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Monetary Policy and Systemic Risk on Financial Markets – Concepts, Transmission Channels and Policy Implications

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Preface

This thesis was written during my time as a research and teaching assistant at the Institute of Economics at the University of Hohenheim, Germany, and was accepted as dissertation in August 2015. It was successfully defended on December 1st, 2015. I hereby would like to express my gratitude to a number of persons.

First and foremost, I would like to thank my supervisor Prof. Dr. Peter Spahn for his continuous support and encouragement. He created an always enjoyable and fruitful research environment and I have benefited to a great extent from his recommendations and suggestions. It was a true privilege to learn from him, not only as an economist but also as a person. Furthermore, it was his undergraduate lecture which awoke my interest for the field of monetary economics in the first place.

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Moreover, I would like to express my deep gratitude to my family; to my wife Nadine, to my son Ferdinand, to my parents Angelika and Günter and to my sister Nora. Their loving support has been the all-important foundation for the success of this project.

Last, but certainly not least, I would like to dedicate this thesis to my grandmother for a very special reason: Back in 2010, when visiting Stuttgart to join my diploma graduation ceremony, she insisted that she would not live long enough to witness me completing my dissertation. I am very happy to tell that she has been wrong.

Stuttgart,
January 2016 *Lukas Scheffknecht*

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Chapter 1

Introduction

1.1 Motivation and Objectives

The recent financial crisis has been extraordinarily costly: It triggered sharp and persistent declines in economic activity and a rise in unemployment in almost any advanced economy. Central banks across the world continue to struggle with economic slack and weak inflation while the scope for conventional stimulus is constrained by the zero-lower bound on nominal interest rates. Moreover, fiscal stabilization programs for the financial sector led to substantial increases in government debt burdens. In the special case of the Euro Area, the financial crisis has contributed to the unfolding of the sovereign debt crisis which still impedes a noticeable economic recovery.

Understandably, the crisis experience has brought a well-known question back on top of the agenda of both researchers and policymakers: *Are financial markets inherently unstable and do we need to rethink their regulation?* Simultaneously, heterodox theories such as the "Financial Instability Hypothesis" advocated by Minsky (1986, 1992) have experienced a revival. This appeared reasonable, as mainstream economic theory was perceived to be unable to explain the root causes of the crisis, not to mention that only few did manage to predict the events which unfolded after August 2007.

Indeed, the recent events make it hard to deny that financial systems are inefficiently vulnerable in the absence of proper regulation. Fortunately, the fields of macroeconomics and finance have made substantial progress within the last years in explaining this phenomenon. A quickly increasing strand of literature relates financial crises to the presence of *systemic externalities*. If market participants do not internalize the consequences of their actions with respect to the stability of the system as such, *systemic risk* on financial markets may become excessive, which calls for regulatory responses being usually summarized under the term *macroprudential regulation*.

Notwithstanding the evolution of the regulatory paradigm for financial markets, there is another question: *Should monetary policy pursue a more active role in financial market stabilization?* This issue has already been debated in the aftermath of the dotcom-bubble, when most economists and central bankers agreed that such a policy would be undesirable (Bernanke and Gertler, 1999, 2001). Yet with respect to the recent crisis, Taylor (2007) claims that the Federal Reserve kept interest rates "too low for too long," thereby contributing to the build-up of the American housing bubble. On the other hand, Bernanke (2010) and Greenspan (2010) defend the US policy stance in the run-up to the crisis as being justified by downside risks to inflation.

Thus, the role of monetary policy in ensuring financial stability is again subject to a lively debate. The literature on the interplay of monetary policy and financial markets has made progress as well. Borio and Zhu (2008, 2012) have proposed a *risk-taking channel* of monetary policy transmission. The concept of the risk-taking channel holds that an accommodative policy stance with low interest rates enhances risk-taking within the financial sector through various mechanisms, giving rise to a nexus between monetary policy and the evolution of systemic risk. Hence, central banks possibly need to account for the impact of their policy stance on systemic risk.

As a general objective, my thesis aims to contribute to the analysis of the two aforementioned key questions. I try to illustrate the evolution in the understanding of the processes which yield an undesirable build-up of systemic risk. In particular, I seek to shed light on the potential role of monetary policy in that respect. For that purpose, I extensively discuss both the theory of systemic risk and the concept of the risk-taking channel of monetary policy transmission. Merging important results from these different research areas allows me to analyze the interplay between monetary policy and systemic risk on financial markets and its policy implications in a coherent fashion.

1.2 Non-Technical Summary

The thesis is divided in two parts. The first part seeks to provide the foundations for the concept of (excessive) systemic risk. The second part elaborates on the mechanics of the risk-taking channel of monetary policy transmission and discusses potential implications for the conduct of monetary policy.

Apart from organizing and categorizing the current state of research in the aforementioned areas, I try to contribute to the literature in several respects. First, I provide a selective survey of the theoretical literature on systemic externalities. Second, I develop a simple framework which clarifies the distinction between the risk-taking channel and the traditional understanding of monetary policy transmission. Third, I estimate a vector autoregression model of the US economy which is augmented with a set of risk-taking indicators and find supportive evidence for the existence of a significant risk-taking channel. Fourth, I construct a simple macro-financial model in order to explore the macroeconomic implications of the risk-taking channel as well as optimal policy responses.

Part One: Systemic Risk and Macroprudential Regulation

Somewhat tautologically, systemic risk can be defined as the risk of the occurrence of a severe financial crisis. It can be decomposed into the crisis probability and the losses conditional on the crisis outbreak. Both components may evolve over time. I claim that both the probability and the conditional loss implied by a financial crisis are endogenous variables. If this holds true, the phenomenon of systemic risk calls for a regulatory response for three main reasons. First, the macroeconomic costs of financial crises are typically large. Second, traditional financial supervision fails to acknowledge threats to the stability of the financial system as such. Third, the emerging level of systemic risk under the absence of proper regulation is inefficiently high. The necessity to carefully substantiate the latter proposition leads over to my analysis of possible *determinants of systemic risk*. I distinguish between two approaches.

On the one hand, there are various theories which explain the existence of boom-bust cycles on financial markets with *limited rationality*. I briefly present three loosely related concepts: (i) The Financial Instability Hypothesis of Hyman P. Minsky, (ii) the Behavioral-Finance Approach and (iii) Agent-Based Financial Market Models. These approaches have in common that they explain boom-bust cycles with the formation of overoptimistic expectations during the boom. These systematic expectation errors are attributed to the presence of cognitive limitations and mechanisms of expectation formation under bounded rationality. However, I conclude that these theories have little to offer for the analysis of systemic risk. Dismissing the rationality postulate tends to go hand in hand with a loss in analytical precision and theoretical stringency. These shortcomings make it especially problematic to analyze appropriate regulatory interventions.

On the other hand, a relatively recent and in my view superior approach highlights the role of *systemic externalities* for the build-up and the materialization of systemic risk. An excessive level of systemic risk emerges endogenously, as financial market participants do not internalize the consequences of their actions with respect to the stability of the system. Presuming the existence of market imperfections such as private information is sufficient to make the case for an inherent fragility of the financial system. Very importantly, this hold true even when assuming strict rationality. My understanding of the literature lets me distinguish five different areas in which systemic externalities matter:

(1) Interconnectedness: Financial intermediaries engage in risk sharing via the accumulation of reciprocal claims and liabilities. While risk sharing is useful from a microeconomic perspective, the emerging financial networks are often inefficiently vulnerable and enhance the risk of financial contagion.

(2) Strategic Complementarities: Banks' decisions to expose themselves to certain risks are influenced by the behavior of their peers. For example, banks have the incentive to deliberately correlate their investments. As they consequently tend to fail jointly in adverse states, bailout measures to prevent a systemic crisis become more likely. The downside risk for banks is thus contained, however at the expense of systemic stability.

(3) Fire Sales: If a bank is forced to sell assets at short notice in a distressed market, this is likely to happen with a steep discount. Other banks with similar positions consequently suffer from an adverse valuation effect, which may trigger a vicious circle of falling asset prices and the need for deleveraging. Ex ante, banks do not internalize their own contribution to potential fire-sale dynamics. Hence, they take too much risk.

(4) Liquidity Externalities: While liquidity hoarding under adverse market conditions makes sense from an individual perspective, it may magnify the intensity of an ongoing

crisis. Intermediaries have the incentive to hoard liquidity for both precautionary and speculative reasons. Yet this very behavior aggravates systemic liquidity shortages.

(5) Adverse Selection: Asymmetric information can lead to the collapse of important financial market segments. The interbank market for short-term liquidity can break down in a crisis, if the solvency of participating banks is not publicly observable. Similar phenomena may occur on secondary markets for complex assets since the value of the latter is private information.

Thus, inherent and excessive fragility of financial markets can be explained with orthodox methods and assumption sets. There is no need to recur to approaches featuring limited rationality. Thinking about excessive systemic risk as an outcome of systemic externalities facilitates an analytically precise view on the underlying market failures. This allows to deduce theoretically well-founded assertions on appropriate regulatory measures. I conclude that strict capital requirements are particularly well-suited to contain systemic risk. They should be complemented with adequate liquidity requirements. After that, I give a brief overview on the practical implementation of macroprudential supervision and its potential instruments in the Euro Area. Moreover, I discuss practical methods for measuring and forecasting systemic risk.

To complete the first part, I finish with an evaluation of the regulatory measures which were adopted in response to the crisis. I argue that these measures are hardly sufficient to contain systemic risk in the future. Especially capital requirements continue to be inadequately low. Hence, systemic risk ultimately becomes a concern for monetary policy, as the central bank is the only remaining actor who is capable to stabilize financial markets.

Part Two: Monetary Policy and Systemic Risk

The second part of my thesis analyzes the impact of monetary policy on the evolution of systemic risk. As a start, I highlight why systemic risk should be a general concern for monetary policy by illustrating how the recent financial crisis caused a massive violation of traditional monetary policy objectives.

After that, I address the question how monetary policy influences the build-up of systemic risk. To do so, I first sketch out the traditional understanding of monetary policy transmission and show that it neglects the potential interplay between monetary policy and systemic risk. Consequently, I introduce the concept of the *risk-taking channel*. It argues that a tighter (looser) policy stance leads to less (more) risk-taking within the financial sector. I explore the implications of the risk-taking channel within a simple graphical exposition of the credit market.

In what follows, I distinguish between long-term and short-term effects of monetary policy on systemic risk. I argue that both the objectives and the strategy of monetary policy may have long-term effects on systemic risk. For that purpose, I recur on the Consumption-Based Asset Pricing Model (CCAPM) as laid out in Cochrane (2001) in conjunction with the New Keynesian Model (NKM) for monetary policy analysis (Gertler et al., 1999; Gali, 2008). The CCAPM predicts that the pricing of risk in an economy critically depends on macroeconomic volatility. In turn, the NKM highlights that macroeconomic volatility is dependent on the relative importance of inflation and output stabilization objectives and the general strategy of monetary policy. Thus, there is a direct link between monetary policy and the pricing of risk. If monetary policy manages to reduce macroeconomic volatility, the price of risk declines. In that respect, some authors point out the possibility of a so-called paradox of credibility (Borio and Lowe, 2002; Borio and White, 2004). The very success of monetary policy in containing macroeconomic volatility may induce financial market participants to take unsustainable amounts of risk, such that systemic risk increases despite successful macro-stabilization.

The short-term relationship between the actual stance of monetary policy and systemic risk needs to be examined in a different way. In recent years, various models have been developed that depict the impact of the policy rate on risk-taking within the banking sector. Ideally, it is possible to distinguish between three dimensions of bank risk-taking. First, there is the riskiness of the asset portfolio. Second, banks decide upon the stability of their refinancing structure. And third, banks choose their leverage, which is the ratio of total assets to capital. I discuss several models, which consistently predict that a looser policy stance leads banks (i) to engage in riskier assets, (ii) to operate with higher leverage and (iii) to increase their reliance on potentially unstable funding.

Subsequently, I perform an empirical analysis which essentially confirms these theoretical results. I estimate a vector autoregression model for the US economy and find that an unexpected decline in the policy rate decreases the sensitivity of banks towards credit risk and increases their reliance on unstable funding. Thus, I find supportive evidence for the risk-taking channel in the US and hence, more generally, for a link from monetary policy to the evolution of systemic risk.

After that, I investigate the implications of the risk-taking channel within a reduced-form macro model which is augmented by a stylized financial sector. The latter actively adjusts its aggregate balance sheet to changes in market conditions, which gives rise to a procyclical relationship between the policy stance, lending activity and risk premia. In this sense, it serves as a simplified description of the risk-taking channel. Model simulations reveal that the behavior of the financial sector amplifies macroeconomic shocks and is a source of macroeconomic volatility in its own right. Tightening capital constraints for the intermediation sector weakens the risk-taking channel within the model and is generally beneficial. The analysis of optimal rule-based monetary policy shows that the central bank should react systematically to balance sheet dynamics in the financial sector. With respect to the coordination of monetary policy and capital regulation, it is shown that a dominant role for monetary policy in financial market stabilization delivers the best results.

The second part of the thesis is completed by a discussion of the question how monetary policy needs to be adjusted in practice in the light of the previous findings. Taking for granted that the actual setup of financial regulation is not sufficient to contain systemic risk at an acceptable level, monetary policy needs to include financial stability considerations in the decision-making process. However, this is not a desirable outcome per se, it is rather a consequence of inadequate financial regulation: Monetary policy may be burdened with an additional trade-off if macroeconomic conditions and financial stability considerations deliver diverging recommendations for the policy stance. I argue that such a trade-off may arise in the case of benign shocks to inflation and if financial booms lead to asset price inflation whereas goods prices remain stable. After that, I sketch out the arguments made for and against active financial market stabilization by the central bank during the 2000s ("leaning-versus-cleaning debate"). I argue that the financial crisis has strengthened the case for monetary policy preemptively counteracting build-ups of systemic risk and subsequently discuss the model of Woodford (2012) which provides a formal treatment of monetary policy taking account of systemic risk.

Afterwards, I try to explore how systemic risk considerations could be incorporated in practical policy frameworks. As it is close to impossible to estimate macroeconomic costs of a future financial crisis with sufficient precision, monetary policy should pursue an intermediate-target approach, under which central banks react to the evolution of financial market variables with predictive power for a future crisis. The collected evidence in my thesis shows that these variables exist and that monetary policy is capable to influence them. As proposed by De Grauwe and Gros (2009) and Galí (2010), such an approach could be implemented as a modification of the two-pillar framework of the European Central Bank (henceforth ECB). The monetary pillar would serve the purpose of systemic risk diagnosis, whereas the economic pillar would continue to cover macroeconomic determinants of the policy stance. Moreover, I briefly discuss possibilities to equip the central bank with a second policy instrument as well as to rely on measures of economic activity which account for the stage of the financial cycle. In a last step, I focus on potential coordination problems between monetary policy and macroprudential regulation. Under some circumstances and in absence of coordination, both policies may work against each other which delivers suboptimal outcomes. Hence, I conclude that macroprudential supervision authorities should be assigned to the central bank to ensure a high degree of coordination.

Finally, I provide concluding remarks which summarize my results and give an outlook for future avenues of research as well as for the development of practical policymaking.

Part I

Systemic Risk and Macroprudential Regulation

Chapter 2

What is Systemic Risk?

Grasping the phenomenon of systemic risk in a comprehensive fashion is a difficult task. This is mirrored in the vagueness of its common definitions. For example, in ECB (2009) systemic risk is broadly defined as the risk "that financial instability becomes so widespread that it impairs the functioning of a financial system to the point where economic growth and welfare suffer materially." The crisis-related G20-Report (2009) defines systemic risk in a similar fashion as "a risk of disruption to financial services that is caused by an impairment of all or parts of the financial system and has the potential to have serious negative consequences for the real economy." And the Global Financial Stability Report of the International Monetary Fund (henceforth IMF) acknowledges that "[systemic risk] is a term that is widely used, but is difficult to define and quantify. Indeed, it is often viewed as a phenomenon that is there "when we see it," reflecting a sense of a broad-based breakdown in the functioning of the financial system, which is normally realized, ex post, by a large number of failures of [financial institutions]." (IMF, 2009)

At least, the aforementioned definitions share that systemic risk can be regarded as the risk of experiencing a severe financial crisis. However, neither of these definitions elaborates on the dimension, the nature and, most importantly, on the potential sources of systemic risk. Hence, three important questions are left open. How and in which dimension should we measure systemic risk? Is systemic risk an endogenous or an exogenous phenomenon? And what are potential sources of systemic risk? In what follows, I will try to contribute to the clarification of these questions.

2.1 The Dimension of Systemic Risk

How should one measure systemic risk in an appropriate dimension? I propose to define systemic risk as the expected costs of a financial crisis at a given point in time. Thus, systemic risk can be divided into two components, namely crisis probability and the costs which the crisis is likely to produce if it actually materializes. Thus, a crude (and somewhat tautological) expression of systemic risk in a certain period t is

$$SR_t = p_t C_t \tag{2.1}$$

where SR_t denotes the level of systemic risk, p_t denotes the crisis probability and C_t stands for the costs of the crisis. In this sense, systemic risk can be regarded as a stock. Of course, systemic risk may evolve dynamically over time if the crisis probability or crisis costs change. Potential mechanisms will be discussed in detail in Chapter 3 and Chapter 4. For example, financial intermediaries tend to take more risk during a boom which leads to a gradual increase in p_t.[1] Moreover, increasing risk exposures are likely to make a crisis particularly severe, thereby increasing C_t. Hence, the gradual build-up of systemic risk tends to occur when economic and financial conditions appear to be relatively benign. There are various possibilities to actually measure the expected costs of a financial crisis. Most obviously, expected losses of the financial sector come to mind, for instance expressed in percentage points of total financial assets. Alternatively, it is conceivable to measure SR_t in macroeconomic terms, for example by the crisis-related decline in GDP per capita.

Systemic risk can be broken down further in two categories (Caruana, 2010; Galati and Moessner, 2013). The *cross-sectional dimension* captures the distribution of risk in the financial system at a given point of time. Put differently, this dimension covers the individual contribution of single institutions to SR_t. The *time dimension* captures the dynamic evolution of SR_t in aggregate.

However, the practical real-time quantification of both p_t and C_t is intrinsically difficult. Given the enormous complexity of modern financial systems and their various interlinkages with the real economy, it is unrealistic to expect that systemic risk can be

[1] The terms "banks" and "financial intermediaries" will be used interchangeably throughout the remainder, unless specified otherwise.

adequately captured by one single indicator. Furthermore, each financial crisis is different. Currency crises in emerging markets follow different patterns than a banking crisis in advanced countries. Moreover, assessing the costs of a crisis requires the formulation of a counterfactual. It is therefore necessary to not only forecast the path of the economy in the crisis case, but also to forecast economic performance for the case in which the crisis does not materialize. It is hard to imagine that such exercises could be carried out with sufficient precision. Hence, the operationalization of the definition given above is extremely challenging. Indeed, practical attempts at systemic risk measurement (to be discussed at a later stage in Chapter 5) pursue a more humble approach and tend to focus on detecting specific types of vulnerabilities within the financial sector instead of trying to quantify crisis probabilities and crisis costs up to the last farthing.

Thus, my definition efforts should be regarded as a (trivial) conceptual exercise rather than as valuable guidance for reality. Nevertheless, I believe that explicitly defining the dimension of systemic risk is important in order to coherently gather the phenomenon of systemic risk from a theoretical perspective in the first place.

2.2 The Nature of Systemic Risk

Is a financial crisis a genuinely exogenous event or the natural and inevitable consequence of an endogenous build-up of financial vulnerabilities? Put differently, is systemic risk driven by market-immanent forces or by factors beyond the control of both market participants and regulators?

The traditional way to approach systemic risk assumed that financial crises emerge from exogenous shocks (de Bandt and Hartmann, 2000). While it was emphasized that the propagation and the amplification of shocks within the system is ultimately an endogenous process, the shock as the root cause was nevertheless treated as an event mostly beyond the control of both market participants or regulators. According to this *traditional view*, the crisis probability p_t in Equation (2.1) would be treated as exogenous from the perspective of market participants and regulators, whereas the costs of a crisis C_t are endogenously determined by the capability of the financial system to withstand adverse shocks.

