Mañas, A. T. (2008). La crisis financiera internacional. Documentos de Trabajo 08/2008, Instituto Universitario de Análisis Económico y Social (IAES).
- Manasfi, J. A. (2013). Systemic Risk and Dodd–Frank’s Volcker Rule. *William & Mary Business Law Review*, 4(1):181–212.

- Mann, C. L. (2002). Perspectives on the U.S. Current Account Deficit and Sustainability. *Journal of Economic Perspectives*, 16(3):131–152.
- Marcinkowska, M. (2010). *Standardy kapitałowe banków. Bazylejska Nowa Umowa Kapitałowa w polskich regulacjach nadzorczych*. Regan Press.
- Marianoff, D. and Wayne, P. (1944). *Einstein: An Intimate Study of a Great Man*. Doubleday, Doran & Company. New York.
- Marlatt, J. and Beck, M. (2015). A User’s Guide to The Volcker Rule Complexities.
- Mas-Colell, A., Whinston, M. D., and Green, J. R. (1995). *Microeconomic Theory*. Oxford University Press, New York.
- Masselink, M. and van den Noord, P. (2009). The Global Financial Crisis and Its Effects on the Netherlands. *ECFIN Country Focus*, 6(10):1–7.
- Mayer, C. J. and Pence, K. (2008). Subprime Mortgages: What, Where, and to Whom? NBER Working Paper 14083, National Bureau of Economic Research, Cambridge, MA.
- Mačys, G. (2012). The Crisis and Economic Recovery in Baltic Countries. *International Journal of Humanities and Social Science*, 2(19):202–209.
- McCaffrey, D. P. (2016). The Transformation of the Over-the-Counter Derivatives Market, 1984–2016. *Comparative Political Economy: Regulation eJournal*.
- McCoy, P. A. (2017). Knightian Uncertainty, Systemic Risk Regulation, and the Limits of Judicial Review. *Regulation of Financial Institutions eJournal*.
- McDonald, O. (2016). The Repeal of the Glass-Steagall Act: Myth and Reality. Technical Report Policy Analysis No. 804, Cato Institute. November 16, 2016.
- McNamara, C. M. and Metrick, A. (2019). The Lehman Brothers Bankruptcy F: Introduction to the ISDA Master Agreement. *Journal of Financial Crises*, 1(1):137–150.
- McPherson, M., Smith-Lovin, L., and Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, 27:415–444.
- Meh, C. A. and Moran, K. (2010). The role of bank capital in the propagation of shocks. *Journal of Economic Dynamics and Control*, 34(3):555–576.
- Meltzer, J. P., Steven, D., and Langley, C. (2013). The United States After the Great Recession: The Challenge of Sustainable Growth. Technical Report Working Paper 60, Brookings Institution, Global Economy & Development Program.
- Mencía, J. and Saurina, J. (2016). Macroprudential policies: Objectives, Instruments and Indicators. Documentos Ocasionales 1601, Banco de España.
- Mendicino, C., Nikolov, K., Suarez, J., and Supera, D. (2018). Optimal Dynamic Capital Requirements. *Journal of Money, Credit and Banking*, 50:1271–1297.
- Michel, N. J. and Furth, S. (2017). The Macroeconomic Impact of Dodd–Frank – and of Its Repeal. Issue Brief 4682, The Heritage Foundation.
- Miller, B. B. (2017). Information Asymmetries Conceal Fraud and Systemic Risks in the U.S. Banking Industry. *Harvard Law School Forum on Corporate Governance and Financial Regulation*. Posted August 19, 2017.

- Ministry of Economy and Finance, France (2025). Understanding the hcsf – missions of the haut conseil de stabilité financière. <https://www.economie.gouv.fr/hcsf-en/understanding-hcsf/missions>.
- Minsky, H. P. (1986). *Stabilizing an Unstable Economy*. Yale University Press, New Haven, CT.
- Minsky, H. P. (1992). The Financial Instability Hypothesis. Technical Report Working Paper No. 74, The Jerome Levy Economics Institute of Bard College, Annandale-on-Hudson, NY. Prepared for Handbook of Radical Political Economy, Edward Elgar, Aldershot (1993).
- Miron, J. A. (2009). Bailout or Bankruptcy? *Cato Journal*, 29(1):1–17.
- Mishkin, F. S. (2007). *The Economics of Money, Banking, and Financial Markets*. Pearson Addison Wesley, Boston, 8th edition.
- Mishkin, F. S. and Herbertsson, T. T. (2011). Financial Stability in Iceland. In Aliber, R. Z. and Zoega, G., editors, *Preludes to the Icelandic Financial Crisis*, pages 107–159. Palgrave Macmillan, London.
- Misina, M. and Tessier, D. (2008). Non-linearities, Model Uncertainty, and Macro Stress Testing. Bank of Canada Staff Working Paper 30, Bank of Canada.
- Mitchell, C. (2016). *Saving the Market from Itself: The Politics of Financial Intervention*. Cambridge University Press, Cambridge.
- MNB (2015a). Borrower-based measures (LTV, DSTI) – legally binding rules from 1 January 2015.
- MNB (2015b). MNB helps to phase out remaining household foreign currency loans.
- MNB (2015c). Mortgage funding adequacy ratio (MFAR).
- MNB (2016). Macroprudential report – October 2016.
- MNB (2017). Mortgage Funding Adequacy Ratio (MFAR). Regulation introducing the MFAR to reduce maturity mismatches and support stable mortgage-backed funding.
- MNB (2018). Borrower-based measures (LTV, DSTI) – recalibration of DSTI limits by interest rate fixation period.
- MNB (2025a). Archive of decisions on the countercyclical capital buffer (CCyB) for Hungarian exposures.
- MNB (2025b). Countercyclical capital buffer (CCyB) — the macroprudential toolkit.
- Moloney, N. (2014). *EU Securities and Financial Markets Regulation*. Oxford University Press, Oxford, 3 edition.
- Moore, T. (1934). Security Affiliate versus Private Investment Banker: A Study in Security Organizations. *Harvard Business Review*, 12:478–484.
- Morgan, I. W. and Davies, P. J., editors (2010). *Assessing George W. Bush’s Legacy: The Right Man? The Evolving American Presidency*. Palgrave Macmillan, New York.
- Morgan, P. J., Regis, P. J., and Salike, N. (2015). Loan-to-Value Policy as a Macroprudential Tool: The Case of Residential Mortgage Loans in Asia. ADBI Working Paper 528, Asian Development Bank Institute (ADBI).