The potential costs of a crisis are inter alia determined by the system's vulnerability to *contagion*. Hellwig (2014) distinguishes between three forms of contagion. First, contagion can occur due to physical exposures, i.e., if banks are interconnected via reciprocal claims and liabilities. The bankruptcy of one institution affects all institutions holding claims on the defaulting entity. At worst, a cascade of domino-like defaults may arise. Second, contagion can also be information-based: If imperfectly informed creditors infer from the default of one institution that other (similar) institutions are likewise prone to failure, this could give rise to a systemic run. And third, contagion can occur via markets and prices. If a distressed bank is fire-selling assets, the associated downward pressure on market prices may trigger the need for write-downs at institutions with similar exposures. Then, these institutions may face the need to sell assets themselves, which gives rise to a vicious spiral.

Indeed, it is hard to deny that the stability of the financial system may be adversely affected by events which are for the most part exogenous from the perspective of market participants and regulators. According to de Bandt and Hartmann (2000, p. 11), such exogenous shocks can be either idiosyncratic or systematic. On an idiosyncratic level, the failure of an individual bank, for instance due to fraudulent practices or unauthorized speculation, may serve as an example. On the other hand, a recession emerging due to non-financial factors exemplifies a systematic shock.

However, allowing for exogenous shocks does not imply that financial crises can not arise due to endogenous reasons. Put differently, it is unrealistic to treat the crisis probability p_t as a variable which is not influenced by the behavior of the financial sector. It is more reasonable to assume that exuberance during the boom - both increasing the crisis probability and the potential for adverse contagion - inevitably sows the seeds for the subsequent bust. Both the probability and the severity of a crisis are ultimately an endogenous market outcome. This is the *novel view* on systemic risk.

According to this view, systemic risk is an entirely endogenous phenomenon. The role of exogenous shocks is greatly de-emphasized. They are regarded as mere trigger events, which eventually reveal the fragility that has built up in the system during good times. However, they do not constitute the root cause of financial distress. Brunnermeier et al. (2009, p. 6) put it as follows:

> "[F]inancial crises are predominantly caused by market dynamics, not just by external shocks, though such shocks, e.g. the downturn in the US housing market in 2006, the quadrupling of oil prices in 1973/74, the Stock Market collapse in 1929, may well have been the trigger."

If systemic risk has built up gradually, its materialization is only a matter of time. The actual trigger event is of minor relevance, as it is in fact interchangeable. Put differently, a rise in p_t (most likely accompanied by an increase in C_t) decreases the resilience of the financial system against exogenous shocks. However, the latter are inevitable by nature and at some stage even small disturbances are sufficient to uncover the underlying fragility of the system. In that respect, Borio et al. (2014, p. 3) declare that

> "[f]inancial crises are not like meteorite strikes from outer space. They resemble volcanic eruptions or earthquakes: they reflect the sudden and violent release of pressure that has built up gradually over time. The pressure takes the form of protracted financial booms, which often straddle business cycle fluctuations until they become unsustainable, thereby sowing the seeds of their subsequent demise. The build-up of such financial imbalances gives rise to endogenous boom-bust processes, or "financial cycles" [.]"

Table 2.1 tries to highlight the differences between the traditional and the novel approach towards systemic risk. Both views acknowledge the presence of endogenous amplification via a variety of contagion channels. Yet the traditional approach stresses the importance of exogenous shocks as the genuine source of a financial crisis whereas the novel approach recognizes that both the build-up of financial vulnerabilities as well as their realization are market outcomes, with inevitable shocks acting as mere triggers. In comparison, I consider the novel approach towards systemic risk to be the more realistic one. The example of the recent financial crisis illustrates the shortcomings of the traditional approach. The latter would treat the initial turmoil on the market for mortgage-backed securities (MBS) in the United States as an exogenous event, which was endogenously amplified within the system and finally led to a catastrophic financial crisis.

Components of Systemic Risk	Traditional View	Novel View
Crisis Probability p_t	Exogenous	Endogenous
Crisis Costs C_t	Endogenous	Endogenous
Role of Exogenous Shocks	Genuine Source	Interchangeable Trigger

Table 2.1: *Systemic Risk: A Comparison of Different Views*

This is arguably a misleading perception. As emphasized by Dell'Ariccia et al. (2012) and Justiniano et al. (2015) among others, financial intermediaries fueled the boom-bust cycle on US housing markets through the erosion of lending standards and the accumulation of large common exposures. Put differently, the expansion of credit supply has to be regarded as one of the key drivers of the US housing boom. Thus, the collapse of the MBS market has not been a "meteorite strike from outer space," it was rather an unavoidable consequence of imprudent lending behavior, which gradually increased both the probability and the costs of a crisis.

Furthermore, it is telling that apparently unspectacular rating downgrades of some mortgage-backed securities acted as a trigger event, as highlighted by Brunnermeier (2009) in a comprehensive account of the recent crisis. And even though losses on MBS tranches were large in absolute terms, this market comprised a relatively small part of the financial system (Hellwig, 2009). So it needs to be explained why the collapse of a relatively small market subsequently developed into a full-blown financial crisis.

The reason is that the financial system has developed into a state of fragility during the previous years, despite that (or probably precisely because) macroeconomic conditions looked extraordinarily benign. Banks operated with little equity and large maturity mismatches, relied to a great extent on unstable refinancing and extended high-risk lending (Hellwig, 2009). The turmoil on US housing markets did nothing but to reveal these vulnerabilities. A magnitude of losses which could have been easily absorbed by a healthy system now brought the financial sector close to a catastrophic meltdown. The novel approach of systemic risk seeks to describe the build-up of fragility before the crisis as an endogenous process. In what follows, I will examine potential market-immanent explanations for the endogenous build-up of systemic risk.[2]

[2] To be sure, there is also a lively debate on whether secular trends may have contributed to the crisis. Fitoussi and Saraceno (2010) argue that rising inequality and the associated weakening of aggregate demand may have led monetary policy to pursue a policy stance with an expansive bias. Holmstrom (2015) points out that strong global demand for (seemingly) safe assets - probably stemming from countries like China with large wealth positions but relatively weakly developed financial markets - may have contributed to the extraordinary and unsustainable growth of the MBS-issuing shadow banking industry, and the financial sector in advanced economies in general. This complements the famous savings-glut hypothesis by Bernanke (2005), who argued that various secular factors such as demographic change increased the global supply of savings and hence demand for US assets. However, the detailed examination of these mechanisms is beyond the scope of this work.

2.3 Systemic Risk as a Policy Issue

Before turning to the potential sources of systemic risk, it is necessary to clarify why (and if at all) systemic risk on financial markets does represent a policy issue. Put differently, it is necessary to reflect on the optimal level of systemic risk. Optimal systemic risk is certainly not zero, since exogenous drivers of systemic risk are neither controllable nor insurable.[3] Furthermore, risk allocation and risk sharing are the key functions of a modern financial system which should not be constrained without good reason. Following Brunnermeier et al. (2009), I argue that three conditions have to hold in order to render systemic risk a relevant policy issue.

Condition 1: *The macroeconomic costs of financial crises are extraordinarily high.*

It is straightforward to make the case for the first condition, both from a theoretical and an empirical perspective. A healthy financial system is important to ensure the provision of funding for investment in any sector of the real economy. Disruptions of financial intermediation may therefore dramatically lower aggregate investment and economic activity in general. By contrast, crises in other sectors are unlikely to create such powerful and adverse spillovers to the entire economy. The special property of the financial sector is the enormous degree of interconnectedness between market participants through reciprocal claims and liabilities, a feature which is arguably less present in other sectors. Somewhat paradoxically, the failure of a financial institution tends to weaken its competitors instead of strengthening them. Thus, a modern financial system is not only of utmost importance for economic welfare but is also suffering from particular vulnerability.

Empirical evidence confirms that the macroeconomic fallout which follows systemic financial crises is especially painful. For instance, Jorda et al. (2013) study over 200 recessions in advanced countries between 1870 and 2008 and find that recessions which were preceded by a financial crisis involve larger output losses than recessions during which the financial system has been relatively stable. Similar results are delivered by Reinhart and Rogoff (2009), who additionally emphasize that financial crises trigger persistent increases in unemployment and government debt burdens.[4]

3 In that respect, risks stemming from natural disasters or geopolitical tensions come to mind.

4 See Claessens and Kose (2013) and the references therein for further empirical evidence on the macroeconomic costs of financial crises.

Condition 2: *Traditional financial supervision with its aim to secure the individual soundness of financial institutions is insufficient to contain systemic risk.*

Traditional *microprudential* supervision seeks to prevent distress at individual institutions and pursues the ultimate objective to protect bank creditors (Borio, 2003). However, the claim that securing individual soundness implies systemic stability suffers from a fallacy of composition. Microprudential supervision may turn out as insufficient (or even counterproductive) for delivering *systemic* stability since there are plausible circumstances where individually prudent behavior of financial institutions may exacerbate systemic risk.

For instance, diversification may weaken the resilience of the financial sector. This might appear as a bold claim since diversification lies at the core of financial intermediation and is, in principle, a beneficial strategy enjoying regulatory support. On the other hand, while diversification fosters risk sharing, it creates common exposures and therefore the danger of contagion. For example, in the run-up to the sub-prime crisis, European banks invested into US mortgage securities, not least to improve their geographical diversification. While individual institutions indeed managed to improve diversification, the entire system became commonly exposed towards turmoil on the US housing market (Wagner, 2010).

Another mechanism of overwhelming importance is the phenomenon of deleveraging. Suppose that several banks within the system report substantial losses which eat into their capital.[5] Hence, they possibly violate the capital requirement imposed by the microprudential supervisor. In order to fulfill capital requirements (and since raising capital in a distressed environment is difficult) banks scale back their balance sheet by selling assets, such that the ratio of capital to total assets recovers. However, this individually prudent behavior may trigger an adverse feedback loop of falling asset prices, further losses and the need to sell even more assets. Microprudential regulation with its narrow focus on enforcing capital requirements does not account for the systemic implications of deleveraging (Hanson et al., 2011). In that respect, Hellwig (2009, pp. 179-180) claims that "the currently existing regime of prudential regulation of banks through capital adequacy requirements [...] is highly procyclical, allowing banks to expand in goods times and forcing them to contract in bad times. Such behavior of the

5 The terms "capital" and "equity" will be used interchangeably throughout the remainder, unless specified otherwise.

bank reinforces fluctuations in the rest of the financial and economic system." Similar concerns have been expressed by Kashyap and Stein (2004) and Repullo and Suarez (2008), who argue that Basel II, the internationally applicable capital adequacy framework, may exert substantial procyclical effects.

Moreover, physical contagion and deleveraging may powerfully reinforce each other, as highlighted in the simple example in Figure 2.1. Bank A is assumed to be exclusively invested in Asset 1, while Bank B is exclusively exposed to Asset 2. Asset prices are fundamentally uncorrelated. Bank A and Bank B have accumulated reciprocal interbank claims to achieve some degree of diversification. Now, if Asset 1 delivers low payoffs, its price declines which puts pressure on the balance sheet of Bank A.

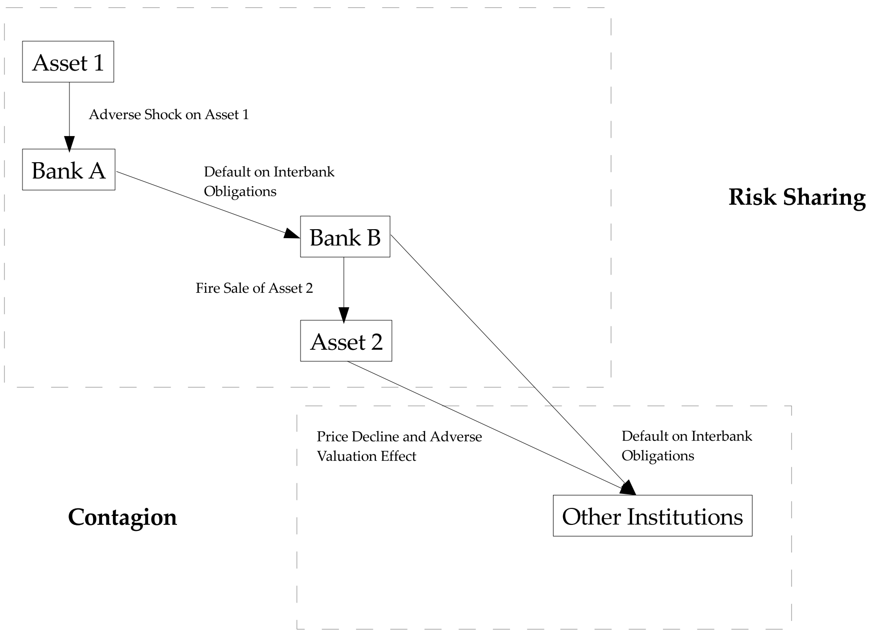

Figure 2.1: *Risk Sharing, Deleveraging and Contagion*

If Bank A subsequently defaults on its obligation to Bank B, distress is propagated to the latter. So far, this process is the outcome of pure risk sharing. However, the distress of Bank B induces contagious higher-order propagation effects. Facing losses from its exposure to Bank A, Bank B may be forced to sell its holdings of Asset 2 or will likewise default on its obligations. This behavior harms additional agents that are only indirectly exposed to Bank A and a systemic crisis may develop. Formally, risk sharing implies a higher correlation of banks' portfolio returns. If risk sharing induces contagion, however, fundamentally unrelated asset prices become correlated and it is the latter phenomenon which ultimately triggers a systemic crisis (Gallegati et al., 2008). Note that microprudential supervision does little to contain these effects.

Another shortcoming of the microprudential view is the missing distinction between individual and aggregate maturity mismatches (Hellwig, 1995). While maturity transformation of individual institutions may seem moderate, the degree of *systemic* maturity transformation may be substantial which enhances the risk of sudden liquidity shortages. This may especially occur in a regime with long intermediation chains and pronounced interbank linkages. In Figure 2.2, it is supposed that some ultimate saver places a deposit at the first bank of the chain. This bank (Bank 1) subsequently uses the deposit for interbank lending with a maturity of one month. The borrowing bank (Bank 2) in turn uses the deposit to finance interbank lending to a third bank with a maturity of two months and so on. The case can be extended to N banks and the last bank in the chain lends to some ultimate borrower for N months. The individual maturity mismatch of each bank amounts to one month.

However, the systemic maturity mismatch amounts to N months and a deposit withdrawal by the ultimate saver can trigger a disordered unwinding of the inherently fragile structure of short-term claims and liabilities. Moreover, the system is heavily exposed to interest rate risk, as rising rates may compress thin interbank intermediation margins very quickly. Nevertheless, financial supervisors with a narrow view centered on individual institutions may form the mistaken belief that risks from maturity transformation are moderate.

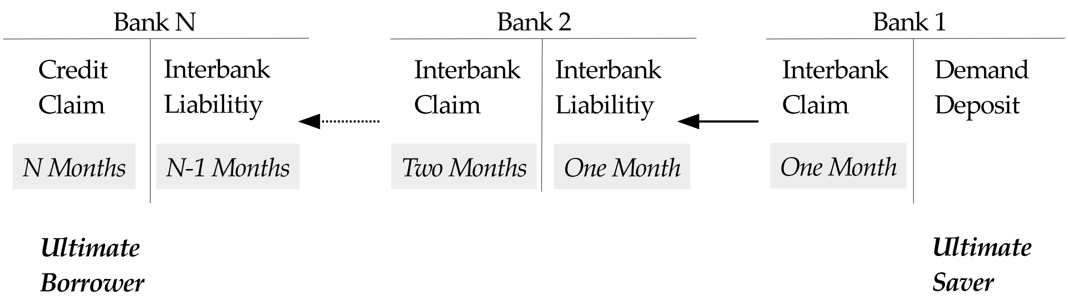

Figure 2.2: *Individual and Aggregate Maturity Mismatch*

The previous examples tried to clarify that focusing on the individual soundness of financial institutions is not enough. In order to achieve systemic stability, traditional supervision needs to be complemented with *macroprudential regulation*, which seeks to limit the risk of systemic crisis episodes.[6]

> **Condition 3**: *The level of systemic risk is excessive under the absence of appropriate macroprudential measures.*

The question whether the third condition is fulfilled is certainly the most interesting one. It is not clear at first sight (at least from a theoretical perspective) whether the prevalence of a certain level of systemic risk impairs aggregate welfare in the sense that policy intervention may deliver a superior outcome. After all, it is equally conceivable that the financial system endogenously trades off efficiency and stability and ends up with a socially efficient level of systemic risk as an outcome of private optimization. In order to analyze whether the prevailing level of systemic risk is indeed excessive, it is necessary to highlight potential sources of systemic risk in greater detail. As briefly laid out in my introductory remarks in Chapter 1, there are two paradigms which deliver a potential explanation for excessive systemic risk.

On the one hand, there are various theories which attribute the existence of boom-bust cycles on financial markets to *limited rationality*. These approaches have in common that they explain boom-bust cycles with the formation of overoptimistic expectations during the boom. These systematic expectation errors occur due to the presence of cognitive limitations and expectation formation under bounded rationality. Overoptimism leads financial institutions to take too much risk, and as soon as their expectations become disappointed (which is inevitable given enough time), the painful correction of financial imbalances is set in stage.

On the other hand, a relatively recent approach highlights the role of *systemic externalities* in the build-up and the materialization of systemic risk. An excessive level of systemic risk emerges endogenously, as financial market participants do not internalize the consequences of their actions with respect to the stability of the system.

6 See Borio (2003) for an extensive discussion of the differences between micro- and macroprudential regulation approaches. Potential macroprudential instruments will be discussed in detail on a later stage in Chapter 5.

The next Chapters will be devoted to the extensive review of both the abovementioned concepts. I will argue that especially the concept of systemic externalities provides a convincing explanation of excessive systemic risk and the need for macroprudential regulation. In that sense, I consider each of the three previously mentioned conditions as fulfilled. Systemic risk is an important issue which needs to be tackled using appropriate macroprudential measures.

Chapter 3

Limited Rationality and Systemic Risk

Limited rationality is a potential driver of excessive systemic risk. If agents form expectations in a way which is inconsistent with economic fundamentals, financial boom-bust cycles may be driven by waves of optimism and pessimism. Probably the most famous account of the general possibility of such behavioral patterns is the notion of "animal spirits," highlighted by John Maynard Keynes in his General Theory:

> "[T]here is the instability due to the characteristic of human nature that a large proportion of our positive activities depend on spontaneous optimism rather than mathematical expectations, whether moral or hedonistic or economic. Most, probably, of our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as the result of animal spirits - a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities." (Keynes, 1936, pp. 161-162)

The notion of waves of optimism and pessimism is also present in Irving Fisher's debt-deflation theory (Fisher, 1932, 1933). He stresses that the presence of new and profitable investment opportunities generates overoptimistic expectations for the future and gives rise to a self-reinforcing boom of debt-financed investment and speculation, where the accumulation of eventually unsustainable debt burdens during the boom sows the seeds for a vicious circle of falling prices and rising real debt burdens during the bust. The following quotations illustrate these points:

> "No debt is so excessive as one based on mistaken hopes, but when disillusionment comes, the adventure is denounced as a "bubble" that has been pricked." (Fisher, 1932, p. 48)

> "[O]ver-investment and over-speculation are often important; but they would have far less serious results were they not conducted with borrowed money. [...] The same is true as to over-confidence. I fancy that over-confidence seldom does any great harm except when, as, and if, it beguiles its victims into debt. [...]" (Fisher, 1933, p. 341)

The idea of favorable supply-side developments developing into unsustainable booms driven by both overoptimism and unsustainable debt accumulation is also at the heart of the "Financial Instability Hypothesis" developed by Minsky (1986, 1992), which will be discussed in Section 3.3. It is also noteworthy that the famous historical analysis of financial crises by Kindleberger and Aliber (2011) recurs to Minskyian ideas to a great extent.

To sum up, the notion that exaggerated optimism may contribute to the build-up of financial crises appears to be well-known in economic theory.[1] Yet it remains unclear how and why overoptimistic expectation patterns arise in the first place. Put differently, the mechanism of expectation formation with its potential flaws deserves closer examination. In what follows, I will briefly discuss two approaches which offer explanations for the cyclical interplay of optimism and pessimism and its potential contribution to the build-up of excessive systemic risk. I will first elaborate on the Behavioral Finance Approach in Section 3.1. After that, Section 3.2 will outline the merits of Agent-Based Financial Market Models in this respect. Lastly, I will discuss Minsky's Financial Instability Hypothesis and the question whether it implicitly incorporates motives which are formalized within the former two approaches.

[1] Clearly, my treatment of these venerable theories is superficial and intentionally stylized. For a much more thorough discussion of the historical role of psychological factors in the theory of business cycles in general, see Geiger (2016) and the references therein.

3.1 The Behavioral Finance Approach

Behavioral Finance parts with the assumption of Rational Expectations, which is at the heart of traditional finance models.[2] The properties of Rational Expectations are neatly described by Barberis and Thaler (2003, p. 1055), who write:

> "[T]he Rational Expectations Equilibrium framework (REE) [...] assumes not only individual rationality but also consistent beliefs [...]. Consistent beliefs means that agents' beliefs are correct: the subjective distribution they use to forecast future realizations of unknown variables is indeed the distribution that those realizations are drawn from. This requires not only that agents process new information correctly, but that they have enough information about the structure of the economy to be able to figure out the correct distribution for the variables of interest."

Obviously, the concept of Rational Expectations makes stark assumptions on the ability of agents to collect and to process information. Thus, it is perhaps not completely surprising that work in the field of empirical finance has discovered several asset pricing anomalies which are hard to explain in the context of traditional finance models.[3] Motivated by the empirical shortcomings of rational asset pricing models, Behavioral Finance approaches take issue with the notion of Rational Expectations in two possible ways:

> "Behavioral finance departs from REE by relaxing the assumption of individual rationality. An alternative departure is to retain individual rationality but to relax the consistent beliefs assumption: [...] [Agents] lack the information required to know the actual distribution variables are drawn from. This line of research is sometimes referred to as the literature on bounded rationality[.]" (Barberis and Thaler, 2003, p. 1055)

[2] As will become apparent from the references, my overview on Behavioral Finance heavily relies on the insightful survey of Barberis and Thaler (2003). Nevertheless, the subsequent discussion is deliberately brief and inevitably incomplete.

[3] With respect to the US stock market, Barberis and Thaler (2003) distinguish three empirical puzzles. The *Equity Premium Puzzle*, detected by Mehra and Prescott (1985), shows that US stocks display historical excess returns which are not explainable in a plausibly calibrated rational asset pricing model. The *Volatility Puzzle*, first stressed by Shiller (1981), implies that stock prices are far more volatile than predicted by rational asset pricing models. And finally, the *Predictability Puzzle*, as for instance documented by Fama and French (1988), consists of the fact that stock prices can be (to some extent) forecasted over the longer-term, which is at odds with the Efficient Market Hypothesis.

However, it is not clear how agents departing from individual rationality and/or with model-inconsistent beliefs should manage to survive. Agents with systematically incorrectly expectations will inevitably lose their capital and finally vanish from the market, as rational agents with "correct" expectations can exploit non-fundamental developments in asset prices by taking essentially riskless arbitrage positions.

Yet this argument overlooks that arbitrage in the real world is risky and complicated by various frictions. This imposes *limits to arbitrage*. According to Barberis and Thaler (2003, pp. 1058-1061), risks and frictions associated with arbitrage can be broken down into four categories. First of all, arbitrageurs face *fundamental risk* which for instance arises if the price of a presumably underpriced asset drops further in the wake of bad news. Second, *noise trader risk* creates the danger that non-rational traders further deepen the mispricing of an asset which may cause temporary but significant losses for the arbitrageur. Third, arbitrage entails considerable *implementation costs* for example through fees and commissions but also through the costs of learning about the mispricing of a certain asset. Fourth, arbitrage may be limited by *institutional constraints* such as a ban of short-selling.

In a well-known paper, Shleifer and Vishny (1997) formally show that noise trader risk may lead to limited arbitrage and persistent deviations of asset prices from their fundamental value. Rational investors who know the fundamental price of an asset may refrain from betting against its mispricing if they fear that noise traders magnify the mispricing in subsequent periods. The reason is that in this case, financiers would possibly withdraw funds due to (temporarily) negative return performance such that liquidation losses associated with withdrawals exceed the expected gains from arbitrage.

3.1.1 Cognitive Biases and Irrational Beliefs

If limited arbitrage indeed allows for the viability of non-rational behavior on financial markets, the next step would be to try to classify potential types of irrational behavior and the associated implications for expectation patterns.[4] According to Avgouelas

[4] A different approach is to question whether standard preferences in economic models featuring decisions under risk, as first introduced by von Neumann and Morgenstern (1947) in their expected-utility framework, really reflect human behavior. In this respect, the *prospect theory* of Kahneman and Tversky (1979) is an important alternative. For instance, experimental evidence has shown that people tend to form decisions under risk with a particular aversion towards losses and overly focus on outcomes with small probabilities. See for instance Barberis et al. (2001) for an asset pricing model based on preferences rooted in prospect theory.

(2009), one important pillar of human decision making is the use of heuristics or rules of thumb. Heuristics may be useful to cope with situations which are characterized by informational complexity and uncertainty. However, heuristics may exhibit severe cognitive biases giving rise to *non-rational beliefs*. Biases result from of the use of heuristics if they come along with systematic estimation errors of known (statistical) quantities and systematic deviations of individual, intuitive judgments from the principles of probability theory.

Extensive research in the field of cognitive psychology has shown that people indeed tend to use biased heuristics, which explains observed departures from rational decision-making in both experimental and (to a lesser extent) empirical studies.[5] Barberis and Thaler (2003, pp. 1065-1069) provide an extensive list of cognitive biases. I subsequently provide a selective list of them, dependent on their potential contribution to excessive systemic risk.

(1) *Overconfidence*: People overstate the precision of their estimates of future outcomes and potential forecast errors are greatly underestimated. Additionally, people tend to believe that high-probability outcomes occur almost with certainty while low-probability outcomes are neglected. Naturally, this comes along with an overly optimistic bias towards favorable outcomes and a neglect of seldom but particularly detrimental outcomes.

(2) *Availability*: The probability of outcomes is estimated with respect to their imaginability. Rare and unprecedented events are consequently underestimated. In that sense, the availability bias can be viewed as a complement to the overconfidence bias.

(3) *Anchoring*: Estimation processes usually require an initial value as a "starting point" from which agents depart by adjusting to newly available information. However, agents rely too heavily on initial values and adjustments do not take place at all or occur in a very sluggish fashion.

(4) *Representativeness*: Generally speaking, when people try to infer the probability that an object A belongs to a class B, the probability is estimated according to whether A reflects defining characteristics of B. While such a heuristic is useful, it may give rise to two biases. The first one is *base rate neglect*, implying that agents put too much weight on whether an object is representative of B, and too less weight on the unconditional

5 See Kahneman and Tversky (2000) for an overview.

probability that an object belongs to class B in the first place.[6] The second and closely related bias is *sample size neglect*: People tend to prematurely infer general characteristics from a sample after few observations.

3.1.2 Representativeness and Distorted Loan Pricing

Representativeness per se is a useful heuristic to assess the probability of an outcome A given the observation of an Event B. Bayes' law helps to calculate the respective conditional probability as follows:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \tag{3.1}$$

where $P(A|B)$ denotes the conditional probability of an outcome A conditional on the occurrence of outcome B, $P(B|A)$ denotes the respective conditional probability vice versa and $P(A)$ and $P(B)$ denote unconditional a priori probabilities of events A and B. Applying Bayes' law is particularly helpful if $P(B|A)$ is easily observable while $P(A|B)$ is not.

Consider now a bank which can lend either to some safe borrower A or some risky borrower B where the type of a borrower is private information and unknown to the bank. The probability of repayment R from borrower A is given by $P(R|A) = 1$ and the probability of repayment from borrower B is given by $P(R|B) = 0.8$, implying that lending to A is essentially riskless and (ceteris paribus) more profitable. Assume further that the pool of potential borrowers consists of A and B in equal number so that $P(A) = P(B) = 0.5$. The ex ante repayment probability when lending to an unknown borrower is then given by

$$P(R) = P(A)P(R|A) + P(B)P(R|B) = 0.5 \times 1 + 0.5 \times 0.8 = 0.9 \tag{3.2}$$

[6] Consider the following example. Suppose that an object A is described as follows: "A is a young man struggling with self-doubts." People need to assess the probability that A belongs to the class B, where B is defined as "PhD students close to finishing their thesis." Intuitively, people will consider it very likely that $A \in B$, as the description of A is (unfortunately) representative of class B. Yet this intuitive judgment overlooks the base rate, i.e. the general (and arguably rather low) probability that the young man is a PhD student in the first place. Technically, this means that people tend to disregard Bayes' law (see Equation (3.1)). Not every young man struggling with self-doubts is a PhD student close to finishing his thesis.

Naturally, banks have a vital interest in revealing the type of a borrower as soon as possible, especially when the question of renewing the credit contract arises. As laid out in Sharpe (1990), the only possible way to obtain this information in such a stylized setting is to gradually deduce it from the actual performance of the borrower with the help of Bayes' law. Hence, banks seek to estimate $P(A|R)$, which is the probability that a borrower is safe given a successful repayment. Applying Bayes' law yields:

$$P(A|R) = \frac{P(R|A)P(A)}{P(R)} = \frac{1 \times 0.5}{0.9} \approx 0.55 \tag{3.3}$$

Note that this is a perfectly rational learning strategy under limited information, where banks do not know the true type. The bank updates the probability that its specific borrower is safe to 55%, conditional on the obtained information that repayment actually occurred. Hence, the updated repayment probability $P(R)^*$ which is assigned to this specific borrower is given by

$$\begin{aligned} P(R)^* &= P(A|R)P(R|A) + (1 - P(A|R))P(R|B) \\ &= 0.55 \times 1 + (1 - 0.55) \times 0.8 = 0.91. \end{aligned} \tag{3.4}$$

However, banks may misapply Bayes' law due to the representativeness bias. Banks neglect the base rate $P(A)$ and weigh $P(R|A)$ overly prominent which would imply $P(A|R) = P(R|A)$ in the extreme. Successful repayment leads the bank to overestimate the possibility that the borrower is of type A, just because successful repayment is *representative* of a safe borrower. Referring to the example, the bank feels certain that the borrower is safe (as $P(R|A) = 1$), thereby overlooking the fact that risky borrowers may also succeed in repayment, albeit with a lower probability. Base rate neglect may consequently lead to severe errors in calculating conditional repayment probabilities and the associated required risk compensation. Specifically, the falsely assumed repayment probability under extreme base rate neglect would amount to

$$P(R|A)^2 + (1 - P(R|A))P(R|B) = 1. \tag{3.5}$$

Hence, banks cease to demand any default risk compensation. The representativeness bias makes them negligent towards credit risk. Favorable states where repayment is successful lead to a relaxation of credit conditions. Yet if the borrower turns out to be of type B and will fail to repay, the bank is ill-prepared. After all, accumulated interest rate revenues can be loosely regarded as a cushion against future defaults. If interest rate charges haven been too low, this cushion might easily turn out to be insufficient. Hence, biased heuristics are generally capable to provide a formalization of emerging overoptimism and the associated increase of systemic risk during a boom.[7] A formally more rigorous treatment of the role of the representativeness bias for the emergence of boom-bust cycles is given in Gennaioli et al. (2015). In their model, investors overreact to a series of good news as they (incorrectly) perceive them to be representative of a good state, which leads to excessive debt issuance and overoptimistic return expectations. Vice versa, bad news can induce pronounced pessimism which gives rise to a crisis.

The other biases may play an equally important role in shaping boom-bust cycles. For example, the overconfidence bias may lead to the underestimation of the probability of rare but disastrous events, such as the joint repayment failure of a large amount of US mortgage borrowers or the breakdown of important markets for short-term funding. Sample size neglect may give rise to extrapolative expectations, such that agents expect asset prices to rise simply because they have increased in previous periods. In this respect, Barberis (2013) argues that extrapolation may have played a role in shaping beliefs of steadily growing US house prices prior to the crisis.

3.2 Agent-Based Financial Market Models

To start with a semantic quibble, I consider the term "Agent-Based Financial Market Models" to be a slight misnomer. After all, the mechanics of almost any economic model are in some sense based on the decisionmaking of agents. However, while the majority of models in both finance and macroeconomics assume a representative agent, Agent-Based Financial Market Models are firmly based on the concept of *heterogeneous* agents. Specifically, agents are often modeled to be different with respect to their expectation

7 It should be noted, however, that Bayesian Learning per se tends to be inherently procyclical. Even if Bayes' law is applied correctly, successful repayment triggers a relaxation of credit conditions (albeit to a lesser extent). Indeed, a critical question in the learning literature is whether agents are able to uncover objective probability distributions with the help of enough observations. Put differently, the question is whether learning models converge to the Rational Expectations Equilibrium. See for instance Adam and Marcet (2011) for an asset pricing model with Bayesian Updating which is capable of generating boom-bust cycles and Evans and Honkapohja (2009) for a survey on macroeconomic learning models.

formation.[8] For example, there may be diverging opinions towards future asset prices. While some agents perceive that asset prices will equal some specific value ("fundamentalists"), others extrapolate past price developments into the future ("chartists").

Very importantly, the shares of agents pursuing certain beliefs can vary endogenously over time (Brock and Hommes, 1997, 1998). In the absence of model-consistent rational expectations, agents evaluate expectation formation mechanisms according to their past forecast performance. If asset prices rise for several successive periods, the forecast performance of an extrapolative expectation rule may turn out as superior. Hence, agents who were sticking to the expectation of some constant asset price become disappointed by its forecast performance. They will consequently switch to the chartist expectation pattern. Since the expectation of continuous price increases fosters asset demand, the expectation of rising asset prices becomes self-fulfilling. Hence, Agent-Based Financial Market Models are capable to explain boom-bust cycles in asset prices by endogenous expectation cycles. Put more simply, these models are able to capture endogenous waves of optimism and pessimism and their asset-pricing implications (Hommes, 2006).

It is noteworthy that such patterns are not entirely irrational. Agents do not know the true model, which of course can be justified with the cognitive inability of agents to collect and process every relevant information for the Rational Expectation Equilibrium.[9] Yet they are individually rational in the sense that they compare available expectation heuristics with respect to their past forecast performance. Hence, in line with the categorization of Barberis and Thaler (2003), agents can be characterized as acting under bounded rationality. They fail to generate model-consistent beliefs but are nevertheless individually rational.

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8 There is a rich literature analyzing the implications of heterogeneity with respect to characteristics besides expectation formation. For example, Cúrdia and Woodford (2009) extend a New-Keynesian model with an (endogenously arising) credit market. They do so by assuming that agents are heterogeneous in their time preference. Aiyagari (1994) emphasizes the importance of heterogeneity if agents face idiosyncratic and non-insurable shocks. See also Krusell and Smith (2006) for a general survey highlighting applications of heterogeneous agents in both a macroeconomic and an asset pricing context.

9 Sims (2003, 2010) puts forward the alternative concept of *rational inattention*. While agents are basically capable of processing every relevant information, the cost of doing so is prohibitively high. Hence, it is optimal to abstain from forming rational expectations.

3.2.1 A Simple Example

In order to illustrate the mechanics of Agent-Based Financial Market Models, I review the simple asset market model proposed by Westerhoff (2008). In the model, agents have three alternative trading strategies. They can trade according to a fundamentalist strategy F which assumes that the fundamental asset price is constant. Alternatively, agents can follow a chartist trading strategy C, which extrapolates expected asset prices from past price movements. Moreover, agents can stay out of the market and choose to not trade at all (strategy 0). Hence, agents have three potential heuristics at hand. The asset price evolves according to a price impact function given by

$$P_{t+1} = P_t + a(W_t^C D_t^C + W_t^F D_t^F) + \alpha_t \tag{3.6}$$

where P_t denotes the log of the asset price in the respective period t, a is a positive price adjustment coefficient, D_t^C and D_t^F reflect asset demand by chartist and fundamentalist traders, respectively, W_t^C and W_t^F denote the weights of agents pursuing these trading rules and α_t is a normally distributed stochastic disturbance with zero mean and finite variance. Hence, the asset price (ceteris paribus) increases if $D_t^C + D_t^F > 0$, which represents an excess demand constellation. If $D_t^C + D_t^F < 0$, the asset price declines. The latter can be thought of as an excess supply constellation, where negative values of D_t^C and/or D_t^F indicate the desire to sell the asset. Demand functions are determined by *trading rules*. Demand by the chartist trader is given by

$$D_t^C = b(P_t - P_{t-1}) + \beta_t \tag{3.7}$$

where $b > 0$ denotes a reaction parameter and β_t is another stochastic disturbance term. The chartist increases (decreases) its asset demand if the asset price increased (decreased) in the past as he implicitly assumes that prices will continue to rise (decline) further. By contrast, fundamentalists follow a trading strategy of

$$D_t^F = c(F_t - P_t) + \gamma_t \tag{3.8}$$

where F_t denotes the log of the perceived fundamental value of the asset. If F_t is lower than (exceeds) P_t, the asset is considered as expensive (cheap) and fundamentalists adjust their demand accordingly. The fundamentalist trading rule is likewise augmented with a stochastic disturbance term γ_t.

Agents decide on which trading rule to follow by comparing their past attractiveness according to so-called *fitness functions*. The fitness function for the chartist trading rule is given by

$$A_t^C = (\exp[P_t] - \exp[P_{t-1}])D_{t-2}^C + dA_{t-1}^C \tag{3.9}$$

from which it is apparent that the attractiveness of a certain trading rule is governed by its past profits, depicted by past asset demand multiplied with past price changes.[10] Moreover, evaluation is assumed to exhibit persistence, such that agents not only account for current but also for past profitability of the trading strategy. Hence, past profits A_{t-1}^C enter the fitness function and are weighed with some memory parameter $0 \leq d \leq 1$. The fitness function for the fundamentalist trading strategy is written analogously as

$$A_t^F = (\exp[P_t] - \exp[P_{t-1}])D_{t-2}^F + dA_{t-1}^F. \tag{3.10}$$

The fitness function for the strategy to stay out of the market is normalized to zero, i.e., $A_t^0 = 0$. Agents permanently compare the relative attractiveness of each strategy. As a result, the share of agents pursuing a certain strategy $S \in \{C, F, 0\}$ is given by the following function:

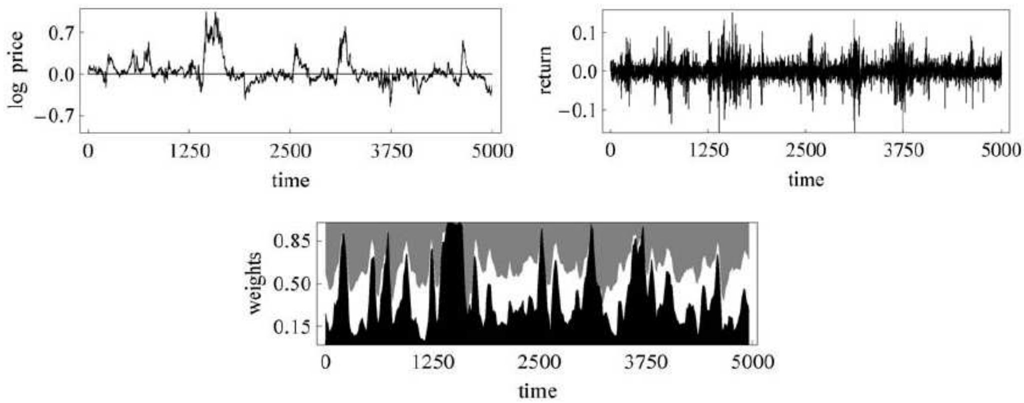
$$W_t^S = \frac{\exp\{eA_t^S\}}{\exp\{eA_t^C\} + \exp\{eA_t^F\} + \exp\{eA_t^0\}} \tag{3.11}$$

where e is the so-called intensity-of-choice parameter. If $e = 0$, each strategy is constantly pursued by a third of traders, regardless of differences in fitness function values. If $e \to \infty$, even small changes in relative attractiveness induce agents to switch collectively to the best-performing strategy. Intermediate values of e ensure gradual adjustment towards the best strategy over time. In any case, it holds that $\sum W_t^S = 1$.