- Morris, S. and Shin, H. S. (2002). Social Value of Public Information. *American Economic Review*, 92(5):1521–1534.
- Moussa, A. (2011). *Contagion and Systemic Risk in Financial Networks*. PhD thesis, Columbia University, New York. Ph.D. thesis.
- Muellbauer, J. and Kaszowska-Mojša, J. (2023). The Effects of Borrower-Based Measures. Expert report, Finansinspektionen. Commissioned for macroprudential policy evaluation in Sweden.
- Myers, S. C. (1977). Determinants of Corporate Borrowing. *Journal of Financial Economics*, 5:147–175.
- Myerson, R. B. (1979). Incentive Compatibility and the Bargaining Problem. *Econometrica*, 47(1):61–73.
- Myerson, R. B. (1986). Multistage Games with Communication. *Econometrica*, 54(2):323–358.
- Nagatani, K. (1975). On a Theorem of Arrow. *Review of Economic Studies*, 42(3):483–485.
- Nakamoto, M. and Wighton, D. (2007). Citigroup chief stays bullish on buy-outs. Accessed: 25-02-2025.
- NBP (2007). Uchwała nr 1/2007 Komisji Nadzoru Bankowego z dnia 13 marca 2007 r. w sprawie zakresu i szczegółowych zasad wyznaczania wymogów kapitałowych z tytułu poszczególnych rodzajów ryzyka, w tym zakresu i warunków stosowania metod statystycznych oraz zakresu informacji załączonych do wniosków o wydanie zgody na ich stosowanie.
- NBP (2015a). Act on Macroprudential Supervision of the Financial System and Crisis Management in the Financial System. Journal of Laws 2015, item 1513; entered into force 1 November 2015.
- NBP (2015b). Household Wealth and Debt in Poland. Pilot survey report 2014. Technical report, Narodowy Bank Polski, Warsaw. First Polish edition of the HFCS results.
- NBP (2017). Household Wealth and Debt in Poland. Report of 2016 survey. Technical report, Narodowy Bank Polski, Warsaw. Second Polish edition of the HFCS results.
- NBP (2025a). Buffer rate / wskaźnik antycyklicznego bufora kapitałowego.
- NBP (2025b). Other systemically important institution (O-SII) buffer.
- NBP (2025c). Systemic risk buffer.
- NBS (2013). Act no. 132/2013 coll. Amending act no. 747/2004 coll. on financial market supervision.
- NBS (2018). Introduction of borrower-based measures: DTI, DSTI and maturity limits in Slovakia.
- NBS (2021). Borrower-based measures in Slovakia: early introduction and tightening of LTV, DSTI and DTI limits.
- NBS (2025a). Countercyclical capital buffer (CCyB) — overview of decisions (Slovakia).
- NBS (2025b). Debt-to-income (DTI) ratio – macroprudential instrument description.
- NBS (2025c). Financial stability legislation – macroprudential policy framework.
- Ncube, M. (2016). Bank bailout under TARP in the US. Working Paper 2016/010, Blavatnik School of Government, University of Oxford.

- Neagu, F., Tatarici, L., and Mihai, I. (2015). Implementing Loan-to-Value and Debt-Service-to-Income Measures: A Decade of Romanian Experience. Technical Report 65988, MPRA, Munich.
- Newman, M. E. J. (2003). The structure and function of complex networks. *SIAM Review*, 45(2).
- Nier, E. and Forte, G. (2016). Preventing the Next Financial Crisis. *IMF Economic Issues*.
- Nier, E., Osiński, J., Lâcome, L., and Madrid, P. (2011). Towards Effective Macroprudential Policy Frameworks: An Assessment of Stylized Institutional Models. IMF Working Paper 11/250, International Monetary Fund.
- Nier, E., Yang, J., Yorulmazer, T., and Alentorn, A. (2007). Network models and financial stability. *Journal of Economic Dynamics and Control*, 31(6):2033–2060. Tenth Workshop on Economic Heterogeneous Interacting Agents.
- Nier, E. and Zicchino, L. (2008). Bank Losses, Monetary Policy and Financial Stability: Evidence on the Interplay from Panel Data. IMF Working Paper WP/08/232, International Monetary Fund.
- Nili, Y. (2015). FSOC: Are Asset Managers’ Products and Activities Creating Systemic Risk? Harvard Law School Forum on Corporate Governance and Financial Regulation.
- Novotný, J. (2007). On the Measurement of Regional Inequality: Does Spatial Dimension of Income Inequality Matter? *The Annals of Regional Science*, 41:563–580.
- Obama, B. (2009). Remarks by the President on Financial Rescue and Reform.
- Obstfeld, M. and Rogoff, K. S. (2004). The Unsustainable U.S. Current Account Position Revisited. NBER Working Paper 10869, National Bureau of Economic Research.
- OECD (2016). Latvia: Review of the financial system. Technical report, OECD Committee on Financial Markets.
- OeNB (2024). Financial Stability Report 48, Recent developments and macroprudential policy update.
- OFHEO (2004). Report of Findings to Date: Special Examination of Fannie Mae. Technical report, Office of Federal Housing Enterprise Oversight (OFHEO), Washington, D.C. Special examination report; findings through September 17, 2004.
- Ólafsson, S. and Kristjánsson, A. S. (2013). Income Inequality in Boom and Bust: A Tale from Iceland’s Bubble Economy. In Gornick, J. C. and Jäntti, M., editors, *Income Inequality: Economic Disparities and the Middle Class in Affluent Countries*, Studies in Social Inequality, pages 416–438. Stanford University Press, Stanford, CA.
- Oliver Wyman (2012). Bank of Spain stress testing exercise. Technical report, Banco de España.
- Olszak, M. (2011). *Bankowe normy ostrożnościowe*. Temida 2, Białystok.
- Olszak, M. (2015). *Procykliczność działalności bankowej*. C. H. Beck. Warszawa.
- Olszak, M., Pipień, M., Kowalska, I., and Roszkowska, S. (2014). What drives heterogeneity of procyclicality of loan loss provisions in the EU? Working Paper 3, University of Warsaw, Faculty of Management.
- Onado, M. (2010). European Financial Supervision after the de Larosière Report: Are We on the Right Track? *Bancaria Special Issue*, (03-2010):16–26.