In this setup, an endogenous asset-price boom can emerge as follows: If the asset price increases due to some random disturbance, the fundamentalist strategy appears

10 The timing assumption of the model is as follows: Orders submitted in $t-2$ are executed with a lag of one period in $t-1$. Thus, the ex-post profitability of a trade is determined by the price difference between t and $t-1$. The timing assumption is not innocuous. When simulating this very model as preparatory work for a similar approach laid out in Scheffknecht and Geiger (2011), we found that this timing assumption is critical to ensure dynamic stability. If orders are executed without a time lag, asset prices frequently explode.

to perform worse. By contrast, the chartist strategy appears profitable and agents will gradually switch towards the latter. The corresponding increase in demand fuels the asset price boom and the chartist strategy becomes self-validating. In the end, almost every agent is a chartist and the asset price apparently increases without bounds. However, at some stage a negative disturbance will inevitably interrupt the boom. Agents then recognize that the chartist strategy has become unprofitable. Hence, they switch to the fundamentalist strategy and try to sell their asset holdings altogether such that the asset price collapses.[11]



Source: Westerhoff (2008, p. 201)

Figure 3.1: *Price and Return Dynamics in an Agent-Based Financial Market Model*

Figure 3.1 gives an impression of the model dynamics from a simulation over 5000 periods, where the log of the fundamental asset price was normalized to zero. The upper left panel depicts the evolution of the log asset price. The asset price displays strong fluctuations and booms which are ended by sharp price collapses. The upper right panel displays per-period returns, indicating that pronounced boom-bust episodes go along with clustered return volatility. The bottom panel depicts the weights of agents in each period, where the black area denotes chartists, the grey area denotes fundamentalists and the white area corresponds to the weight of agents following the no-trade strategy. It is observable that in each boom episode the overwhelming majority

11 See also DeGrauwe (2010, 2011) for an application of a similar expectation switching mechanism to a macroeconomic model. Similar to the model under consideration, it is found that small macro shocks can trigger persistent business cycles driven by the endogenously emerging predominance of chartist expectations.

of agents follow the chartist strategy, in line with the verbal description given above. Hence, this simple model is capable to generate boom-bust cycles on financial markets out of the endogenous interaction between heterogeneous agents and their respective trading rules.

3.2.2 Systemic Risk Applications

The previously described model example is without doubt highly stylized. It takes a partial-market perspective and is silent on potential repercussions between financial markets and the real economy. Moreover, trading rules would certainly deserve a somewhat more rigorous analytical foundation, especially with respect to potential financing constraints traders might face. Nevertheless, it is remarkable how well such a simple model can replicate some empirical regularities of asset prices such as clustered return volatility and fat tails, whereas traditional asset pricing models continue to struggle with this task.[12]

In the aftermath of the financial crisis, several authors developed agent-based models which try to highlight key channels of the endogenous build-up of systemic risk. For instance, Geanakoplos et al. (2012) built an agent-based model of the US housing market, whose calibration is based on a rich set of micro-level data on housing units in the Washington DC area, such as demographics, income, loan characteristics and attributes of houses as such. Both house sellers and prospective house buyers are modeled according to behavioral rules which for instance describe pricing decisions of sellers and financing decision of buyers. Interestingly, even though the model is calibrated on data from only one specific state, it matches the behavior of the aggregate US housing market from 1997-2009 remarkably well. Moreover, counterfactual analysis suggests that a relaxation of lending standards has been the key driver for the boom in US house prices.

Thurner et al. (2012) developed an agent-based model of leveraged asset purchases. It includes four types of agents. First, there are *noise traders* with random demand behavior causing random fluctuations of the asset price. Second, there are *funds* which

[12] In the jargon, fat tails mean that extreme asset returns occur more frequently than implied by a Gaussian normal distribution. Mandelbrot (1963, 1967) is widely regarded to be the first author who consistently highlighted this empirical regularity. A formal statistical model of clustered volatility has first been provided by Engle (1982). Cont (2001) provides a more recent overview on stylized empirical facts of asset price behavior, broadly confirming the existence of fat tails and volatility clusters.

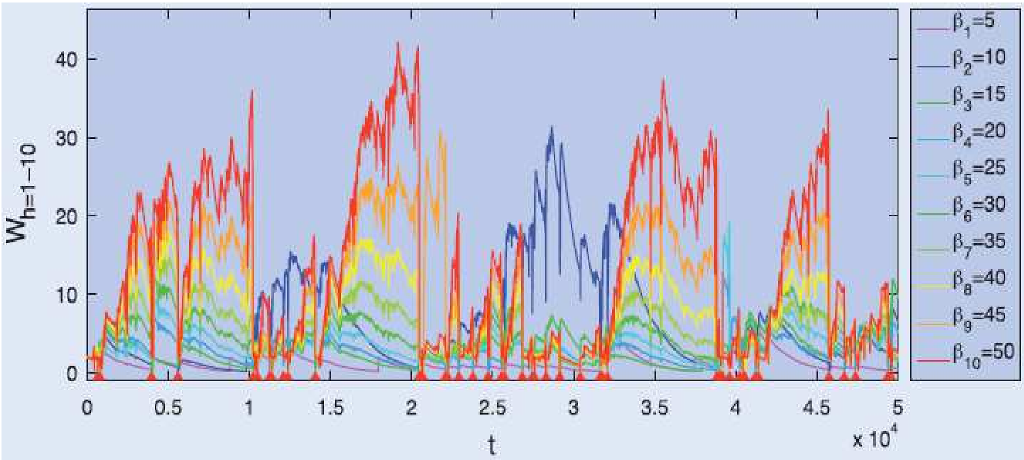
seek to exploit mispricings. Hence, their demand turns positive if the asset price is below its perceived fundamental value. They obtain financing by *investors*, who allocate their wealth to funds according to their past performance. Investors thus act under bounded rationality and rely on extrapolative expectations. Moreover, funds can leverage their positions by obtaining loans from the *banking sector*. Loans have to be collateralized with the respective assets and banks insist that fund leverage does not exceed some maximum threshold. Put differently, funds are subject to a leverage constraint which may become occasionally binding.

Funds differ with respect to their "aggressiveness." Aggressive funds are willing to exploit asset mispricings to the maximally feasible extent. For that purpose, they increase their position in the asset with the help of bank loans, thereby realizing a high degree of leverage. On the other hand, there also somewhat more conservative funds, which refrain from the aggressive use of leverage in a mispricing situation. The presence of leverage and collateralized loans introduces fragility. For example, consider a highly indebted fund being close to the maximum leverage threshold. If the asset price falls due to random noise trader actions, the fund realizes losses on its assets which eat into its equity position. Its leverage consequently increases. If the maximum threshold for leverage is hit, banks will demand a partial repayment of their loans (margin call). In order to ensure repayment, the fund has to sell assets in a situation of falling prices, which exacerbates the downturn.

The general model dynamics are as follows: Consider an initial mispricing situation. Aggressive funds will accumulate a comparably large position in the asset financed by deposits of investors and collateralized loans. The former can be regarded as equity in that respect.[13] If the mispricing is corrected, the associated price increase creates large profits for aggressive funds, especially due to the heavy use of leverage. In general, leverage amplifies profits in favorable states but also magnifies losses in adverse situations. Investors with deposits at other, less aggressive funds consequently reallocate their funds to the most aggressive funds, given their superior return performance. Hence, leveraged funds gain in market share and start to dominate market dynamics. Therefore, their investment strategy may become partly self-validating, because their

[13] To avoid semantic confusion, it is important to recall that making deposits at a fund is fundamentally different from making deposits at a bank. The value of the former fluctuate with the asset price, whereas the latter are fixed in value. Technically speaking, deposits at a fund deliver state-contingent payoffs while deposits at a bank deliver state-non-contingent payoffs. Hence, the payoff profile of the former resembles the characteristics of equity whereas bank deposits are debt titles.

demand affects asset prices to a greater extent now. However, at some point, there will be a random decrease in the asset price which makes the leverage constraint binding. Funds consequently have to deleverage and the asset price collapses. Simulations show that this behavior gives rise to clustered volatility and fat tails. Interestingly, individually prudent behavior by funds, such as adjusting maximally acceptable leverage inversely with observed asset-price volatility, makes the system as such more vulnerable, since leverage constraints bind more frequently.

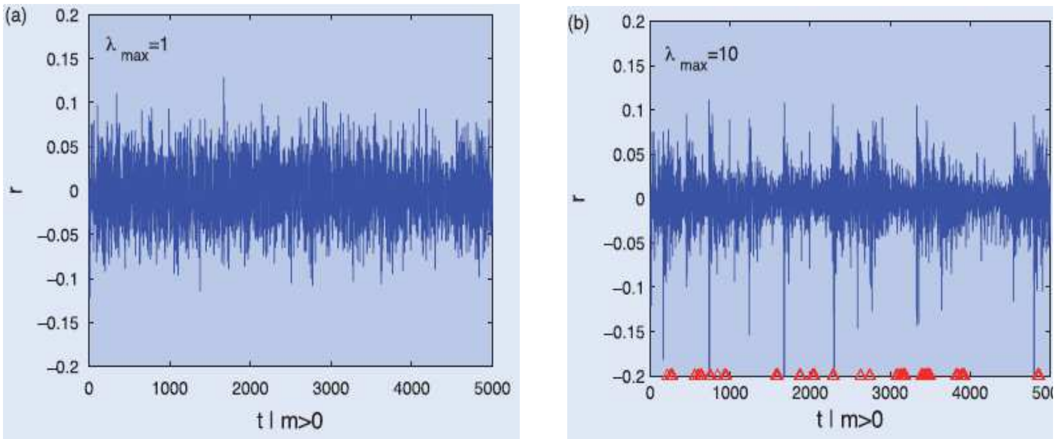


Source: Thurner et al. (2012, p.700)

Figure 3.2: *Wealth Dynamics of Funds with Heterogeneous Aggression Parameters*

Figure 3.2 depicts simulation results for the evolution of equity/wealth W_h for ten different funds $h = 1, 2 \ldots 10$ which differ in their willingness to leverage asset positions, as indicated by the aggressiveness parameter β_h. It is apparent that highly leveraged funds with a comparably large β_h gain in wealth during booms, partly at the expense of conservative funds with a lower β_h. Hence, market dynamics in the boom become almost entirely driven by leveraged funds. However, at some stage, the asset price randomly declines and these funds realize large leveraged losses. Their wealth consequently collapses to zero. The red triangles located at the x-axis depict situations where the leverage constraint becomes binding. These constellations are almost always accompanied by sharp deleveraging and the erosion of wealth.

Figure 3.3 depicts the behavior of asset returns r conditional on the presence of a mispricing signal $m > 0$ for two constellations. The left panel depicts returns if funds are not allowed to take additional leverage, i.e., the maximum ratio of total assets to equity is constrained to $\lambda_{MAX} = 1$. The right panel plots returns if funds are allowed to leverage their positions ($\lambda_{MAX} = 10$). Apparently, the presence of leverage makes extreme return realizations more frequent. Moreover, they tend to coincide with constellations where the leverage constraint becomes binding, as again indicated by the red triangles.



Source: Thurner et al. (2012, p. 701)

Figure 3.3: *Comparison of Return Behavior With and Without Leverage*

Hence, the model highlights that the presence of leverage in conjunction with extrapolative expectation patterns of fund investors creates powerful non-linearities and endogenous crises. In its spirit, it is closely related to the limited-arbitrage model of Shleifer and Vishny (1997). Funds, which essentially pursue an arbitrage strategy by investing in underpriced assets, always face noise trade risk, especially when leverage is high. The latter is the inevitable outcome of evolutionary market dynamics, because highly leveraged funds realize the largest returns when the asset price increases. Hence, they gain in market share.

Aymanns and Farmer (2015) present a similar model emphasizing the important role of leverage. Banks, who act as stock investors, manage risks using a *Value-at-Risk constraint*.[14] Value-at-Risk (VaR) is a measure of how much losses a portfolio maxi-

[14] This is not an arbitrary assumption. Most banks tend to manage asset risk with Value-at-Risk models. Their use enjoys particular regulatory support.

mally produces with a pre-specified probability p. Hence, the 95%-VaR is the forecasted amount of losses the respective portfolio will not exceed with a probability of 95%. Conversely, this loss is exceeded with a probability of 5%. If the equity position of a bank equals the 95%-VaR, its default probability - the probability of a large loss which wipes out its entire equity cushion - is consequently 5%.

Technically, the VaR corresponds to the $1-p$ quantile of the return distribution multiplied with the investment amount C. As inter alia shown in Franke and Hax (2004, pp. 601-602), the VaR under normally distributed returns with mean μ and standard deviation σ is given by

$$VaR_p = C(\mu + z(1-p)\sigma) \tag{3.12}$$

where $z(1-p)$ is the $1-p$ quantile of the standard normal distribution.[15] Suppose that a bank invests an amount $C = 1000$ in an asset portfolio with expected net return $\mu = 0.05$ and standard deviation $\sigma = 0.05$. Since $z(1-0.95) = -z(0.95) \approx -1.64$, the 95%-VaR is then given by

$$VaR_{95\%} = 1000 \times (0.05 + (-1.64 \times 0.05)) = -32 \tag{3.13}$$

implying that a loss of -32 is not exceeded with a probability of 95%. Of course, the portfolio VaR depends critically on return volatility. If the latter declines, the VaR decreases as well. At a given equity endowment of $E = 32$, the bank is now capable to acquire additional assets and to increase its leverage while maintaining some constant default probability potentially required by its creditors. Put differently, the decrease in σ facilitates an increase in C at a constant VaR level.

Aymanns and Farmer (2015) show that such risk management practices magnify booms and busts and give rise to a leverage cycle. Banks operate under bounded rationality in two ways. First, they extrapolate expected stock returns from past returns. Second, the VaR is calculated based on historical return volatilities from a short time window. If stock prices increase randomly, banks will start to increase their demand for stocks. This puts further upward pressure on stock prices. Importantly, continuous price increases lead to a decline of measured return volatility and an increase in

[15] The quantiles of the standard normal can be read off from readily available tables, such as in Hamilton (1994, pp. 751-752) or virtually any other econometrics textbook.

measured returns so that the VaR declines. Banks can thus take more leverage and buy additional assets, further fueling the boom. At some stage, a negative noise-trader shock inevitably leads to a decline in asset prices. Banks face leveraged losses and a tightening of the VaR constraint due to elevated return volatility as well as a decrease in measured returns. This gives rise to a powerful spiral of falling asset prices, elevated return volatility and systemic deleveraging. Exogenously imposed leverage limits or countercyclical leverage restrictions (implying that permitted leverage declines in the boom and is raised in the downturn) can dampen stock price fluctuations considerably.[16]

As a conclusion, it can be conjectured that agent-based models are capable of modeling the endogenous build-up of systemic risk quite satisfactory. Hence, they offer a more formal approach to the notion of animal spirits and debt-driven booms. In what follows, I review Minsky's Financial Instability Hypothesis, highlighting that it implicitly incorporates concepts from Behavioral Finance as well as the Agent-Based approach.

3.3 The Financial Instability Hypothesis

The Financial Instability Hypothesis of Hyman P. Minsky has experienced a revival in the wake of the current crisis.[17] For instance, McCulley (2009) has coined the term "Minsky Moment" referring to the beginning of the recent financial crisis in August 2007. Minsky was relentless in emphasizing that financial instability is an endogenous phenomenon. He attributes boom-bust cycles of financial and economic variables, most notably aggregate credit and investment, to an inherent indeterminacy of a market economy which gives rise to self-fulfilling investment and credit booms. In my view, Minsky's work is similar in spirit to the approaches pursued in both the Behavorial Finance and the Agent-Based literature, since expectation formation of firms and bankers, albeit not modeled explicitly, is subject to limited rationality.

[16] Importantly, managing risks with the Value-at-Risk approach is inherently procyclical even when banks are fully rational and use model-consistent return and volatility measures. This is highlighted in Adrian and Shin (2010b) as well as Zigrand et al. (2010). The former model will be discussed extensively in Section 8.4.

[17] See for example Kregel (2008) and Wray (2012) for examinations of the current crisis through the lens of Minskyian ideas.

3.3.1 The Taxonomy of Financing Regimes

As clarified in Minsky (1992), the Financial Instability Hypothesis rests on two theorems. The *first theorem* states that the economy is characterized by different financing regimes, which either act stabilizing or destabilizing. In this context, Minsky famously defined three possible financial states of economic units. The term "economic unit" should be understood globally as it includes firms, households, financial intermediaries but also governments. In Minsky (1986, pp. 371-379), it is distinguished between Hedge Units, Speculative Units and Ponzi Units. They differ in their ability to meet the contractually fixed repayments implied by their liability structure. *Hedge Units* are able to entirely meet their liabilities out of operating cash flows which is typically associated with a relatively low level of leverage. A Hedge Unit is thus characterized by the following proposition

$$CC = \tau(Q - \lambda\sigma_Q^2) \tag{3.14}$$

where CC stands for contractual cash liabilities, Q for expected cash flows and σ_Q^2 for their expected variance. The value of the parameter λ is chosen such as to assign a sufficiently low probability to the event that Q falls short of CC, while $\tau < 1$ measures the so-called *margin of safety*, which has to be regarded as a cushion against erroneous and overoptimistic expectations of cash flows and their variance, respectively. If τ increases, the margin of safety becomes smaller and vice versa.

In contrast, *Speculative Units* are basically solvent entities which face a short-term funding gap. Put differently, they operate with a liquidity mismatch. Banks are an obvious example. The presence of short-term liquidity needs implies that such entities are dependent on the willingness of creditors to provide revolving short-term loans. In the short-term for some period $i < t$ it holds that

$$CC > Q - \lambda\sigma_Q^2 \tag{3.15}$$

implying that cash liabilities CC exceed cash flows Q, and the funding gap needs to be covered by raising short-term external funds. Conversely, in the long-term for $i \geq t$ it is still ensured that

$$CC \leq Q - \lambda\sigma_Q^2. \tag{3.16}$$

Alternatively, by using Equation (3.14) as a reference point, it can be stated that speculative units realize $\tau > 1$ for $i < t$ and $\tau \leq 1$ otherwise. Hence, τ can be regarded as a measure for the liquidity risk exposure of a Speculative Unit.

The cash flows of *Ponzi Units* are insufficient to cover their external liabilities, neither in the short-term nor in the long-term, implying that $CC > Q$ and $\tau > 1$ for any period t. In order to guarantee repayments, Ponzi Units need to rely on additional borrowing or available liquidity balances, which is only feasible under narrow conditions such as moderate interest rates. Yet the long-term solvency of a Ponzi unit is highly questionable and is only maintained if some favorable event in the future improves its financial condition.[18] Minsky (1986, p. 379) notes that

> "[t]he viability of the [Ponzi] unit depends upon a big event occurring [...]. Indeed, the emergence of a skeptical attitude toward the big event materializing leads to funds not being available to keep the project afloat." (Minsky, 1986, p. 379)

Minsky claims that the predominance of Hedge Units implies a stable financing regime and fosters economic stability. If, however, the majority of economic units operates under a speculative or even a Ponzi regime, the financing regime is unstable and economic instability occurs. Specifically, he notes that

> "[a]n increase in the ratio of Ponzi, [sic!] finance, so that it is no longer a rare event, is an indicator that the fragility of the financial structure is in a danger zone for a debt-deflation." (Minsky, 1986, p. 379)

It is also interesting that by using the term debt-deflation, he recurs to Fisher (1932, 1933). Minsky in fact embraces Fisher's debt-deflation theory and regards is as an important cornerstone for the explanation of prolonged slumps.

[18] As an example, one might think of the debt-financed exploration of an oil field with highly uncertain output. Minsky (1986, p. 378) asserts that "Ponzi schemes are often, but not always, quests for an El Dorado. Micawber's belief that something will turn up might characterize a Ponzi-financing promoter, who, in his own mind, is not committing a fraud."

3.3.2 Endogenous Transition towards Financial Fragility

The *second theorem* of the Financial Instability Hypothesis states that the prolonged presence of benign macroeconomic conditions induces a transition from formerly stable to unstable financing regimes, that is, an economy which was predominantly characterized by Hedge Units moves towards a higher share of Speculative and Ponzi Finance. This may happen via a gradual erosion of the margin of safety τ but also through the (erroneous) perception of a decreasing variance of expected cash flows.