- Ord. 7/93 (1993). Ordinance no. 7/93 of the president of the national bank of poland on standards concerning the coverage of bank assets with own funds. Official Gazette of the National Bank of Poland, 24 May 1993.
- Ozkan, F. G. and Unsal, D. F. (2014). On the use of Monetary and Macroprudential Policies for Small Open Economies. Working Paper 14/112, International Monetary Fund.
- Paddrik, M., Rajan, S., and Young, H. P. (2016). Contagion in the CDS Market. Working Paper 16-12, Office of Financial Research, U.S. Department of the Treasury.
- Pajares, M. (1998). *La inmigración en España: retos y propuestas*. Icaria.
- Palley, T. I. (2009). America's Exhausted Paradigm: Macroeconomic Causes of the Financial Crisis and Great Recession. Technical Report No. 02/2009, Institute for International Political Economy Berlin (IPE Berlin).
- Palley, T. I. (2012). *From Financial Crisis to Stagnation: The Destruction of Shared Prosperity and the Role of Economics*. Cambridge University Press.
- Pangallo, M., Nadal, J.-P., and Vignes, A. (2019). Residential income segregation: A behavioral model of the housing market. *Journal of Economic Behavior & Organization*, 159:15–35.
- Park, S. and Kim, Y.-H. (2023). The impact of macroprudential policy on inequality and implications for inclusive financial stability. *Journal of Banking & Finance*, 146:106716.
- Paulson Jr., H. M., Steel, R. K., and Nason, D. G. (2008). Blueprint for a Modernized Financial Regulatory Structure. Also known as the Paulson Plan.
- Peirce, H. and Broughel, J., editors (2013). *Dodd-Frank: What It Does and Why It's Flawed*. Mercatus Center, George Mason University.
- Perelstein, J. S. (2009). Macroeconomic Imbalances in the United States and Their Impact on the International Financial System. Working Paper 554, Levy Economics Institute of Bard College.
- Perotti, E. and Suarez, J. (2011). A Pigovian Approach to Liquidity Regulation. *International Journal of Central Banking*, 7(4):3–41.
- Pethokoukis, J. (2012). How would a weak second half of 2012 affect Obama's reelection chances? Blog post, American Enterprise Institute.
- Petrone, D. and Latora, V. (2018). A dynamic approach merging network theory and credit risk techniques to assess systemic risk in financial networks. *Scientific Reports*, 8(1):5561.
- Pinto, E. J. (2011). Government Housing Policies in the Lead-up to the Financial Crisis: A Forensic Study. Technical report, American Enterprise Institute, Washington, D.C. AEI Economic Policy Working Paper.
- Pipień, M. (2013). Commentary to G. Koloch's PhD Dissertation. Unpublished commentary.
- Piskorz, P. (2017). Zmiany rekomendacji ostrożnościowych Bazylejskiego Komitetu Nadzoru Bankowego wpływających na kształt regulacji rynku bankowego w Unii Europejskiej. *Zeszyty Naukowe Towarzystwa Doktorantów UJ*, (16 (1/2017)):7–25.
- Poledna, S., Martínez-Jaramillo, S., Caccioli, F., and Thurner, S. (2021). Quantification of systemic risk from overlapping portfolios in the financial system. *Journal of Financial Stability*, 52:100808.
- Poledna, S., Miess, M. G., Hommes, C., and Rabitsch, K. (2023). Economic forecasting with an agent-based model. *European Economic Review*, 151:104306.

- Popoyan, L., Napoletano, M., and Roventini, A. (2017). Taming macroeconomic instability: Monetary and macro-prudential policy interactions in an agent-based model. *Journal of Economic Behavior & Organization*, 134:117–140.
- Pousseur, H. (1959). Forme et pratique musicales. *Revue belge de Musicologie / Belgisch Tijdschrift voor Muziekwetenschap*, 13(1–4):98–116.
- Pousseur, H. (1970). En guise de conclusion: Pour une périodicité généralisée. In *Fragments théoriques I: Sur la musique expérimentale*, pages 241–290. Éditions de l’Institut de Sociologie, Université Libre de Bruxelles, Brussels.
- Pousseur, H. (1997). Zeitmaße: série, périodicité, individuation. In *Musiques croisées*, pages 171–189. L’Harmattan, Collection Musique et Musicologie, Paris.
- Pradelle, P. (2012). Impact of the Financial Crisis in Central and Eastern Europe: An Overview. Technical Report 2012/1, Instytut Obywatelski.
- Prasad, E. S. (2009). Rebalancing Growth in Asia. *Finance & Development*, 46(4).
- Presidencia del Gobierno (1978). Los Pactos de la Moncloa: Política de empleo y rentas, salarios y seguridad social.
- Quint, D. and Rabanal, P. (2014). Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. *International Journal of Central Banking*, 10(2):169–236.
- Quintana, E. F. (1984). El Plan de Estabilización Económica de 1959, 25 años después. *Información Comercial Española*, pages 25–40.
- Quintana, E. F. (1986). La economía española desde el Plan de Estabilización de 1959: el papel del sector exterior. In Vara, T. M., editor, *Mercado y desarrollo económico en la España contemporánea*. Siglo XXI, Madrid.
- Radelet, S. and Sachs, J. D. (1998). The East Asian Financial Crisis: Diagnosis, Remedies, Prospects. *Brookings Papers on Economic Activity*, 1998(1):1–90.
- Radner, R. (1970). Problems in the Theory of Markets Under Uncertainty. *American Economic Review*, 60(2):454–460.
- Radner, R. (1982). Equilibrium under Uncertainty. In Arrow, K. J. and Intriligator, M. D., editors, *Handbook of Mathematical Economics*, volume 2 of *Handbooks in Economics*, pages 923–1006. North-Holland, Amsterdam.
- Rajan, R. G. (2010). *Fault Lines: How Hidden Fractures Still Threaten the World Economy*. Princeton University Press, Princeton, NJ.
- Rasmussen, R. K. and Skeel Jr., D. A. (2017). Governmental Intervention in an Economic Crisis. *ECGI Working Paper Series in Law*, (345):1–48.
- Reg. 1011 (2016). Regulation (EU) 2016/1011 of the European Parliament and of the Council of 8 June 2016 on indices used as benchmarks in financial instruments and financial contracts or to measure the performance of investment funds (Benchmarks Regulation, BMR). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R1011>. *Official Journal of the European Union*, L 171, 29.6.2016, pp. 1–65.
- Reg. 1022 (2013). Regulation (EU) no 1022/2013 amending regulation (EU) no 1093/2010 establishing a European supervisory authority (European Banking Authority) as regards the conferral of specific tasks on the European Central Bank. OJ L 287, 29.10.2013, pp. 5–14.

- Reg. 1060 (2009). Regulation (EC) no 1060/2009 of the European parliament and of the council of 16 September 2009 on credit rating agencies. OJ L 302, 17.11.2009, pp. 1–18.
- Reg. 1075 (2016). Commission delegated regulation (EU) 2016/1075 of 23 march 2016 supplementing directive 2014/59/EU with regard to regulatory technical standards specifying the content of recovery plans, resolution plans and group resolution plans, the minimum criteria that the competent authority is to assess as regards recovery plans and group recovery plans, the conditions for group financial support, the requirements for independent valuers, the contractual recognition of write-down and conversion powers, the procedures and contents of notification requirements and of notice of suspension and the operational functioning of the resolution colleges. OJ L 184, 8.7.2016, pp. 1–167.
- Reg. 1286 (2014). Regulation (EU) No 1286/2014 of the European Parliament and of the Council of 26 November 2014 on key information documents for packaged retail and insurance-based investment products (PRIIPs). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R1286>. *Official Journal of the European Union*, L 352, 9.12.2014, pp. 1–23.
- Reg. 1624 (2018). Commission implementing regulation (EU) 2018/1624 of 23 October 2018 laying down implementing technical standards with regard to procedures and standard forms and templates for the provision of information for the purposes of resolution plans for credit institutions and investment firms pursuant to directive 2014/59/EU. OJ L 262, 23.10.2018, pp. 1–30.
- Reg. 1751 (2021). Commission implementing regulation (EU) 2021/1751 of 1 October 2021 laying down implementing technical standards for the application of directive 2014/59/EU with regard to uniform formats and templates for notifications of determination of the impracticability of including contractual recognition of write-down and conversion powers. OJ L 348, 4.10.2021, pp. 1–35.
- Reg. 2365 (2015). Regulation (EU) 2015/2365 of the European Parliament and of the Council of 25 November 2015 on transparency of securities financing transactions and of reuse and amending Regulation (EU) No 648/2012. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015R2365>. *Official Journal of the European Union*, L 337, 23.12.2015, pp. 1–34.
- Reg. 462 (2013). Regulation (EU) no 462/2013 of the European parliament and of the council of 21 May 2013 amending regulation (EC) no 1060/2009 on credit rating agencies. OJ L 146, 22.5.2013, pp. 1–13.
- Reg. 513 (2011). Regulation (EU) no 513/2011 of the European parliament and of the council of 11 May 2011 amending regulation (EC) no 1060/2009 on credit rating agencies. OJ L 145, 31.5.2011, pp. 1–15.
- Reg. 575 (2013a). Regulation (EU) No. 575/2013 of the European Parliament and of the Council of 26 June 2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No. 648/2012.
- Reg. 575 (2013b). Regulation (EU) No 575/2013 of the European Parliament and of the Council of 26 June 2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012 (CRR). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0575>. *Official Journal of the European Union*, L 176, 27.6.2013, pp. 1–337.
- Reg. 596 (2014). Regulation (EU) No 596/2014 of the European Parliament and of the Council of 16 April 2014 on market abuse (Market Abuse Regulation) and repealing Directive 2003/6/EC and Commission Directives 2003/124/EC, 2003/125/EC and 2004/72/EC. OJ L 173, 12.6.2014, pp. 1–61.