The transition process is governed by an endogenously emerging investment boom and is described extensively in Minsky (1986, ch. 8). In a Minskyian economy, fluctuations in investment are regarded as the main driver of the business cycle. The amount of investment, in turn, critically depends on financial conditions. In Minsky (1986, pp. 160-165), this point is introduced within a highly stylized example. Consider a simple static economy with two sectors producing consumption and investment goods. Regarding only direct labor costs and assuming that workers spend their wages entirely on consumption goods implies that revenues of the consumption sector equal the aggregate wage bill, such that

$$P_C Q_C = W_C N_C + W_I N_I \tag{3.17}$$

where P_C denotes the price level of consumption goods, Q_C denotes their respective amount, W_C and W_I denote wages in the consumption and the investment sector and N_C and N_I denote the amount of hours worked in the respective sector. Profits in the consumption sector are given by

$$\pi_C = P_C Q_C - W_C N_C = W_I N_I. \tag{3.18}$$

Aggregate investment equals revenues of the investment sector, which in turn equal the sum of wage bill and profits. Hence, it holds that

$$I = P_I Q_I = W_I N_I + \pi_I = \pi_C + \pi_I \tag{3.19}$$

which establishes the result that aggregate profits equal aggregate investment. In general, investment depends on the expectation of profits. Since aggregate profits and aggregate investment are inextricably linked, any investment level is feasible. Investment is self-validating in a sense that the investment process *as such* generates the amount of profits which is necessary to make an investment worthwhile. In an intertemporal setting, investment today depends on future expected profits and thus on future investment. In that respect, (Minsky, 1986, p. 163) notes that:

> "[i]nvestment and financing are undertaken only in the expectation that profits over a run of future periods - years - will reach or exceed some level. But profit equals investment. Thus, in a capitalist economy, investment takes place now because it is expected that investment will take place in the future."

To speak with technical terms, it seems that Minsky implicitly assumes that investment is characterized by *indeterminacy*. If investment today depends on expectations on future investment, any arbitrary sequence of expectations can generate some corresponding amount of current investment. The mere expectation of benign investment conditions in the future increases investment today.[19]

If the desired amount of investment is dependent on arbitrary but self-fulfilling profit expectations, the availability of external finance represents the ultimate constraint which finally determines the actual amount of investment. However, Minsky assumes that external finance constraints tend to vary procyclically, so that an investment boom goes hand in hand with increasingly fragile financing schemes. The inevitable end of the boom leads to a painful unwinding of financial imbalances and a depression of aggregate investment and economic activity in general.

Consider again the simple economy from above. If investment increases, both the wage bill $W_I N_I$ and profits π_I of the investment sector will rise. Increasing wage bills in the investment sector translate into higher profits for the consumption sector. The latter can be seen by solving Equation (3.17) for P_C, which yields

$$P_C = \frac{W_C N_C}{Q_C} \left(1 + \frac{W_I N_I}{W_C N_C} \right). \tag{3.20}$$

[19] Consider extrapolative expectations as the most simple case. If $E_t I_{t+1} = E_t \pi_{t+1} = I_t$, it holds that on expectation, any investment amount today is ex ante justified by the expectation of tomorrow's profits. It is also interesting to note that indeterminacy can arise even under rational expectations, if the no-bubble condition is violated (Blanchard, 1979; McCallum, 1983). However, I believe that Minsky's ideas are more consistent with an expectation pattern showing limited rationality.

The price level of consumption goods increases (ceteris paribus) as rising labor income $W_I N_I$ in the investment sector boosts demand for consumption goods. This finally increases profits in the consumption sector as well.[20] Upward revisions of profit expectations may now trigger further increases in investment and give rise to a self-reinforcing spiral. At one point in time, profit expectations will be disappointed as they cannot be justified perpetually if fundamental drivers are lacking. This inevitable outcome will reverse the spiral towards diminishing profit expectations and decreasing investment.

The financial system fails to provide a binding budget constraint since bankers follow the same expectation schemes as firms, which yields a gradual relaxation of lending standards and an expansion of credit supply in the upswing. Put differently, banks are willing to accept that borrowing firms increase their leverage and gradually become Speculative or even Ponzi Units. The following quotation (emphasis added) illustrates that Minsky traces the emergence of booms back to endogenous expectation cycles:

> "In an economy in which the debt financing of positions in capital and financial assets is possible, there is an irreducible speculative element, for the extent of debt-financing of positions and the instruments used in such financing reflect the willingness of businessmen and bankers to speculate on future cash flows and financial market conditions. *Whenever full employment is achieved and sustained, businessmen and bankers, heartened by success, tend to accept larger doses of debt-financing*." (Minsky, 1986, pp. 198-199)

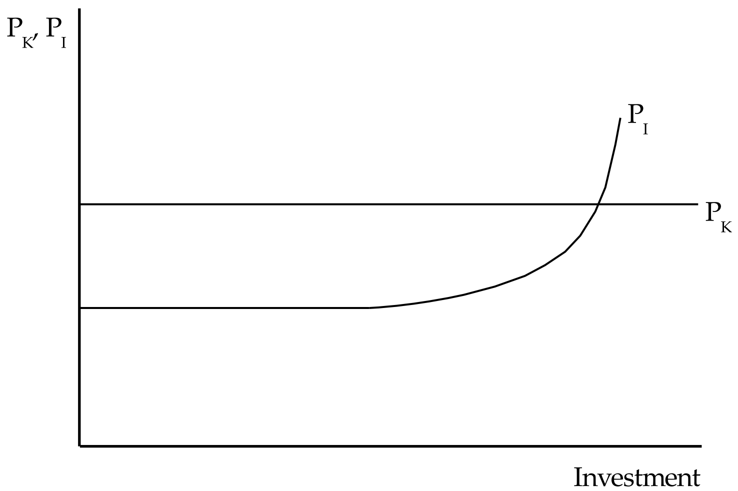
Moreover, as pointed out in Wray (2015), Minsky regarded the money supply as endogenous and money creation as a process which is primarily conducted by commercial banks. Hence, quantitative monetary constraints are absent. Procyclical risk tolerance in the banking sector thus accommodates and amplifies self-feeding investment booms.

Minsky's theory is a close cousin of behavioral-finance approaches insofar as profit expectations of both borrowers and lenders show apparent signs of limited rationality. It would be reasonable to suppose that firms and bankers form profit expectations according to some Bayesian learning rule. While Bayesian updating is procyclical per se, fluctuations may be further amplified by the previously highlighted cognitive biases such as base rate neglect. Alternatively, it is conceivable to model profit expectations in

[20] Incorporating the government sector and allowing for savings of workers and consumption of firm owners leaves the qualitative results unchanged (Minsky, 1986, pp. 165-171).

an extrapolative way, as it is popular in the agent-based literature. Hence, the financial instability hypothesis can be regarded as a predecessor of these approaches, whereas the latter seek to formalize the mechanisms which Minsky describes merely on a verbal level.

A more detailed look on a Minskyian boom is possible when examining his graphical exposition of the market for capital assets (Minsky, 1986, p. 210-218). He distinguishes between supply and demand prices of capital assets which form a "two-price system." The demand price P_K equals expected discounted profits of existing capital assets. The supply price P_I primarily reflects production costs of capital assets, i.e., their replacement costs. If P_K exceeds P_I, investment conditions are favorable since replacement costs are lower than the price of existing assets (and vice versa), which closely resembles the q-theory of Tobin (1969).



Source: Adapted from Minsky (1986, p. 210)

Figure 3.4: *Investment Determination without External Finance*

The relative price P_K/P_I is the key determinant of investment conditions and thus of business cycle dynamics. Figure 3.4 illustrates the determination of investment in a world without external finance. Demand for capital assets is infinitely elastic and constitutes a horizontal line at the level of the demand price P_K. For low and intermediate levels of investment, supply for capital assets is likewise infinitely elastic and horizontal at the supply price P_I. Since $P_K > P_I$ and hence $P_K/P_I > 1$, investment conditions are favorable. If the level of investment becomes sufficiently high, the slope of the supply curve turns positive. From there on, P_I increases in investment due to now binding capacity constraints and hence higher production costs. Aggregate investment is finally determined by the intersection of supply and demand prices, i.e., new investment takes place as long as it holds that $P_K/P_I \geq 1$.

The introduction of external finance now allows to illustrate Minsky's second theorem, the transition towards fragile financing regimes in periods of prolonged prosperity. It is depicted in Figure 3.5 and will be explained extensively in the remainder.

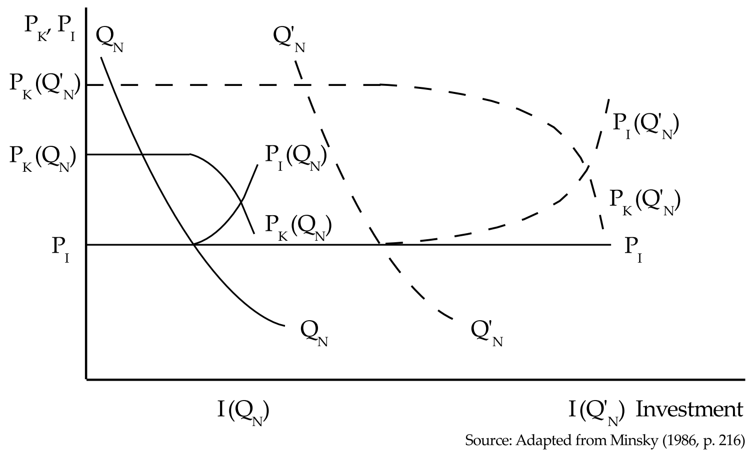


Figure 3.5: *The Transition of Financing Regimes*

The (expected) availability of internal funds is depicted by the hyperbolic curve $Q_N Q_N$. If internal funds Q_N are used for investment, it holds that $Q_N = P_I Q_I$ and a hyberbolical curve emerges, displaying feasible combinations of P_I and the amount of investment Q_I for a given amount of internal cash flows Q_N. Its intersection with the supply curve for capital assets determines the amount of investment that can be funded internally.

Additional investment can only be conducted with the help of external finance. Obtaining external finance comes along with the *borrower risk* to default, i.e., the risk of being unable to meet contractual repayments in bad states and to be forced to exit the market so that future profits are lost. Facing this risk as soon as external finance comes into play, investors are only willing to acquire capital assets at a lower demand price and the demand curve of investment $P_K(Q_N)$ hence becomes downward-sloping with a further increase in investment, since the latter comes along with an increasing reliance on external finance.

Moreover, granting external financing to investors also carries a *lender risk* of not getting repaid. Lenders seek to get compensated through interest-rate payments which increase in the share of external funding. Since increasing interest-rate payments are costs associated with the acquisition of capital assets, they can be regarded as a factor which increases their supply price. Hence, the supply curve P_I becomes positively sloped, where the positive slope now reflects both cost pressure due to capacity constraints and financing costs increasing in the amount of external funding. As in the case without financing considerations, the intersection of supply and demand determines aggregate investment $I(Q_N)$, the price for capital assets and also the share of external funding.

In the case of prolonged prosperity, (expected) cash flows will increase. This triggers an upward shift of the demand curve to $P_K(Q'_N)$, since increasing cash flows boost the profitability of capital assets and hence their demand price. Simultaneously, the curve depicting internal fund availability shifts to the right to $Q'_N Q'_N$ (see the dashed lines in Figure 3.5). In addition, the slopes of both supply and demand curve in the external finance region become *flatter*, implying that the elasticity of supply and demand prices with respect to additional exposures to lender and borrower risk declines. Both borrowers and lenders become increasingly insensitive towards the risks of external finance. Hindsight indicates that previous risk assessments have putatively been overcautious, and both lenders as well as borrowers are willing to engage in financing patterns with a lower margin of safety and higher debt-to-equity ratios.[21]

The dashed lines in Figure 3.5 now represent the new outcome. Aggregate investment has increased (to $I(Q'_N)$), and so have the total level as well as the *share* of external finance. Since investment is self-validating at least in the short-term, profits (and hence P_K), investment and the share of external finance will rise further. The financing regime will thus become increasingly fragile with a higher portion of Speculative and Ponzi finance. Banks nevertheless continue to provide financing since they are satisfied with the past performance of their debtors.

While the ultimate disappointment of profits expectations appears to be the most natural expectation for the end of the boom, Minsky rather stresses the importance of

[21] Higher expected cash flows Q, a decrease in their perceived variance σ_Q^2 and lowered margins of safety τ may each contribute to a rise in outstanding liabilities CC. This can be easily seen when going back to Equation (3.14).

the endogenous adjustment of interest rates: The investment boom almost naturally comes to a halt, as a continuously rising demand for external finance - potentially accompanied by stabilization attempts of the monetary authority - increases interest rates over the entire maturity spectrum. This development decreases P_K and increases P_I such that investment conditions and profits deteriorate. Deteriorating profits are then no longer sufficient to serve existing debts, companies eventually default on their loans and the economy gets stuck in a spiral of deleveraging, decreasing investment and decreasing profits.

It is quite obvious that Minsky's analysis cannot be reconciled with the presence of model-consistent rational expectations. After all, agents equipped with rational expectations would (on average) correctly forecast the interest rate increases that make investment unprofitable later on. Moreover, the presumed prevalence of Ponzi Finance is also at odds with rational expectations.[22] Hence, the Minskyian cycle is in fact a cycle of expectations, where exuberance in the boom is inevitably followed by sharp crises.

What has the Financial Instability Hypothesis got to offer with respect to the analysis of the sources of systemic risk? Just like virtually any other approach stressing limited rationality, it traces boom-bust cycles back to overoptimism in conjunction with excessive investment and unsustainable debt accumulation. Hence, Minsky provides an explanation of the build-up of systemic risk in the time dimension during a period of prolonged economic prosperity. Like Irving Fisher, Minsky emphasizes the critical role of debt as the all-important amplifier of the cycle.

However, to my best knowledge, Minsky never formalized his thoughts in an analytically rigorous way. His analysis, despite sporadically enriched with graphical expositions and simple analytical examples, remains qualitative. In a recent attempt explicitly recurring to Minsky, Bhattacharya et al. (2011) provide a banking model which depicts the transition of financing regimes during benign macroeconomic conditions. Agents are modeled as Bayesian learners. Recent realizations of a good state yield a more optimistic assessment of future economic conditions (and vice versa). Sequences of good states induce banks to (i) increasingly engage in risky projects and (ii) to increase borrowing and hence their leverage. If a sequence of good states is followed by

22 Indeed, rational expectation models typically rule out unsustainable debt accumulation by imposing an appropriate no-Ponzi-condition, which states that discounted revenues cannot exceed discounted expenditures. Put differently, the no-Ponzi condition ensures that budget constraints are binding for the infinite time horizon such that net worth cannot become asymptotically negative. The no-Ponzi-condition is important to guarantee a unique equilibrium (Acemoglu, 2008, ch. 8), which seems to be implicitly ruled out in a Minskyian economy.

a bad state, banks suffer from dramatic losses and default on a large part of their obligations. Importantly, the possibility of such outcomes is not reflected in banks' funding costs ex ante, since depositors have an identical expectation pattern and hence share the optimism of banks.

3.4 Shortcomings of the Limited Rationality Approach

It is very tempting to embrace the Limited Rationality Approach. Everyday life seems to be filled with examples of humans making non-rational decisions. As generally pointed out by Akerlof and Shiller (2009), limited rationality matters for economic outcomes and should therefore be incorporated into economic models. Moreover, the presented approaches are very well capable of showing how systemic risk endogenously emerges from behavior that is subject to limited rationality. Furthermore, it is obvious that rational expectations presume an unrealistic amount of information processing capabilities.

However, there are various important objections which render the Limited Rationality Approach problematic for thinking about the appropriate regulation of a crisis-prone financial system. First of all, limited rationality is not necessary to explain endogenous systemic risk properly. It is equally possible to explain the vulnerability of financial systems within a framework of optimizing, rational agents.[23] The presence of financial frictions, for example due to asymmetric information, may give rise to constellations in which individually optimal behavior leads to an excessive level of systemic risk.[24] Put differently, excessive systemic risk can be explained by the presence of externalities, or more generally, by the presence of market failures. The potential advantages of this approach are highlighted by De Nicoló et al. (2012, p. 7):

> "[R]egulation needs to be justified by market failures. This approach clarifies that macroprudential policies are justified by the need to correct

[23] Furthermore, as highlighted by Sims (2003) and Levine (2009) among others, imperfect learning or, more generally, the presence of a constraint on the information processing capability of agents, is often equally able to explain phenomena which are superficially attributed to irrational behavior.

[24] Scheinkman (2013) stresses that even the apparently irrational emergence of overoptimism can be rationalized. In the model of Hong et al. (2008) for example, investors seek assistance from advisors of unknown type who differ in their ability to understand new technologies. Advisors who are technology experts issue overoptimistic forecasts on technology assets to signal their competence, i.e., their ability to understand the potential of a new technology. If some investors do not account for the incentive of competent advisors to issue forecasts with an upward bias, an asset price bubble may emerge as a result.

> market failures, and not simply because the financial system is "fragile." It also provides a justification for specific forms of regulation, and a framework to analyze the economics behind recent policy proposals."

Moreover, as shown previously, the literature on limited rationality offers plenty of potential behavioral patterns. Observed behavior may be explained with a variety of behavioral biases, which may all generate the same facts. In that respect, Driscoll and Holden (2014) admit that behavioral economics suffers from the problem of "observational equivalence." Maybe even worse, results from behavioral economics are sometimes contradicting each other. For example, as discussed in Section 3.1, prospect theory suggests that humans overweigh small probabilities in their decisionmaking. On the other hand, availability and overconfidence biases suggest systematic underestimation of small-probability events. Under these circumstances, the strategy to explain economic phenomena with specific behavioral biases can be easily criticized for its dependence on questionable assumptions. Moreover, as mentioned in Geanakoplos et al. (2012), behavioral rules may need to be revised if circumstances are changing. The presence of a large number of different and sometimes contradictory forms of irrationality is very likely to prevent the development of a persuasive and widely accepted benchmark model of an economic agent operating under limited rationality.

In contrast, the rationality approach is timeless and unique. While there are many ways to model limited rationality, there is essentially only one way to model rational agents, namely as agents maximizing a utility function representing axiomatic preferences subject to a set of constraints. This approach is nicely summarized in the Nobel Lecture of Sargent (2012, p. 8):

> "In economic theory, an agent is a constrained optimization problem. A model consists of a collection of constrained optimization problems."

In my view, on of the key advantages of this approach is that it imposes discipline by defining a reference paradigm. The quality of a model can be (more or less) objectively judged by whether it complies with a common set of rationality assumptions and whether it is able to explain real-world phenomena. If a model is rejected by the data, its failure is attributed to omitted constraints and omitted frictions, but not to a fundamentally flawed representation of human behavior. Sims (2003, p. 666) notes that for economists, the "comparative advantage has been in using the optimization assumption to sweep aside psychological detail in modeling behavior[.]" Generally speaking, the rationality assumption acts as a convenient filter which allows to focus on the implications of economic incentives instead of struggling with the peculiarities of human behavior.

Moreover, Levine (2009) emphasizes that psychology and economics differ in their objectives, which casts doubts on the strategy of incorporating findings out of psychological studies into economic models:

> "The key difference between psychologists and economists is that psychologists are interested in individual behavior while economists are interested in explaining the results of groups of people interacting. Psychologists also are focused on human dysfunction - much of the goal of psychology [...] is to help people become more functional. In fact, most people are quite functional most of the time. Hence the focus of economists on people who are ‚rational'." (Levine, 2009, pp. 14-15)

Furthermore, the use of behavioral economics for assessing whether the financial system can and should be regulated in a potentially welfare-improving way is likely to be limited due to a very simple argument: If agents are characterized by limited rationality, so are regulators. After all, it would be highly questionable to assume that regulators have some superior cognitive abilities.[25] Yet if regulators suffer from the same limitations as market participants, it is very doubtful whether regulation is able to do any good. Put differently, it is questionable whether a social planner subject to limited rationality can act in a benevolent manner. An example is given in the model of Bhattacharya et al. (2011), which was briefly discussed in Section 3.3. If the regulator sets capital requirements according to perceived credit risk, he is prone to the same overoptimism which is prevalent on the market. Besides, it is difficult to define a welfare criterion as such.[26] If agents act according to heterogeneous and distorted beliefs it is unclear which belief should be chosen as the relevant benchmark, especially if the

[25] Notwithstanding these objections, several models employing agents with limited rationality perform welfare analysis as if the regulator knew objective probability distributions. See for instance Gennaioli et al. (2012).

[26] Several authors have proposed welfare criteria for settings with heterogeneous and distorted beliefs. See for example Brunnermeier et al. (2014) or Bernheim (2009). However, even if an adequate welfare criteria can be defined, welfare analysis will be complicated to a great extent.

correct belief is unknown. Besides this, the majority of behavioral finance approaches focuses on the explanation of stock-market anomalies which are arguably not at the core of systemic financial crises. Conversely, little attention is devoted to the mechanics of credit creation within the intermediation sector.