- Reg. 600 (2014). Regulation (EU) No 600/2014 of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments and amending Regulation (EU) No 648/2012 (MiFIR). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0600>. *Official Journal of the European Union*, L 173, 12.6.2014, pp. 84–148.
- Reg. 648 (2012). Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC derivatives, central counterparties and trade repositories (EMIR). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0648>. *Official Journal of the European Union*, L 201, 27.7.2012, pp. 1–59.
- Reg. 65 (2014). Directive 2014/65/EU of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments and amending Directive 2002/92/EC and Directive 2011/61/EU (MiFID II). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0065>. *Official Journal of the European Union*, L 173, 12.6.2014, pp. 349–496.
- Reg. 806 (2014). Regulation (EU) No 806/2014 of the European Parliament and of the Council of 15 July 2014 establishing uniform rules and a uniform procedure for the resolution of credit institutions and certain investment firms in the framework of a Single Resolution Mechanism and a Single Resolution Fund. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0806>. *Official Journal of the European Union*, L 225, 30.7.2014, pp. 1–90.
- Reg. 876 (2019). Regulation (EU) 2019/876 of the European Parliament and of the Council of 20 May 2019 amending Regulation (EU) No 575/2013 as regards the leverage ratio, the net stable funding ratio, requirements for own funds and eligible liabilities, counterparty credit risk, market risk, exposures to central counterparties, exposures to collective investment undertakings, large exposures, reporting and disclosure requirements, and Regulation (EU) No 648/2012. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0876>. *Official Journal of the European Union*, L 150, 7.6.2019, pp. 1–225.
- Reg. 877 (2019). Regulation (EU) 2019/877 of the European Parliament and of the Council of 20 May 2019 amending Regulation (EU) No 806/2014 as regards the loss-absorbing and recapitalisation capacity of credit institutions and investment firms (SRMR II). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0877>. *Official Journal of the European Union*, L 150, 7.6.2019, pp. 226–252.
- Reg. 879 (2019). Directive (EU) 2019/879 of the European Parliament and of the Council of 20 May 2019 amending Directive 2014/59/EU as regards the loss-absorbing and recapitalisation capacity of credit institutions and investment firms and Directive 98/26/EC (BRRD II). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019L0879>. *Official Journal of the European Union*, L 150, 7.6.2019, pp. 296–344.
- Reinhart, C. M. and Rogoff, K. S. (2008). This Time Is Different: A Panoramic View of Eight Centuries of Financial Crises. NBER Working Paper 13882, National Bureau of Economic Research.
- Republican Staff, Committee on Financial Services, U. H. o. R. (2014). Failing to end “too big to fail”: An assessment of the DODD-FRANK Act four years later. Technical Report 113th Congress, Second Session, Committee on Financial Services, U.S. House of Representatives. Report prepared by the Republican Staff of the Committee on Financial Services, U.S. House of Representatives (Chairman Jeb Hensarling).
- Repullo, R. and Saurina, J. (2011). The Countercyclical Capital Buffer of Basel III: A Critical Assessment. Working Paper 1102, CEMFI.

- Repullo, R. and Suarez, J. (2013). The Procyclical Effects of Bank Capital Regulation. *The Review of Financial Studies*, 26(2):452–490.
- Richiardi, M., Leombruni, R., Saam, N. J., and Sonnessa, M. (2006). A Common Protocol for Agent-Based Social Simulation. *Journal of Artificial Societies and Social Simulation*, 9(1).
- Rigotti, L. and Shannon, C. (2005). Uncertainty and Risk in Financial Markets. *Econometrica*, 73(1):203–243.
- Rogowski, W., editor (2014). *Nowe koncepcje nadzoru i regulacji rynku finansowego*. Oficyna Wydawnicza Instytutu Allerhanda, Warszawa–Kraków.
- Roland Berger Cons. (2014). The State of the European Banking Industry. Technical report, Roland Berger Strategy Consultants.
- Rosati, D. (2014). Regulacje makroostrożnościowe a stabilność sektora bankowego. *Bank i Kredyt*, 45(4):373–406.
- Rosefelde, S. and Mills, D. Q. (2013). *Democracy and Its Elected Enemies: American Political Capture and Economic Decline*. Cambridge University Press.
- Rubio, M. and Carrasco-Gallego, J. A. (2014). Macroprudential and monetary policies: Implications for financial stability and welfare. *Journal of Banking & Finance*, 49:326–336.
- Rubio, M. and Unsal, D. F. (2017). Macroprudential Policy, Incomplete Information and Inequality: The case of Low-Income and Developing Countries. Working Paper 2017/59, International Monetary Fund.
- Rudne, J. (1998). Clarifying Frank Knight’s Discussion of the Meaning of Risk and Uncertainty. *Cambridge Journal of Economics*, 22:539–546.
- Rumsfeld, D. H. (2002). DoD News Briefing: “Known Knowns, Known Unknowns, Unknown Unknowns”. U.S. Department of Defense, Pentagon news briefing transcript; famous quote on “known unknowns” and “unknown unknowns”.
- Ruwet, N. (1959). Contradictions du langage sériel (Contradictions within the Serial Language). *Revue belge de Musicologie / Belgisch Tijdschrift voor Muziekwetenschap*, 13(1–4):83–97.
- Ryback, W. (2011). Case Study on Bear Stearns. Technical report, Toronto Centre, Leadership in Financial Supervision.
- Sala Ríos, M., Torres Solé, T., and Farre Perdiguier, M. (2016). Credit and business cycles’ relationship: evidence from Spain. *Portuguese Economic Journal*, 15(3):149–171.
- San Jose, A. and Georgiou, A. (2009). Financial soundness indicators (FSIs): framework and implementation. *IFC Bulletin*, 31:277–282.
- Sancho, A. E. (1997). Reflexiones sobre España y la convergencia Europea. *Revista De Treball Economia I Societat*, (6):35–39.
- Saurina, J. (2009a). Dynamic Provisioning. *The World Bank Public Policy Journal: The Crisis Response*, (7):1–6.
- Saurina, J. (2009b). Loan Loss Provisions in Spain: A Working Macroprudential Tool. *Estabilidad Financiera*, (17):11–26.
- Savage, L. J. (1951). The Theory of Statistical Decision. *Journal of the American Statistical Association*, 46(253):55–67.

- Savage, L. J. (1954). *The Foundations of Statistics*. John Wiley & Sons, New York.
- Savage, L. J. (1961). The Foundations of Statistics Reconsidered. In Neyman, J., editor, *Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability*, pages 575–586. University of California Press, Berkeley.
- Schoenmaker, D., Gros, D., Langfield, S., and Pagano, M. (2014). Allocating macro-prudential powers. Technical Report 5, European Systemic Risk Board, Advisory Scientific Committee.
- Schoenmaker, D. and Wierds, P. (2011). Macroprudential Policy: The Need for a Coherent Policy Framework. Policy Paper 13, Duisenberg School of Finance.
- Schultz, P. H., editor (2014). *Perspectives on Dodd-Frank and Finance*. MIT Press, Cambridge, MA.
- Schürz, M., Schwaiger, M., and Übeleis, J. (2009). A review of the impact of the crisis on Austria's financial sector. In *Financial Stability Report 17*, pages 54–62. Oesterreichische Nationalbank.
- Seelig, S. A. (2003). Too Big to Fail: A Taxonomic Analysis. In Gup, B. E., editor, *Too Big To Fail: Policies and Practices in Government Bailouts*. Praeger.
- Segoviano, M. A. and Goodhart, C. (2009). Banking Stability Measures. *IMF Working Paper*, (WP/09/4).
- Shadow Financial Regulatory Committee (2005). Statement No. 221: Statement on the Federal Housing Enterprise Regulatory Reform Act of 2005. Technical report, Shadow Financial Regulatory Committee, Washington, D.C. Shadow Statement No. 221.
- Shapiro, M. D. and Slemrod, J. (2009). Did the 2008 Tax Rebates Stimulate Spending? *American Economic Review*, 99(2):374–379.
- Sherman, M. (2009). A Short History of Financial Deregulation in the United States. Technical report, Center for Economic and Policy Research (CEPR), Washington, D.C. CEPR Report.
- Shiller, R. J. (2007). Understanding Recent Trends in Housing Prices and Homeownership. NBER Working Paper 13553, National Bureau of Economic Research (NBER). Also published in *Proceedings – Economic Policy Symposium – Jackson Hole*, Federal Reserve Bank of Kansas City, 2007, pp. 89–123.
- Shorrocks, A. F. (1980). The Class of Additively Decomposable Inequality Measures. *Econometrica*, 48(3):613–625.
- Shull, B. and Hanweck, G. A. (2001). *Bank Mergers in a Deregulated Environment: Promise and Peril*. Praeger / Bloomsbury Academic, Westport, CT / New York, NY, 1st edition.
- Shumway, D. L. and Koide, R. T. (1995). Size and reproductive inequality in mycorrhizal and nonmycorrhizal populations in *Abutilon theophrasti*. *Journal of Ecology*, 83:613–620.
- Sierminska, E. and Medgyesi, M. (2013). The Distribution of Wealth Between Households. Technical report, European Commission.
- Simon, H. A. (1955). A Behavioral Model of Rational Choice. *The Quarterly Journal of Economics*, 69:99–118.
- Simon, H. A. (1978). Rational Decision-Making in Business Organizations. *Nobel Prize Lecture Series*. Lecture presented in Stockholm; published as part of Nobel Lectures, Economics 1969–1980.

- Simpson Thacher & Bartlett LLP (1998). Travelers Group Inc. and Citigroup Merger Analysis. Legal commentary. Analysis of the Federal Reserve's approval of the merger.
- Skeel, D. A. (2016). The New Synthesis of Bank Regulation and Bankruptcy in the Dodd–Frank Era. *Faculty Scholarship at Penn Law*, (1564):1–41. Originally forthcoming in: *Research Handbook on Corporate Bankruptcy Law*, edited by B. Adler, Edward Elgar Publishing.
- Smaga, P. (2014). The Concept of Systemic Risk. *SRC Special Paper*, (5):1–26. Accessed: 17 Oct 2025.
- Smith, A. and Zywicki, T. J. (2014). Behavior, Paternalism, and Policy: Evaluating Consumer Financial Protection. Technical Report 14-06, George Mason Law & Economics Research Paper.
- Smith, C. A. B. (1961). Consistency in Statistical Inference and Decision. *Journal of the Royal Statistical Society: Series B (Methodological)*, 22(1):1–37.
- Sobkowicz, P. (2009). Modelling Opinion Formation with Physics Tools: Call for Closer Link with Reality. *Journal of Artificial Societies and Social Simulation*, 12(1):11.
- Soultanaeva, A. and Nordberg, A. (2010). The impact of a maximum loan-to-value ratio on the borrowers' expenditure. https://archive.riksbank.se/Upload/Dokument_riksbank/Kat_publicerat/Ekonomiska%20kommentarer/2010/ek_kom_nr5_10eng.pdf.
- Spiegler, P. and Milberg, W. (2011). Methodenstreit 2011? Historical Perspective on the Contemporary Debate Over How to Reform Economics. Working Paper 06/2011, Department of Economics, The New School for Social Research, New York. Working Paper Series.
- Sprague, S. (2017). Below Trend: The U.S. Productivity Slowdown Since the Great Recession. Beyond the Numbers: Productivity Vol. 6, No. 2, U.S. Bureau of Labor Statistics.
- Stackhouse, J. (2017). The Dodd-Frank Act: A Framework for Financial Stability. Speech.
- Stanton, R. and Wallace, N. (2011). The Bear's Lair: Index Credit Default Swaps and the Subprime Mortgage Crisis. Working paper, Haas School of Business, University of California, Berkeley, Berkeley, CA.
- Stiglitz, J. E. (1982). Self-Selection and Pareto Efficient Taxation. *Journal of Public Economics*, 17:213–240.
- Stiglitz, J. E. (2016a). How to Restore Equitable and Sustainable Economic Growth in the United States. *American Economic Review: Papers & Proceedings*, 106(5):43–47.
- Stiglitz, J. E. (2016b). New theoretical perspectives on the distribution of income and wealth among individuals. In Basu, K. and Stiglitz, J. E., editors, *Inequality and Growth: Patterns and Policy. Vol. I: Concepts and Analysis*, volume 156-I of *International Economic Association Series*, pages 1–71. Palgrave Macmillan, London.
- Stiroh, K. J. (2004). Diversification in Banking: Is Noninterest Income the Answer? *Journal of Money, Credit and Banking*, 36(5):853–882.
- Stiroh, K. J. (2006). A Portfolio View of Banking with Interest and Noninterest Activities. *Journal of Money, Credit and Banking*, 38(5):1351–1361.
- Stiroh, K. J. and Rumble, A. (2006). The Dark Side of Diversification: The Case of U.S. Financial Holding Companies. *Journal of Banking & Finance*, 30(8):2131–2161.