To sum up, limited rationality approaches in their current form are principally able to explain financial boom-bust cycles, but they nevertheless suffer from both a lack of analytical rigor and theoretical consistency. In my opinion, it is therefore difficult to deduce robust policy recommendations from these approaches. Hence, Limited Rationality Approaches should be regarded as a complement rather than as a centerpiece for the analysis of systemic risk. In what follows, I will outline the concept of systemic externalities as an alternative. It traces the emergence of excessive systemic risk back to specific market failures, which allows to make theoretically well-founded statements on precisely targeted regulatory measures and their welfare implications. Thus, I consider this concept to be superior, at least for the analysis of excessive systemic risk.

Chapter 4

Systemic Risk and Systemic Externalities

Excessive systemic risk can be explained by the presence of externalities on financial markets.[1] If market participants do not account for the systemic implications of their individual actions, the financial system may become inefficiently vulnerable as a result. In what follows, I first specify the concept of systemic externalities on a general level. Afterwards, I will elaborate on different forms of potentially relevant market failures. Laffont (2008) generally defines an externality as follows:

> "Externalities are indirect effects of consumption or production activity, that is, effects on agents other than the originator of such activity which do not work through the price system. In a private competitive economy, equilibria will not be in general Pareto optimal since they will reflect only private (direct) effects and not social (direct plus indirect) effects of economic activity."

A more formal definition of an externality is given by Brunnermeier and Oehmke (2012). An externality occurs if the action a^k of an agent k affects utility u_i of an agent i pursuing some action a^i . Hence, the marginal externality ϵ can be expressed as

$$\epsilon = \frac{\partial u_i(a^i, a^k)}{\partial a^k} \tag{4.1}$$

1 A preliminary and shortened version of the subsequent Chapter was published as a working paper (Scheffknecht, 2013).

where agent k imposes a negative (positive) externality on agent i if ϵ is negative (positive). Importantly, agent k does not internalize the consequences of his actions on the utility of agent i in his decision making process. Wagner (2010, p. 97) notes that externalities in the context of systemic risk analysis can be defined as follows:

> "An externality [...] is caused by a financial institution and either imposes costs on other financial institutions or on agents outside the financial system. A systemic externality is then an externality whose impact does not only depend on the institution which poses it, but also crucially depends on the state of the financial system at the time the externality is posed."

While these definitions serve as a useful starting point, it is necessary to highlight some peculiarities of externalities within financial systems. The latter are often pecuniary, i.e., they operate through prices. At first sight, it is not clear why a price change induced by actions of some market participant should affect welfare of others.[2] Consider the example of a distressed bank which is forced to fire-sell assets at short notice. If the bank consequently sells for a price below the market value, it realizes losses whereas potential buyers benefit from acquiring these assets with a discount. So far, this amounts to a mere redistribution of wealth, its net effect on aggregate welfare is zero. It may be even efficient that the distressed bank incurs losses, given the fact that its business model seems to be flawed.

However, the induced depression of the market price has *higher-order effects*. Specifically, it causes the positions of other banks in this asset to decline in value as well. In the worst case, they may be forced to likewise conduct disordered asset sales and lose wealth. Thus, the original seller imposes a fire-sale externality on other institutions. The strength of such amplification mechanisms is state-dependent. If banks have strong balance sheets, they can easily absorb an adverse valuation effect. However, if balance sheets are fragile, the aforementioned mechanism is likely to become very powerful. As generally emphasized by Wagner (2010), the financial system is subject to frictions which may turn a pecuniary externality into a real externality with sizable welfare effects. In the example above, one could argue that assets have to be sold to outsiders which are unable to extract their full value and rely on liquidation of the underlying investment projects instead. As a result, the aggregate surplus in the economy

[2] Indeed, pecuniary externalities were typically considered to be neutral in their implications for welfare. This understanding can be traced back to Pigou (1920). See also Holcombe and Sobel (2001) for a treatment relying on modern terminology.

declines. Alternatively, banks could be subject to collateral constraints. If asset prices decline due to the original fire sale, the collateral constraint of other banks starts to bind. They consequently have to cut back lending, and aggregate investment declines. Brunnermeier and Oehmke (2012, p. 31) assert that "pecuniary externalities have efficiency consequences and the competitive equilibrium generally does not lead to an allocation that is constrained efficient." More generally, the fundamental inefficiency theorem derived by Greenwald and Stiglitz (1986) shows that pecuniary externalites produce non-negligible welfare effects in the presence of incomplete markets and/or imperfect information. Market equilibria are constrained inefficient so there is scope for welfare-improving government interventions.[3]

Private internalization is infeasible if banks are regarded as a continuum of atomistic agents since they perceive their influence on market conditions to be negligibly small. For instance, fire-sale prices are regarded as a given, even though they are in fact a result of collective and non-coordinated actions. Another important example for failed internalization is the network structure of interbank claims. Banks account for risks from bilateral exposures, yet they fail to internalize their individual contribution to the establishment of a fragile financial network. A social planner could hence improve aggregate welfare. Put differently, financial stability is a public good whose private provision would be inefficiently low.

Traditional banking supervision measures fail to mitigate systemic externalities as these measures differ in scope: Microprudential regulation focuses on the soundness of individual institutions and on the mitigation of *intra*-bank externalities between different stakeholders. Shareholders have an incentive to take excessive risks, since the presence of limited liability allows them to boost their expected payoff at the expense of creditors (Jensen and Meckling, 1976; John et al., 1991). In order to prevent risk shifting at the expense of creditors, banks have to fulfill capital and liquidity requirements which should be generally designed such as to optimally align incentives of shareholders and creditors.

However, systemic externalities are *inter*-bank externalities or externalities imposed on agents outside the financial system. They tend to occur independently from intra-

[3] In non-technical terms, market incompleteness is understood as a situation in which agents cannot perfectly insure against every conceivable risk. Complete risk sharing is hence impossible. Constrained efficiency means that the market equilibrium is efficient, yet it is a second-best solution, for instance due to the presence of a collateral constraint emerging from limited information. Constrained inefficiency implies that market equilibria under constraints are inefficient in the sense that a social planner could improve on private outcomes.

bank mechanisms. Thus, adequate microprudential regulation may be a necessary but not a sufficient condition for financial stability. Some inter-bank externalities remain unaddressed. As I will argue later in Chapter 5, the mitigation of *inter*-bank externalites should be regarded as the key objective of *macro*prudential regulation. Unfortunately, confusion may arise from the fact that the regulation of both intra- and inter-bank externalities typically relies on the very same instruments, i.e., capital and liquidity requirements. In some cases, it is therefore difficult to attribute a specific requirement to the mitigation of a certain externality. In practice, it is even conceivable that strict microprudential regulation "accidentally" mitigates inter-bank externalities (and vice versa).

In what follows, I discuss different forms of systemic externalities. There are various insightful surveys on macroprudential regulation such as Hanson et al. (2011) or Galati and Moessner (2013). While these elaborate on the general concept of macroprudential regulation and its practical application, I will rather focus on the concept of systemic externalities as a theoretical justification. Its importance for explaining systemic risk has become widely acknowledged in recent years.[4]

4.1 Interconnectedness

A highly connected financial system has ambiguous welfare implications. On the one hand, interconnections between financial institutions may enhance the efficiency of the financial system as they foster the efficient distribution of liquidity within the system and act as a device for sharing idiosyncratic risks. On the other hand, however, interconnections are an important source of systemic externalities. For instance, Stiglitz (2010a, p. 388) notes:

> "[D]iversification and contagion are different sides of the same coin: greater financial integration (especially if not done carefully) increases the risk of adverse contagion in the event of a large negative shock. An analysis of financial integration should weigh the costs with the benefits and begin by asking if there are ways of designing the financial architecture that minimize the downside risk while preserving as much of the upside potential as possible."

[4] See for instance Brunnermeier and Oehmke (2012), De Nicoló et al. (2012) and Wagner (2010) for earlier attempts to survey the literature.

Interconnections may produce *spillovers* of financial distress. An example for direct spillovers is the immediate propagation of losses from one institution to another via the link of direct interbank claims. Note that direct spillovers do not constitute an externality as such. However, direct spillovers trigger higher-order effects which may impose externalities on institutions which are not directly engaged in interbank lending to a distressed institution. Gallegati et al. (2008) refer to direct spillovers as the outcome of *risk sharing*, while indirect spillovers are defined as *contagion*. In line with Hellwig (2014), I distinguish between three potential channels for contagion:

(1) *Higher-Order Propagation Effects*: If creditors of a defaulting institution are forced to default themselves, their borrowers have to bear losses even though they are not directly exposed to the original source of distress.

(2) *Informational Externalities*: If incompletely informed investors infer from the default of an individual bank that other banks are likewise prone to failure, they will withdraw their funds. Financial distress may emerge as a self-fulfilling prophecy, even if banks are fundamentally solvent.

(3) *Fire Sales*: If borrowers of a distressed institution are forced to fire-sell assets, the associated decline in asset prices adversely affects other institutions holding similar positions. Hence, contagion may also operate via prices.

Under risk sharing in a financial network, a shock hitting the network is distributed among its members while the shock's original quantity remains constant. By contrast, contagion multiplies the original quantity of the shock.[5] The question of whether risk sharing yields contagion is a matter of both the size of the shock and of the network structure of interbank claims. Generally, interbank exposures between two institutions can impose adverse effects on other agents, which constitutes a systemic inter-bank externality and may lead to socially inefficient vulnerability to contagious spillovers. Banks do not internalize the individual contribution of their interconnections to the fragility of the system. As a result, socially inefficient networks of interbank claims may emerge. In what follows, I will focus on higher-order propagation effects and informational externalities. Fire sales will be covered in a separate Section, as contagion operating via prices is a phenomenon which tends to operate independently from the actual structure of the financial network.

[5] The distinction between risk sharing and contagion has already been depicted in Figure 2.1 in Section 2.3.

4.1.1 Higher-Order Propagation Effects

Interbank lending acts as a market-immanent insurance device yet the emerging exposures can increase systemic risk. The trade-off between generally beneficial risk sharing and the risk of contagion is illustrated by Allen and Gale (2000).[6] Their model relies on the classical setup of Diamond and Dybvig (1983). In the Diamond-Dybvig model, depositors face uncertain liquidity needs as they do not know ex ante in which period they wish to consume. By pooling deposits and thereby achieving diversification, banks are capable to provide socially valuable liquidity insurance to depositors.

Allen and Gale (2000) extend this setup by splitting the economy into four different but same-sized regions. The model considers three periods $t = 0, 1, 2$. The aggregate shares of late consumers and early consumers are known in the initial period *t=0*.[7] However, these shares differ between regions and their regional distribution is not known ex ante. Banks in regions with many early consumers face large deposit withdrawals in *t=1*, whereas banks in regions with many late consumers need to cover large outflows in *t=2*. Hence, in contrast to the Diamond-Dybvig model, banks are unable to fully resolve uncertainty with respect to the liquidity shock. They have to accumulate precautionary liquidity balances and aggregate investment in profitable yet illiquid long-term projects declines.

Under such circumstances, interbank lending promises efficiency gains as banks obtain reciprocal insurance against region-specific liquidity shocks. In *t=1*, banks facing early withdrawals liquidate their deposits at banks whose depositors turned out to be primarily late consumers, implying that the latter hold excess liquidity balances in *t=1*. Conversely, in *t=2*, these banks liquidate their deposits at banks whose depositors turned out to be primarily early consumers, since these banks hold excess liquidity in *t=2*. Hence, the decentralized market equilibrium is characterized by efficient risk sharing. Every bank is able to pay off its depositors in any state, and the need to hold precautionary liquidity balances is reduced to a great extent.

However, risk sharing may turn out to be detrimental if the system is hit by an unexpectedly large liquidity shock in *t=1*. Specifically, it is assumed that one bank faces unexpected extra withdrawals in *t=1*. If the liquidity shortage is pronounced,

6 Other models analyzing the role of interbank markets are for instance Rochet and Tirole (1996), Freixas et al. (2000) and Brusco and Castiglionesi (2007). They similarly acknowledge a trade-off between ex-ante efficiency gains and an increasing ex-post likelihood of contagious bank failures.

7 Early consumers wish to consume in *t=1*, whereas late consumers wish to consume in *t=2*.

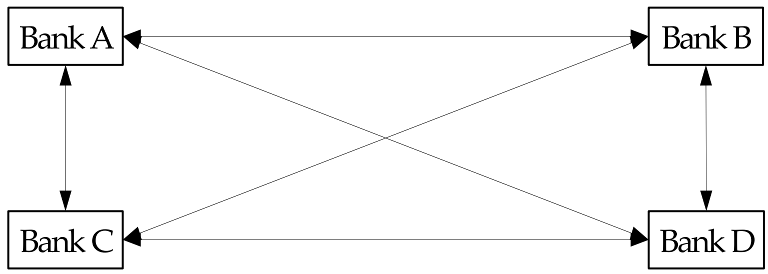


Figure 4.1: *Completely Connected Interbank Network*

the bank cannot meet withdrawals in *t=1* since liquidating the long-term asset entails considerable costs and the bank is forced into bankruptcy. Hence, depositors (and thus also other banks) will run. Given liquidation costs, they will realize losses. In that way, losses spill over to other banks. They may consequently go bankrupt as well which gives rise to further spillovers. In the end, the initial liquidity shock may trigger a systemic meltdown.

The systemic implications of liquidity shocks depend on their size and especially on the interbank market structure. A completely interconnected interbank market (depicted in Figure 4.1) is resilient against moderate shocks since liquidation costs are distributed among several institutions, such that each institution remains solvent. On the other hand, a pronounced liquidity shock triggers a systemic meltdown as each institution is exposed to the initial shock. Conversely, a sparsely connected interbank network (see Figure 4.2) is less resilient towards small shocks, as liquidation costs cannot be properly distributed.[8] However, if a large shock occurs, incomplete interlinkages prevent systemic contagion. As a result, it is difficult to develop an absolute ranking of network alternatives, since their relative performance is dependent on the nature of the shock.

Acemoglu et al. (2013) provide a model of interbank markets in which the formation of the network is endogenized. They show that agents coordinate on socially inefficient

[8] Network figures are adapted from Allen and Gale (2000), Allen et al. (2012) and Acemoglu et al. (2013), respectively. Bi-directional arrows denote reciprocal interbank claims. A uni-directional arrow from Bank *A* to Bank *B* denotes a unilateral claim from Bank *A* against Bank *B*.

Figure 4.2: *Disconnected Interbank Network*

network structures. Their conclusions concerning the properties of different networks mostly resemble the findings of Allen and Gale (2000). For small shocks, sparsely connected networks are found to be more fragile than densely connected networks (and vice versa). The risk of direct spillovers is internalized, as interbank interest rates are set conditional on the counterparty risk exposure of the borrower out of his own interbank lending activities. However, the risk of indirect higher-order spillovers is not reflected in the interest rate.[9] This constitutes a *financial network externality* which leads to the emergence of socially inefficient network structures. Banks do not internalize the costs of network fragility in the formation of bilateral connections, thereby neglecting the individual contribution of their interbank lending and borrowing to systemic fragility.

It is further shown that inefficiencies may arise under different setups. In a constellation with fragmented interbank markets and limited lending opportunities for each bank, interbank lending occurs even though hoarding cash would have been socially preferable and an inefficiently fragile ring network emerges (Figure 4.3). In a ring network, a shock hitting one institution is gradually transmitted to any other institution, akin to a domino effect. Hence, the ring network is extremely vulnerable even in the wake of small shocks. For an integrated interbank market with full lending opportunities and a low probability of a large shock, the completely connected financial network emerges despite being socially inefficient. Social inefficiency arises because

[9] For example, if A lends to B, the interest rate will reflect the counterparty risk of B towards his borrower C. Yet it will not reflect counterparty risk exposure of C against D and its potential feedback to B.

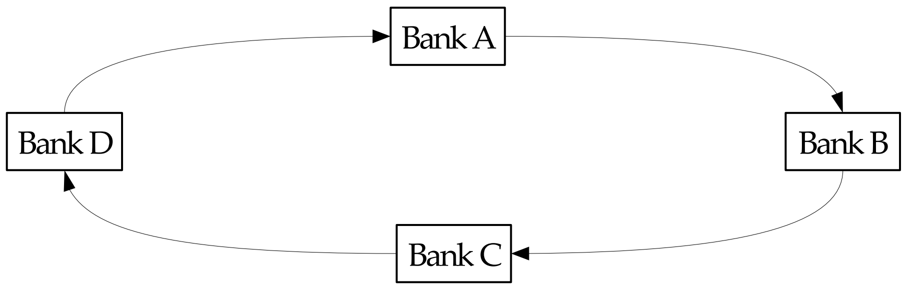


Figure 4.3: *Ring Network*

the expected costs of contagious defaults, which are seldom but especially detrimental in a complete network, exceed the gains from perfectly diversified interbank lending. However, agents do not completely account for the former. Hence, the system is characterized by robustness against small and frequent shocks but also by an inefficient degree of vulnerability against rare and detrimental shocks. It is thus excessively interconnected.

Other authors similarly reach the conclusion that the degree of diversification in the financial system may become inefficiently high, albeit they usually do not model the emerging network structure as an endogenous outcome. Stiglitz (2010b) provides a highly stylized example of undesirable diversification. Suppose that in autarky, i.e., in the absence of interbank linkages, bank profits Π^A are distributed as follows:

$$\Pi^A = \begin{cases} \alpha_2 & \text{with probability} \quad 1-p \\ -\alpha_1 & \text{with probability} \quad p \end{cases} \tag{4.2}$$

It further holds that

$$(1-p)\alpha_2 = p\alpha_1 \tag{4.3}$$

such that expected profits are normalized to zero. Moreover, it holds that $\alpha_1 > \alpha_2$ and hence $p < 0.5$, which implies that the bad state $-\alpha_1$ happens with a relatively low probability but is particularly detrimental. It could be thought of as a rare disaster.

Additionally, the model features bankruptcy. If $\Pi < 0$, losses are contained to $C < \alpha_1$ which captures limited liability. Hence, expected profits of the bank are given by

$$\begin{aligned} \Pi^A &= (1-p)\alpha_2 - pC \\ &= p\alpha_1 - pC = p(\alpha_1 - C) \end{aligned} \tag{4.4}$$

Now suppose that two identical banks of this type engage in diversification. It is assumed that both banks fail if at least one bank realizes the bad state $-\alpha_1$. The probability that both banks jointly realize the good state α_2 is given by $(1-p)^2$. In any other case, at least one bank fails. Hence, the probability of joint failure is $1-(1-p)^2$. Expected bank profits under diversification Π^D are given by

$$\Pi^D = (1-p)^2\alpha_2 - C(1-(1-p)^2) \tag{4.5}$$

which verifies that $\Pi^A > \Pi^D$. Expected profits decrease compared to autarky since the probability of joint success is smaller. Moreover, diversification increases the probability of failure due to the spillover effect.[10] Clearly, this example rests on restrictive assumptions. For instance, there are no gains from risk sharing and the possibility of imperfect diversification (and thus imperfectly correlated failures) is excluded. Stiglitz (2010a) relaxes these assumptions and allows for gains from diversification and networks with more that two agents. Nevertheless, the underlying argument still holds. Perfect diversification is socially undesirable as long as there is the possibility of seldom but large adverse shocks which trigger systemic failure.[11]

Gai et al. (2011) simulate the propagation of liquidity shocks under various network configurations. If some bank within the network is subject to a liquidity shock, it tries to obtain liquidity by unwinding its interbank claims. Hence, direct counterparties may likewise experience liquidity shortages and react by liquidating interbank claims themselves. This higher-order effect is referred to as *funding contagion*. In the worst case, it can lead to a system-wide liquidation of interbank claims with banks not internalizing the systemic implications of their individual behavior. The network of liquidity claims can exhibit two configurations. In a Poisson Network, each bank shows a similar degree of interconnectivity. In a Geometric Network, some banks are more interconnected

[10] Formally, it has to hold that $p < (1-(1-p)^2)$ which is the case for $p < 1$.

[11] Battiston et al. (2012) deliver a network simulation which equally shows that full diversification is undesirable as contagion-related losses exceed gains from risk sharing.

than others. Particularly connected banks are systemically relevant and play a key role in system-wide liquidity distribution. In the Poisson Network, forming interconnections is generally beneficial since it helps to absorb liquidity shocks mutually. In principle, the same holds for the Geometric Network, yet it is slightly more vulnerable to funding contagion. Moreover, the Geometric Network is extremely fragile if liquidity shocks hit systemically relevant banks. Funding contagion becomes almost inevitable in this case. Restrictive liquidity requirements, especially for systemically relevant institutions, considerably reduce the probability of funding contagion.