- Storm, S. and Naastepad, C. (2015). Crisis and recovery in the German economy: The real lessons. *Structural Change and Economic Dynamics*, 32:11–24.
- Stout, L. A. (1999). Why the Law Hates Speculators: Regulation and Private Ordering in the Market for OTC Derivatives. *Duke Law Journal*, 48:701–786.
- Šuler Štavn, T. (2014). Setting the floor on the gross loans to deposits flows ratio as a macro-prudential instrument. Banka Slovenije. <https://doczz.net/doc/7949176/1-setting-the-floor-on-the-gross-loans-to-deposits-flows-%E2%80%A6>.
- Summers, L. H. (2004). The United States and the Global Adjustment Process. The Per Jacobsson Lecture.
- Supreme Court of the United States (1971). Investment Company Institute v. Camp, 401 U.S. 617. U.S. Supreme Court Decision. Decision delivered 14 June 1971.
- Svensson, L. E. (2017). Cost-benefit analysis of leaning against the wind. *Journal of Monetary Economics*, 90:193–213.
- Swagel, P. (2009). The Financial Crisis: An Inside View. *Brookings Papers on Economic Activity*, 2009(Spring):1–75. Brookings Papers on Economic Activity.
- Szczepańska, O. (2008). *Stabilność finansowa jako cel banku centralnego: studium teoretyczno-porównawcze*. Wydawnictwo Naukowe Scholar, Warszawa.
- Szpringer, M. and Szpringer, W. (2017). The European System of Financial Supervision – Regulatory Impact Assessment. *Journal of Banking and Financial Economics*, 2(8):84–104.
- Szpunar, P. (2012). Rola polityki makroostrożnościowej w zapobieganiu kryzysom finansowym. Technical Report Working Paper No. 278, Narodowy Bank Polski, Warszawa.
- Tarashev, N., Borio, C., and Tsatsaronis, K. (2010). Attributing systemic risk to individual institutions. BIS Working Papers 308, Bank for International Settlements.
- Tarne, R., Bezemer, D., and Theobald, T. (2022). The effect of borrower-specific loan-to-value policies on household debt, wealth inequality and consumption volatility: An agent-based analysis. *Journal of Economic Dynamics and Control*, 144:104526.
- Tavman, Y. (2015). A comparative analysis of macroprudential policies. *Oxford Economic Papers*, 67:334–355.
- Thakor, A. V. (2012). The Economic Consequences of the Volcker Rule. Technical report, Olin Business School at Washington University in St. Louis.
- Thompson, S. (2012). *The Obama vs. Romney Debate on Economic Growth: A Citizen’s Guide to the Issues*. iUniverse, Inc., Bloomington.
- Tröger, T. (2014). The Single Supervisory Mechanism: Panacea or Quack Banking Regulation? Preliminary Assessment of the New Regime for the Prudential Supervision of Banks with ECB Involvement. *European Business Organization Law Review*, 15(4):449–497.
- Tsomocos, D. P. (2003). Equilibrium analysis, banking, contagion and financial fragility. Working Paper 175, Bank of England.
- Tversky, A. and Kahneman, D. (1974). Judgment Under Uncertainty: Heuristics and Biases. *Science*, 185(4157):1124–1131.

- Tversky, A. and Kahneman, D. (1986). Rational Choice and the Framing of Decisions. *The Journal of Business*, 59(4):S251–S278.
- Tversky, A. and Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, 5(4):297–323.
- UK Benchmarks Reg. (2020). UK Benchmarks Regulation — retained EU law version of Regulation (EU) 2016/1011 (on indices used as benchmarks) as on-shored in the UK. <https://www.fca.org.uk/markets/benchmarks/regulation>. Financial Conduct Authority, “UK Benchmarks Regulation”, first published 21 April 2016, on-shored 31 December 2020 (updated 04/04/2025).
- U.S. Congress (2010a). Dodd–Frank Wall Street Reform and Consumer Protection Act. Public Law 111-203. Enacted July 21, 2010.
- U.S. Congress (2010b). S.3217 – Restoring American Financial Stability Act of 2010. Senate Bill.
- U.S. General Accounting Office (1988). U.S. Commercial Banks’ Securities Activities in London. Technical report, U.S. General Accounting Office. Report to the Congress of the United States.
- U.S. SEC (2004). Alternative Net Capital Requirements for Broker–Dealers That Are Part of Consolidated Supervised Entities. Final Rule Release No. 34-49830; File No. S7-23-03, U.S. Securities and Exchange Commission, Washington, D.C. Published in Federal Register 69 FR 34428 (June 21, 2004).
- U.S. Securities and Exchange Commission (2012). Post-Madoff reforms. <https://www.sec.gov/spotlight/secpostmadoffreforms.htm>.
- U.S. Senate Committee on Banking and Currency (1934). Stock Exchange Practices: Report of the Committee Pursuant to S.Res. 84 (72d Congress). Technical report, U.S. Government Printing Office. Known as the Pecora Report.
- U.S. Senate, Permanent Subcommittee on Investigations (2011). Wall Street and the Financial Crisis: Anatomy of a Financial Collapse. Senate Report 112-176, U.S. Senate, Committee on Homeland Security and Governmental Affairs, Washington, D.C. Majority and Minority Staff Report.
- Villarreal, M. A. and Fergusson, I. F. (2017). The North American Free Trade Agreement (NAFTA). CRS Report R42965, Congressional Research Service, Washington, D.C. Prepared for Members and Committees of Congress.
- Volcker, P. (2010). The Volcker Rule. Section 619 of the Dodd–Frank Wall Street Reform and Consumer Protection Act, Volcker Rule.
- von Bertalanffy, L. (1968). *General System Theory: Foundations, Development, Applications*. George Braziller, New York.
- Vriend, N. J. (1996). Rational behavior and economic theory. *Journal of Economic Behavior & Organization*, 29(2):263–285.
- Wade, R. H. and Sigurgeirsdóttir, S. (2011). Icelandic meltdown: The rise and fall of international banking in the North Atlantic. *Brazilian Journal of Political Economy*, 31(5):684–697.
- Wallison, P. J. (2009). Deregulation and the Financial Crisis: Another Urban Myth. Technical report, American Enterprise Institute, Washington, D.C. AEI Financial Services Outlook series.
- Wallison, P. J. (2015). Is the Dodd–Frank Act Responsible for the Economy’s Slow Recovery from the Financial Crisis and the Ensuing Recession? Technical report, Hillsdale College Free Market Forum. Paper presented at the Ninth Hillsdale College Free Market Forum, 16 October, 2015.

- Wallison, P. J. (2017). Glass–Steagall and the Volcker Rule. Statement No. 334, Shadow Financial Regulatory Committee, Washington, D.C. Statement of the Shadow Financial Regulatory Committee. Contact: (202) 862-5864.
- Wallison, P. J. and Pinto, E. J. (2012). Free Fall: How Government Policies Brought Down the Housing Market. Technical report, American Enterprise Institute, Washington, D.C. AEI Financial Policy Studies.
- Walter, I., Sylla, R., Cooley, T., Richardson, M., and Acharya, V. (2010). A Critical Assessment of the Dodd-Frank Wall Street Reform and Consumer Protection Act. *CEPR Policy Portal* (VoxEU.org).
- Webel, B. and Labonte, M. (2010). *Financial Interventions in Response to Financial Turmoil*. BiblioGov.
- Weill, P.-O. (2007). Leaning against the Wind. *The Review of Economic Studies*, 74(4):1329–1354.
- Weismann, P. (2016). *European Agencies and Risk Governance in EU Financial Market Law*. Routledge (Taylor & Francis Group), Abingdon, Oxon / New York.
- Wheelock, D. C. (2011). Banking industry consolidation and market structure: Impact of the financial crisis and recession. *Federal Reserve Bank of St. Louis Review*, 93(6):419–438. Published Nov.–Dec. 2011.
- White, E. N. (1986). Before the Glass-Steagall Act: An analysis of the investment banking activities of national banks. *Explorations in Economic History*, 23(1):33–55.
- White, L. J. (2010). The Gramm–Leach–Bliley Act of 1999: A Bridge Too Far? Or Not Far Enough? *Suffolk University Law Review*, 43(4):937–982.
- White House Archive (2008). Summit on Financial Markets and the World Economy – President Bush and World Leaders Agree on the Washington Declaration to Address Current Financial Crisis. Online.
- Wiersema, G., Kemp, E., and Farmer, J. D. (2023). Liquidity Spirals. Working Paper 2023-16, Institute for New Economic Thinking, Oxford Martin School, University of Oxford.
- Wiese, S., Kaszowska Mojsa, J., Dyer, J., Moran, J., Pangallo, M., Lafond, F., Muellbauer, J., Calinescu, A., and Farmer, J. D. (2024). Forecasting Macroeconomic Dynamics Using a Calibrated Data Driven Agent Based Model. *INET Oxford Working Paper*, (2024-06).
- Wiggins, R., Piontek, T., and Metrick, A. (2019). The Lehman Brothers Bankruptcy A: Overview. Technical report, Journal of Financial Crises.
- Wilmarth Jr., A. E. (2017). The Road to Repeal of the Glass–Steagall Act. *Wake Forest Journal of Business & Intellectual Property Law*, 17(4):443–541.
- Wojtyna, A. (2008). Współczesna ekonomia – kontynuacja czy poszukiwanie nowego paradygmatu? (Contemporary Economic Theory - Continuation or the Search for a new Paradigm?). *Ekonomista*, (1):9–32.
- Wojtyna, A. (2014). Czy kryzys w teorii ekonomii jest głębszy niż w gospodarce? *Ekonomista*, (2):193–206.
- Wolff, E. N. (2012). The Asset Price Meltdown and the Wealth of the Middle Class. NBER Working Paper 18559, National Bureau of Economic Research.

- Wong, E., Fong, T., Li, K.-f., and Choi, H. (2011). Loan-to-Value Ratio as a Macro-Prudential Tool: Hong Kong's Experience and Cross-Country Evidence. HKMA Working Paper 01/2011, Hong Kong Monetary Authority, Hong Kong.
- Wurgler, J. and Zhuravskaya, E. (2002). Does arbitrage flatten demand curves for stocks? *The Journal of Business*, 75(4):583–608.
- Yellen, J. L. (2017). Financial Stability a Decade after the Onset of the Crisis. Speech at 'Fostering a Dynamic Global Recovery' Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming.
- Zhang, L. (2023). Macroprudential policies to mitigate housing market risks: Case study - the Netherlands. CGFS Paper No. 69, Bank for International Settlements (BIS).
- Zhang, X. F. (2006). Information Uncertainty and Stock Returns. *The Journal of Finance*, 61(1):105–137.
- Zhu, B., Hu, X., Deng, Y., and Lin, R. (2023). Systemic Risk Prevention Policies Targeting Systemically Important Banks: Does Clustering Pattern Matter? *PLOS ONE*, 18(4):e0284861.



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