Caballero and Simsek (2013) emphasize that the individually rational behavior of interconnected financial market participants may increase complexity of the market environment, giving rise to a so-called *complexity externality*. Complexity means that banks cannot monitor all conceivable higher-order propagation channels of financial distress. During normal times, banks only care about the financial health of their direct counterparties in the financial network. Their financial state can be monitored relatively easy. However, the financial system can be subject to an unexpectedly large liquidity shock, where some banks are forced into fire-selling their assets. Nevertheless, they may go bankrupt which spreads distress to their interbank counterparties. In a large-shock-regime, a bank cannot rule out to take an indirect hit due to higher-order propagation effects anymore (as in Acemoglu et al. (2013)). Since it is impossible to monitor all higher-order interconnections, banks face fundamental uncertainty whether the shock will eventually affect themselves or their direct counterparties. It is rational for banks to switch into a so-called liquidity conservation mode in the wake of heightened complexity. That is, banks try to sell assets to hoard liquidity balances as a precautionary measure. However, this very behavior exacerbates complexity. Since additional asset sales put further downward pressure on their prices, fire-sale discounts increase. The increase in fire-sale discounts drives more banks into bankruptcy and increases the risk of higher-order spillovers and thus complexity. Given the further increase in complexity, hoarding is intensified and an inefficient equilibrium with a large number of costly bankruptcies is established.

As a common feature, the presented models highlight that higher-order propagation is an important source of systemic risk. Banks tend to not internalize implications of their behavior for network fragility, and networks may consequently become inefficiently prone to contagion. The empirical assessment of higher-order propagation is very difficult as bank failures are extremely rare events and comprehensive data on interbank exposures is often unavailable. Hence, contagion risks are usually assessed with the help of counterfactual simulations in which initial network structures are calibrated on the basis of available data. Furfine (2003) follows this approach for the US interbank market and finds negligible contagion risks. Upper and Worms (2004) obtain similar findings for the German interbank market. On the other hand, Iyer and Peydro (2011) find substantial higher-order propagation when inspecting the actual failure of an Indian bank along with detailed data on its interbank linkages.

The somewhat inconclusive evidence notwithstanding, it is a robust stylized fact that interbank lending has gained in importance during recent decades and is typically characterized by a Geometric Network (Gai et al., 2011). Even if contagious chains of failure are seemingly rare in the real world, financial networks are nevertheless fragile. Most reciprocal claims are on a short-term basis, implying that liquidity provision can dry up very quickly in the wake of counterparty risk concerns. Indeed, interbank markets collapsed several times during the recent crisis and left banks with massive funding shortages which finally forced central banks to act as lenders of last resort.

4.1.2 Informational Externalities

Allen et al. (2012) stress the importance of informational contagion, which generally occurs if imperfectly informed creditors infer from the default of one bank that other banks may likewise be prone to failure.[12] The subsequent withdrawal of funding may trigger a systemic bank run and hence a crisis emerges as a self-fulfilling prophecy. The model shows that financial networks differ with respect to their vulnerability against informational contagion. Yet the ex ante network formation is subject to multiple equilibria, and banks may coordinate on forming a fragile network.

As in any other model, banks acquire reciprocal claims to achieve diversification. However, diversification exhibits so-called due-diligence costs which arise because banks have to acquire costly information about their counterparties. The presence of due-diligence costs implies that full diversification is undesirable. In a setup with six banks, it is shown that the optimal trade-off between diversification gains and due-diligence costs implies that each bank should form two connections.[13] This gives rise to two

12 See also Chen (1999) for a model in which informational contagion arises because some depositors cannot observe the true performance of bank assets.

13 Importantly, claims do not represent debt contracts in this setting. Instead, banks hold *direct* state-contingent claims on their respective project payoffs.

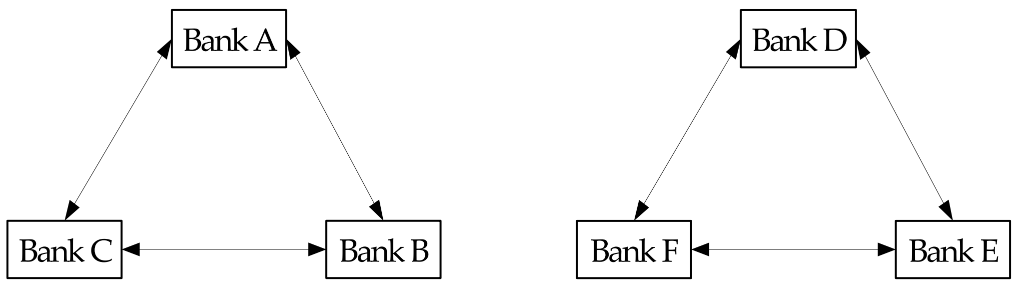


Figure 4.4: *Disconnected Sub-Networks*

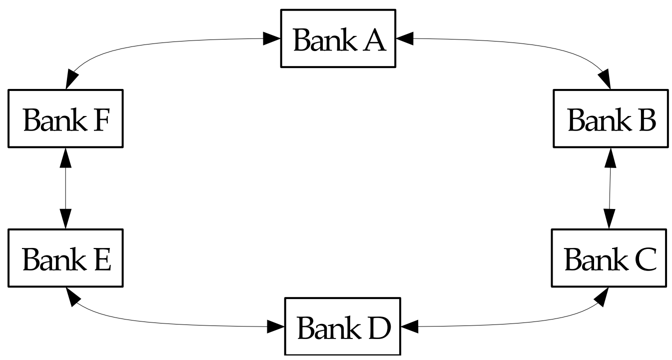


Figure 4.5: *Full-Connection Network*

possible constellations. First, banks can coordinate on two disconnected sub-networks (Figure 4.4). Alternatively, banks can form a full-connection network as depicted in Figure 4.5.

There is no a priori difference between both structures in terms of expected returns, but they have different informational properties in the crisis case. Banks partly rely on revolving short-term funding from outside investors. Short-term investors receive either a good or a bad signal with respect to the solvency of the banking sector. The bad signal is noisy in the sense that it indicates the insolvency of some bank, yet outside investors do not now which bank exactly. They only know whether banks have coordinated in disconnected sub-networks or in a full-connection network. In the former case, banks in each sub-network hold perfectly identical portfolios and hence risk becomes highly concentrated. Bank portfolios are characterized by a higher degree of *asset commonality* and defaults become more correlated. Thus, a default of one bank is likely to lead to the collapse of its entire associated sub-network. Conversely, risk is more dispersed in the full-connection network, where, for example, Bank A is not exposed to Bank D. If Bank D defaults due to a failure of its project, losses are absorbed by Banks C and E, while Bank A stays unaffected.[14]

This difference crucially matters for the decision of outside investors whether to roll over short-term debt of the banking sector. The repayment probability of short-term debt conditional on the bad signal is higher for the full-connection network. It may hold that short-term funding is rolled over for the full-connection network, whereas investors refuse to finance banks operating within disconnected networks. In the latter case, banks are forced into premature and costly project liquidation. The default of a single bank consequently imposes an informational externality on other banks, meaning they do not receive short-term funding any more despite being principally solvent. The key inefficiency arises in the ex-ante formation of the network. The full-connection network is clearly preferable, but banks cannot coordinate on its formation. Building sub-networks is equally consistent with the optimal number of interlinkages arising from private optimization.

4.2 Strategic Complementarities

Strategic complementarity arises when an agent's return for pursuing a certain strategy increases in the number of agents following this strategy (De Nicoló et al., 2012). Brunnermeier and Oehmke (2012, p. 31) offer the following formal definition: An action a^i of an agent i is a strategic complement to the action a^k of an agent k if utility u_i of agent i satisfies

$$\frac{\partial^2 u_i(a^i, a^k)}{\partial a^i \partial a^k} > 0 \tag{4.6}$$

implying that pursuing a^i conditional on agent k choosing a^k raises individual utility. The presence of strategic complementarities constitutes an incentive for coordinated

[14] Note that things would turn out differently if interlinkages were formed using debt contracts. In that case, losses at Bank C would trigger default on its liability to B, such that distress is finally propagated to A. However, B has a *direct* claim on the project of C, whose performance is unaffected by the default of D.

behavior. In the analysis of systemic risk, strategic complementarities are relevant for the analysis of collective moral hazard, the impact of bank competition on systemic risk and the incentives which are implied by reputational concerns. Under some circumstances, banks may find it optimal to jointly embark on strategies even though they are socially undesirable because they lead to the build-up of excessive systemic risk. In that sense, strategic complementarities are important sources for systemic externalities, which are typically imposed on agents outside the financial system.

4.2.1 Collective Moral Hazard

Situations of collective moral hazard arise if banks have the opportunity to coordinate on strategies which maximize their individual profits at the expense of systemic stability. The costs of financial fragility are ultimately borne by taxpayers. Acharya and Yorulmazer (2007) show that banks have the incentive to pursue identical investment strategies. In their model, banks can perfectly correlate their investments such that they either succeed or fail jointly. Joint failures force the regulator to bail out banks, since liquidating the entire banking sector causes prohibitive costs. If regulators cannot correct correlation structures in advance, ex-ante commitments towards a non-bailout strategy suffer from the problem of time inconsistency. Herding is therefore individually optimal for every bank, since bailouts occur with certainty in the joint-failure state which drastically contains downside risk for banks. Put differently, banks ensure that they are *too-correlated-to-fail*. However, this strategy is socially inefficient as it raises the probability of systemic crises.

Within a slightly modified setup, Acharya et al. (2010b) show how regulators can internalize the problem of excessive correlation. The model has three dates $t = 0, 1, 2$ and is populated by two banks, an outside investor, a continuum of depositors and a regulator. The regulator insures bank deposits and charges an insurance premium which is assumed to be paid for by banks out of (past) retained earnings. Banks need to raise one unit of deposits in each period to be able to invest in a risky project. The portfolio payoff $\widetilde{R}$ is distributed as follows:

$$\widetilde{R} = \begin{cases} R & \text{w.p.} \quad \alpha \\ 0 & \text{w.p.} \quad 1-\alpha \end{cases} \tag{4.7}$$

	Identical Project		Different Project	
	Bank B succeeds	Bank B fails	Bank B succeeds	Bank B fails
Bank A succeeds	α	0	α^2	$\alpha(1-\alpha)$
Bank A fails	0	$1-\alpha$	$\alpha(1-\alpha)$	$(1-\alpha)^2$

Table 4.1: *Joint Distribution of Payoff Probabilities*

It holds that $\alpha R > 1$ such that the project earns a positive expected return. If banks decide to invest into identical projects, their returns become perfectly correlated. If banks choose different projects, their returns are independent. If the project pays off R in $t = 1$, the bank continues to operate, again raises deposits in $t = 1$ and invests into the risky project once more. If the crisis state occurs, the bank cannot repay the deposits raised in $t = 0$ and has to be liquidated. Its liquidation value crucially depends on the state of the other bank. If the other bank has invested in an identical project, it realizes zero payoffs as well. In that case, both banks have to be sold to outside investors. If the project of the other bank succeeds, the latter is able to acquire the failed bank. This is only possible if banks have invested in different projects.

Table 4.1 depicts the joint distribution of payoff probabilities for two banks A and B. If banks invest in identical projects, they either succeed or fail jointly with probability α and $1 - \alpha$, respectively. If they invest in different projects with independent returns, it may happen that one banks succeeds and one bank fails with probability $\alpha(1 - \alpha)$. The joint-success probability is α^2, and the probability of joint default $(1 - \alpha)^2$.

If both banks fail jointly (state FF), they are seized by the regulator who tries to sell them to outside investors. The outside investor is willing to acquire banks to gain access to their opportunity to engage in risky projects. However, it is assumed that the outside investor can only extract a payoff $R - \Delta$ from the project in the good state.[15] The outside investor likewise has to attract a unit amount of deposits which are due in $t = 2$. Depositors require a zero return because they are fully insured. Hence, outside investors earn $R - \Delta - 1$ in the good state and zero otherwise. The price p_{FF} an outside investor is willing to pay for a distressed bank is then given by

$$p_{FF} = \alpha(R - \Delta - 1). \tag{4.8}$$

15 The underlying assumption is that the investment project is special, i.e., extracting full payoffs requires specific skills regarding valuation, bargaining and monitoring which are primarily found at banks.

If banks invest in different industries, there are constellations in which one bank fails and the other one is successful (states SF or FS). In that case, the surviving bank acquires the failed bank. The surviving bank is able to extract the full value of the assets which yields an expected net income and hence a maximum price of

$$p_{SF}^{max} = \alpha(R-1), \tag{4.9}$$

which implies that $p_{SF}^{max} > p_{FF}$. This gives rise to a bargaining problem between the surviving bank and the regulator, as the latter can alternatively sell the bank to the outside investor. It is assumed that bargaining power is split such that the price actually paid by the surviving bank (p_{SF}) lies between p_{SF}^{max} and p_{FF}, i.e., it holds that $p_{SF}^{max} > p_{SF} > p_{FF}$. The regulator charges insurance premia from banks to cover expected compensation payments to depositors ex ante. If banks invest in identical projects, the actuarially fair insurance premium q_s charged from each bank is given by

$$q_s = (1-\alpha)(1-p_{FF}), \tag{4.10}$$

since the regulator has to pay the difference between the liquidation value of the bank and the total amount of deposits (which equals unity for each bank) with a probability of $1-\alpha$. If banks invest in different projects, the fair premium q_d is given by

$$q_d = \alpha(1-\alpha)(1-p_{SF}) + (1-\alpha)^2(1-p_{FF}). \tag{4.11}$$

As shown in Appendix A.1, Equation (4.11) can be rearranged to obtain

$$q_d = q_s - \alpha(1-\alpha)(p_{SF} - p_{FF}) \tag{4.12}$$

and since $p_{SF} > p_{FF}$, it holds that $q_s > q_d$. If banks invest in identical projects, joint failures become more likely. Hence, the regulator charges a higher deposit insurance premium ex ante.[16]

As long as no or only one bank fails, there is no need for the regulator to intervene. If both banks fail, however, the regulator faces a trade-off. He can either sell both banks

[16] An additional variant is to assume that one bank is particularly large, such that the smaller bank finds itself unable to acquire the bank in the default case. The large bank should then be charged with q_s in any case, since a sale to outside investors in the failure case is inevitable.

to outside investors at their liquidation value or he can bail out banks by injecting additional funds. It is assumed that bailouts impose a cost of c per injected unit of funds, which implies that bailing out both banks produces costs of $2c$. If both banks fail, the regulator tries to maximize total expected output of the banking sector for $t = 2$ less any bailout or liquidation costs. Expected output Π_l in the liquidation case is given by

$$\Pi_l = 2[\alpha(R - \Delta) - 1]. \tag{4.13}$$

Expected output Π_b in the bailout case is

$$\Pi_b = 2[\alpha R - 1] - 2c. \tag{4.14}$$

The sell-off to outside investors is avoided at the expense of the bailout costs $2c$. The regulator has to weigh bailout costs against the lower project payoffs implied by selling to outside investors. Merging Equations (4.13) and (4.14) yields the no-bailout condition:

$$\begin{aligned} \Pi_l &\geq \Pi_b \\ 2[\alpha(R - \Delta) - 1] &\geq 2[\alpha R - 1] - 2c \\ -2\alpha\Delta &\geq -2c \\ \alpha\Delta &\leq c. \end{aligned} \tag{4.15}$$

Hence, if bailout costs c exceed $\alpha\Delta$, which is the expected reduction in project payoffs if operated by outside investors, no bailout will take place. Conversely, if $\alpha\Delta > c$, the regulator will choose the bailout. In that case, an ex-ante commitment towards a no-bailout strategy is not time consistent.

The derived insurance premia q_s and q_d serve as an example for microprudential regulation. Charging banks with q_s or q_d is sufficient to protect depositors. However, the costs of a systemic crisis, given either by liquidation or bailout costs, are not covered. Put differently, these premia do not account for the individual contribution of each bank to systemic risk, which was defined as the expected cost of a crisis in Section 2.1. In order to incorporate crisis costs, insurance premia would have to be set as follows:

$$q_s^* = (1-\alpha)\Big[(1-p_{FF}) + \min\{\alpha\Delta, c\}\Big] \tag{4.16}$$

$$q_d^* = \alpha(1-\alpha)(1-p_{SF}) + (1-\alpha)^2\Big[(1-p_{FF}) + \min\{\alpha\Delta, c\}\Big]. \tag{4.17}$$

In the joint-failure case, the regulator chooses the cost-minimizing resolution procedure which is captured by $\min\{\alpha\Delta, c\}$. It continues to hold that $q_s^* > q_d^*$. However, it is still not clear how to prevent banks from choosing correlated investment projects, which is the fundamental inefficiency in the model. Expected aggregate project payoffs net of crisis costs with identical projects are given by

$$\Pi_s = 2(\alpha R - (1-\alpha)\min\{\alpha\Delta, c\}). \tag{4.18}$$

With diverse projects, it holds that

$$\Pi_d = 2(\alpha R - (1-\alpha)^2\min\{\alpha\Delta, c\}), \tag{4.19}$$

implying that $\Pi_s < \Pi_d$. Hence, it is indeed desirable to implement an incentive scheme which guarantees that banks invest in diverse projects. In $t = 0$, Banks choose the profit-maximizing correlation $\rho \in \{0, 1\}$. While bank profits in $t = 1$ simply depend on the performance of bank assets, expected second-period profits crucially depend on the regulator's decision. In the case of liquidation, bank profits collapse to zero. If banks are bailed out, they make an expected profit of $p_{SF}^{max} = \alpha(R-1)$. Hence, banks seek to maximize

$$E(\pi_1(\rho)) + E(\pi_2(\rho)), \tag{4.20}$$

where π_1 denotes expected profits in $t = 1$ and π_2 expected profits in $t = 2$, respectively. Since π_1 does not directly depend on the correlation structure, only the behavior of $\pi_2(\rho)$ needs to be examined in detail. Investing in the same industry implies perfect correlation ($\rho = 1$), and expected second-period profits are thus given by

$$E(\pi_2(1)) = \alpha\pi_2^{SS} + (1-\alpha)\pi_2^{FF} - \hat{q}_s, \tag{4.21}$$

where $\pi_2^{SS} = \alpha R - 1$ denotes second-period profits in the joint-success case, π_2^{FF} denotes second-period profits in the joint-failure case and $\hat{q}_s$ is the incentive-efficient deposit insurance premium (to be derived yet) ensuring that banks choose $\rho = 0$. In the case of different industries, expected second-period returns are

$$E(\pi_2(0)) = \alpha^2 \pi_2^{SS} + \alpha(1-\alpha)\pi_2^{SF} + (1-\alpha)^2 \pi_2^{FF} - \hat{q}_d, \tag{4.22}$$

where it holds that $\pi_2^{SF} = \pi_2^{SS} + (p_{SF}^{max} - p_{SF})$, since the acquisition of the assets of the failed bank happens at a discount $p_{SF}^{max} - p_{SF}$, implying that assets can be purchased for a price below their expected profit $\pi_2^{SS} = p_{SF}^{max} = \alpha R - 1$ which gives rise to excess returns. Hence, $E(\pi_2(0))$ can be rearranged to read

$$E(\pi_2(0)) = \alpha \pi_2^{SS} + \alpha(1-\alpha)(p_{SF}^{max} - p_{SF}) + (1-\alpha)^2 \pi_2^{FF} - \hat{q}_d \tag{4.23}$$

Subtracting (4.23) from (4.21) yields

$$E(\pi_2(1)) - E(\pi_2(0)) = \alpha(1-\alpha)[\pi_2^{FF} - (p_{SF}^{max} - p_{SF})] + \hat{q}_d - \hat{q}_s. \tag{4.24}$$

In order to implement the low-correlation regime, it needs to hold that $E(\pi_2(1)) \leq E(\pi_2(0))$, implying that the right-hand side of (4.24) must not exceed zero. Setting $E(\pi_2(1)) = E(\pi_2(0))$ and solving for $\hat{q}_s$ yields the critical value for the incentive-efficient insurance premium:

$$\hat{q}_s = \alpha(1-\alpha)[\pi_2^{FF} - (p_{SF}^{max} - p_{SF})] + \hat{q}_d. \tag{4.25}$$

The incentive-efficient insurance premium crucially depends on whether the no-bailout-condition (4.15) is fulfilled. If the ex-ante announcement of a no-bailout policy is time consistent, charging banks with q_s^* and q_d^* implements the low-correlation regime.[17] If no bailout takes place, it holds that $\pi_2^{FF} = 0$, which eliminates the incentive to invest in identical projects given $q_s^* > q_d^*$. At the same time, q_s^* and q_d^* account for liquidation costs emerging from selling banks to outsider investors. The social costs of bank failures are fully internalized.

[17] This can be verified by setting $\hat{q}_d = q_d^*$ in (4.25) to solve for $\hat{q}_s$. It turns out that $\hat{q}_s = q_s^*$.

However, if the no-bailout condition is violated, banks expect to avoid liquidation in the joint-failure state in $t = 1$, which implies that $\pi_2^{FF} = \alpha R - 1 > 0$. Charging q_s^* would be insufficient to dis-incentivize banks from correlating their projects. Equation (4.25) shows that if $\pi_2^{FF} > 0$, the incentive-efficient insurance premium has to increase above q_s^*. Specifically, it holds that

$$\begin{aligned} \hat{q}_s &= q_s^* + \alpha(1-\alpha)\pi_2^{FF} \\ &= q_s^* + \alpha(1-\alpha)(\alpha R - 1) \end{aligned} \tag{4.26}$$

Optimal regulation is summarized in Table 4.2. In the case of a strict and credible no-bailout policy, charging q_s^* and q_d^* is sufficient to implement the low-correlation regime. If bailouts take place, charging $\hat{q}_s > q_s^*$ and q_d^* similarly prevents that banks correlate their investments.

	Identical Projects	Diverse Projects
No-Bailout Policy (if $\alpha\Delta \leq c$)	q_s^*	q_d^*
Bailout Policy (if $\alpha\Delta > c$)	$\hat{q}_s > q_s^*$	q_d^*

Table 4.2: *Incentive-Efficient Insurance Premia*

To sum up, the model illustrates several important points. First, strategic complementarity leads banks to correlate investments, which ultimately gives rise to excessive systemic risk. Excessive systemic risk imposes an externality on society since aggregate project payoffs become diminished or taxpayers have to carry bailout costs, respectively. Second, traditional banking regulation is ill-suited to tackle this problem, as depositor protection does not imply that systemic risk is efficiently contained. Third, the instrument of deposit insurance premia now entails both micro- and macroprudential components, which highlights that bank supervisors can achieve different regulatory objectives at once with the appropriate calibration of a single instrument.[18]

Banks deliberately becoming too-correlated-too-fail are also present in other models. In Farhi and Tirole (2012), banks likewise coordinate on operating with excessive

[18] However, this result cannot be generalized. In fact, there may be situations in which micro- and macroprudential objectives conflict. For example, during a recession, microprudential regulators seek to increase capital requirements to account for the increasing risk of bank assets whereas macroprudential supervisors prefer a relaxation of capital requirements to avoid a further decline in lending capacity.

liquidity mismatches and correlated default risks. As in Acharya et al. (2010b), no-bailout policy may be time-inconsistent and as a result, systemic risk is excessive. In Cao (2010) as well as Cao and Illing (2011), commercial banks anticipate bailouts and take excessive liquidity risks which forces the central bank into a "low-interest-trap." Given prohibitive liquidation costs, the central bank is forced to cut interest rates in the crisis case. The downside risk for commercial banks is thus effectively eliminated, however, at the expense of depositors who realize lower interest-rate revenues.

4.2.2 Bank Competition

Dell'Ariccia and Marquez (2006) show how strategic interaction between competing banks can accommodate credit booms and lead to an increase in systemic risk. Credit markets are characterized by incomplete information since the quality of potential borrowers is partly unknown. Assume a unit mass of known borrowers, whose individual qualities are known only by some respective bank. Hence, in the presence of N banks, each bank has full information about a subset of $1/N$ known borrowers. There is also a mass λ of entirely unknown borrowers whose true quality is not known to any of the competing banks. Nevertheless, lending to an entirely unknown borrower is, on average, profitable. The magnitude of λ should be interpreted as the intensity of credit demand, i.e., if λ is high, a large amount of unknown borrowers seeks funding.

Depending on λ, the credit market equilibrium can exhibit different characteristics. For a low level of λ, a *separating equilibrium* emerges in which each bank only lends to known borrowers with good quality. Extending credit to unknown borrowers is deemed unprofitable, since most of the remaining potential borrowers are borrowers known to other banks, which however were rejected due to their bad quality. The remaining pool of potential borrowers is thus affected by adverse selection. A rise in λ induces a switch towards a *pooling equilibrium* where banks offer a generic loan contract to every applicant without screening. The intuition is as follows: With an increase in λ, the pool of loan applicants increasingly consists of *entirely* unknown borrowers. This attenuates the adverse selection problem since the market is now to a lesser extent populated by bad-quality borrowers who were already rejected by other banks. The prospect of increasing market shares and additional profits leads banks to jointly embark on a strategy of relaxed lending standards, so that unknown borrowers readily obtain loans.

While aggregate credit in the pooling equilibrium is considerably higher, bank profits and the average quality of bank portfolios decreases. The latter effects increase financial fragility in the case of adverse shocks. Importantly, the probability of a banking crisis increases with λ. Put differently, a severe credit boom is likely to end in a severe crisis. Nevertheless, the banking system endogenously switches to the financially more fragile pooling equilibrium in the wake of rising credit demand, since extending credit is the optimal strategic behavior under competition. Banks fail to recognize that their behavior eventually impairs financial stability.

Gorton and He (2008) show that strategic interaction can trigger changes in lending standards even if exogenous triggers are absent. In their model, the credit market is likewise characterized by the presence of incomplete information about borrower quality and hence the problem of adverse selection. Banks can produce information about loan applicants using a costly screening technology. Under limited competition, banks coordinate on a collusive strategy of charging high interest rates from potential borrowers while screening intensity is relatively low. However, this strategy provides an incentive to deviate. A bank can increase screening intensity, which is assumed to be unobservable for other banks. It can filter out relatively more borrowers with good quality this way, which leaves other banks with an adversely selected pool of remaining borrowers. Hence, the deviating bank increases the credit quality of its portfolio at the expense of its competitors. Deviations become apparent as soon as differences in the relative performances of banks' loan portfolios become public information, for instance through annual reports. Other banks then react by likewise increasing their screening intensity such that they no longer attract bad quality borrowers from other banks. Lending standards tighten in aggregate and credit availability decreases. Put differently, the mere strategic interaction of competing banks can trigger a credit crunch which is entirely unrelated to macroeconomic fundamentals. The authors' analysis of the US credit-card market provides supportive evidence for this mechanism.

Ruckes (2004) similarly shows that it is optimal for banks to set lending standards in a coordinated and procyclical fashion. Banks have to include the screening intensity of competitors into their decision making in order to account for the so-called *winner's curse effect*. This effect arises if a bank attracts borrowers of unknown type which were rejected by the other bank due to a bad screening result. The winner's curse effect is especially prevalent if the competing bank has a high screening intensity, which enables her to sort out creditworthy borrowers, thereby leaving the other bank with an adversely selected portfolio of remaining potential borrowers as in Gorton and He (2008).

The optimal response is to likewise increase screening intensity, which implies that screening intensity and hence lending standards become positively correlated across banks. Moreover, as in Dell'Ariccia and Marquez (2006), lending standards decline during booms, such that the quality of bank portfolios erodes under benign economic conditions.

To sum up, the dynamics of competition on loan markets under incomplete information may have undesirable consequences for systemic risk. Banks coordinate on business strategies which undermine financial stability. Specifically, lending standards of banks become highly correlated and procyclical, i.e., they tend to be relaxed during booms.

4.2.3 Reputational Effects

Rajan (1994) shows that reputational concerns may betray banks into lending policies which exhibit an expansionary bias and generate excessive systemic risk. The underlying crucial assumption is that banks care about their relative performance since the latter affects reputation which in turn influences funding conditions.

The model setup is as follows: Banks make a single loan in some period t and the state of the borrowing sector is revealed in the next period. Importantly, banks are heterogeneous regarding their ability to select creditworthy borrowers. In the good state, borrowers of so-called "high-type-banks" repay with a probability of unity whereas the borrowers of "low-type-banks" repay with some smaller probability. In the adverse state, any borrower experiences repayment difficulties. Bank financiers can neither observe the ability of a certain bank nor the state of the borrowing sector, they can only observe bank earnings.

Publishing lower earnings than the peer group impairs the reputation of a bank. Financiers will infer that it generates lower earnings due to its inferior ability in borrower selection rather than due to generally adverse conditions within the borrowing sector. Banks thus face the incentive to hide losses from the market by prolonging credit relations with non-performing borrowers, for instance by extending loan maturity. This strategy - which is coined *liberal credit policy* - indeed hides losses in the short run but yields higher losses in the longer term.

Reputational concerns produce a strategic complementarity with far-reaching impact. If a bank believes that its peers will embark on a liberal credit policy, it likewise chooses to hide losses. By contrast, if it believes that its competitors pursue a tight credit policy and recognize losses from non-performing loans, it pursues a tight credit policy as well. The reason is that if every bank displays losses, the market infers that this is due to adverse conditions of the borrowing sector and not due to different abilities in borrower selection. Hence, the model can exhibit multiple equilibria. It is possible that banks either coordinate on liberal or tight credit policy. However, the driving force is not a careful assessment of borrower credit quality but rather reputational concerns. In the case of liberal credit policies, inefficiency arises since bank managers embark on a strategy which exacerbates losses in the longer-term and hence enhances systemic risk.

The equilibrium allocation depends on the probability π of the adverse state. If π is low, banks find it optimal to pursue liberal credit policies as overall business conditions are benign and displaying low earnings impairs reputation. For intermediate values of π, both liberal and tight credit policies constitute an equilibrium. The selection of an equilibrium takes places through persistence, i.e., if agents embarked on liberal credit policies in the past period they will continue doing so. For high values of π, agents coordinate on tight credit policies, since overall business conditions are gloomy and low earnings can be reported without losing reputation.[19]

Rajan (1994) further demonstrates that the predictions of the model are mirrored in the data. He shows that after a regional US bank located in a state experiencing a beginning real-estate crisis was forced to extend loan-loss provisions, the bank's peers extended loan-loss provisions as well, even though they were not under similarly intense regulatory scrutiny. The regulatory intervention can be interpreted as an exogenous shock verifying that the borrowing sector has entered an adverse state. Hence, other banks embarked on tight credit policies since recognizing losses was no longer stigmatized.

4.3 Fire Sales

Fire sales represent a special form of contagion. If agents sell assets in distressed markets, this exerts an adverse effect on market prices. Any agent with an exposure to this

[19] If π depends on the choice of credit policies, an endogenous credit cycle emerges. Suppose that π increases with the number of banks pursuing liberal credit policies. Low values of π indicate liberal credit policies and π consequently increases up to the threshold where banks switch to tight credit policies. The cycle then reverts and π starts to decrease until banks switch back to liberal credit policies.

asset will consequently realize a decline in balance sheet valuations regardless of the network structure of interbank claims and liabilities. Fire sales are contagion effects operating via *prices*. Put differently, fire sales can induce systemic repercussions even if the system is entirely disconnected in terms of direct exposures. Shleifer and Vishny (2011, p. 30) offer a comprehensive definition:

> "[A] fire sale is essentially a forced sale of an asset at a dislocated price. The asset sale is forced in the sense that the seller cannot pay creditors without selling assets. The price is dislocated because the highest potential bidders are typically involved in a similar activity as the seller, and are therefore themselves indebted and cannot borrow more to buy the asset. Indeed, rather than bidding for the asset, they might be selling similar assets themselves. Assets are then bought by nonspecialists who, knowing that they have less expertise with the assets in question, are only willing to buy at valuations that are much lower."

However, it is not self-evident why banks should choose to sell assets at dislocated prices instead of raising new debt or issuing additional equity. According to Hanson et al. (2011), corporate-finance theory offers two important arguments. One reason may be that leveraged banks suffer form a *debt overhang problem* as laid out in Myers (1977). Debt overhang makes it impossible to issue new debt claims, since potential investors anticipate that future returns will be mainly appropriated by existing creditors. Hence, investors deny funding even if banks could undertake projects with a positive net present value.[20] As highlighted by Myers and Majluf (1984), the issuance of equity is subject to a similar problem. Under asymmetric information, equity issuance is perceived as a signal that the bank management considers the firm to be overvalued and stock prices drop sharply. Declining stock prices harm existing shareholders and the management hence refrains from equity issuance even if profitable projects could be realized.

If obtaining external funding is indeed impossible or carries prohibitive costs, selling assets to meet (short-term) liabilities is the only remaining solution. However, if financial conditions within the banking sector are positively correlated, banks are likely

[20] In fact, it may be the fire-sale-related decline in asset prices which erodes net worth and creates the debt overhang problem in the first place.

to become finance-constrained simultaneously. Assets are consequently sold to outsiders at a discount, which may give rise to a self-reinforcing spiral of fire sales and declining asset prices. Outside investors may be unable to extract the maximum possible payoff from complex assets which creates a further inefficiency besides the contagion effect. The fire-sale discount may also be due to asymmetric information if outside investors are uncertain about the true asset value (which is not publicly observable). This effect gains in importance if assets are complex and hard to value. Furthermore, genuine investment projects of outside investors might be crowded out if the latter choose to buy distressed banking assets instead. As a result, aggregate investment declines.

To sum up, fire sales can produce inefficiency via various channels. First, they can generate price-driven contagion within the banking sector. Second, assets may finally end up with outside investors who are unable to extract their maximum payoff. Third, crowding out of outsider projects entails a negative aggregate investment externality.

4.3.1 Asset Specificity and Cash-In-The-Market-Pricing

Shleifer and Vishny (1992) provide an insightful framework for understanding fire sales of leveraged entities. They start by developing a general theory of asset liquidity. One of the main determinants of asset liquidity is redeployability, which is the possibility to utilize an asset in alternative (and equally profitable) ways. If an asset can be used for many different purposes, the set of potential buyers is likely to be large. Hence, it can be sold with ease and its liquidity (or: its liquidation value) is high. If an asset can be utilized for only one purpose, and especially if there is the need for specific skills to extract its full value, its liquidity is likely to be low.[21] In a nutshell, liquidity is inversely related to *asset specificity*.

Shleifer and Vishny (1992) continue by presenting a simple model of an industry in which two leveraged firms operate specific assets. In an adverse state, both firms may become finance-constrained simultaneously. Hence, assets have to be sold to non-specialized outside investors with a low liquidation value. In general, the feasible debt capacity is positively related to asset liquidity. This may give rise to multiple equilibria. The mere expectation of benign liquidity conditions induces firms to take on more debt.

[21] For instance, commercial land is highly liquid, since it can be used in various ways by various businesses. Conversely, an airplane or a pharmaceutical patent is a rather illiquid asset. The scope for alternative usage is limited and its best use requires specific skills.

Since this debt is ultimately used to acquire assets, the expectation of ample liquidity becomes self-fulfilling. However, the realization of an adverse state may then become more painful as liquidity disappears and firms end up with a severe debt overhang as well as a stock of illiquid assets. Fire sales at steep discounts are unavoidable then.

Even though this theory was originally applied to real assets, it can also be applied to financial assets. The key criterion of asset liquidity in this case, however, is not alternative usage. After all, every financial asset has the key purpose to deliver cash flows. Instead, necessary and specific skills to extract the full value of an asset become the crucial factor. While standardized assets such as bank deposits or AAA-rated government bonds are easy to manage, complex assets such as mortgage-backed securities require specific skills in valuation as well as monitoring and are prone to adverse selection. Since these specific skills are scarce, the set of potential buyers is limited and liquidity and liquidation values of these assets will be low. Having to sell assets to outsiders who cannot extract their full value therefore leads to inefficiency. The wedge between the liquidation value and the value in best use can thus be regarded as a measure of asset illiquidity.

Allen and Gale (1994) introduced a similar framework to understand the implications of fire sales for asset-price volatility, which they refer to as *cash-in-the-market pricing*. Their model is populated by investors with uncertain liquidity needs. They differ in their probability to experience liquidity shocks. Investor group A experiences liquidity shocks more frequently than investor group B. Agents can invest in profitable long-term assets and/or hold cash. Participating in asset markets entails some fixed cost. If investors find themselves in need of liquidity, assets are sold at short notice. The price impact of short-term asset sales crucially depends on whether other investors in the market stand ready as potential buyers and whether they are sufficiently liquid. If aggregate liquidity is sufficient, the equilibrium asset price equals the discounted value of its future cash flows. In the case of a liquidity shortage, however, the asset price also depends on available liquidity. The scarcer is liquidity, the lower the asset price will be.

Two types of equilibria may emerge. In the *full-participation equilibrium* both A and B enter the market. Investors facing liquidity shocks sell assets at short notice, but the additional supply gets absorbed by other participants with negligible price impacts. The full participation equilibrium is only feasible for low participation costs. For higher participation costs, a *limited-participation equilibrium* sets in. Investor group A no longer participates in the asset market, only Type-B investors continue to participate.[22] Since the latter are less exposed to liquidity shocks and thus hold lower amounts of cash reserves, aggregate liquidity is low. In this setup, short-term asset sales in the wake of liquidity shocks have considerable price implications and cash-in-the-market pricing occurs. Asset-price volatility becomes excessive and prices can deviate considerably from their fundamental value.[23]

There is also a range of parameter values producing multiple equilibria. If investors expect others to participate they will likewise participate since they expect the market to be liquid under all circumstances and the full-participation equilibrium is established in a self-fulfilling fashion. On the other hand, expectations of non-participation may give rise to the limited-participation equilibrium. The former constellation tends to be welfare-superior, which creates the scope for policy intervention so as to push agents to coordinate on full participation.

4.3.2 The Fire-Sale Model of Stein (2012)

The previous Section tried to clarify that fire sales are inefficient because they foster price-driven contagion and may lead to a transfer of assets to agents who are incapable to extract their full value. The model of Stein (2012) shows that banks do not internalize their contribution to adverse fire-sale dynamics. Hence, they decide for a socially inefficient degree of maturity transformation. By relying on an excessive amount of non-contingent short-term debt, banks are forced into selling assets in adverse states. The emerging equilibrium is constrained inefficient and systemic risk, measured by expected losses in the fire-sale state, is unnecessarily high. A social planner can improve outcomes as she recognizes that fire-sale discounts are endogenous and depend on the ex-ante maturity mismatch.

22 Every investor trades off profits from investing in long-term assets against costs of market participation and the exposure to liquidity risk. The threshold where participation costs become prohibitively high is lower for Type-A investors since they value trading of illiquid assets less (given their higher exposure to liquidity shocks).

23 In Allen and Carletti (2008), it is shown that cash-in-the-market pricing and the associated decline in balance-sheet valuations can trigger insolvencies, whereas accounting at historical costs ensures that financial intermediaries survive and are able to meet their liabilities. Hellwig (2009) likewise argues that marked-to-market accounting played in important role in the recent crisis. The general argument is that accounting at historical costs effectively shuts down price-based contagion. On the other hand, uncertainty about true asset values may become elevated, which may cause different problems such as the collapse of short-term funding.

4.3.2.1 Assumptions and General Setup

The model has three periods $t \in \{0, 1, 2\}$. It features households, banks and a regulator. Households receive an initial endowment of goods in $t = 0$. Besides from consuming immediately in $t = 0$, households can postpone consumption to $t = 2$ by investing in either risk-free or risky assets. The risk-free asset should be regarded as money (or a close substitute) and the risky asset is a long-term bond. By assumption, households obtain additional, non-pecuniary benefits from holding money due to its no-risk property. The utility function of the representative household takes the form of

$$U = C_0 + \beta E(C_2) + \gamma M, \tag{4.27}$$

where C_t denotes consumption in period t. Consumption in $t = 2$ is an expected value as payoffs of the risky asset may vary. M is the amount of money in the household portfolio and γ determines the marginal utility of holding money. The parameter β is the discount factor applied to future consumption. These preferences immediately pin down both the equilibrium interest rates on money and bonds, respectively. The gross interest rate on risky assets paying off in $t = 2$ is given by

$$R^B = \frac{1}{\beta}, \tag{4.28}$$

as the preference structure implies that households are indifferent between consuming β units of goods today and holding a risky claim on one consumption unit in $t = 2$. The gross return on holding money is given by

$$R^M = \frac{1}{\beta + \gamma} \tag{4.29}$$

since households are indifferent between consuming an amount $\beta + \gamma$ in $t = 0$ and holding a riskless claim on one unit of consumption in $t = 2$, which delivers consumption utility of β and utility from monetary services of γ. Thus it holds that $R^M < R^B$.[24] Money offers a convenience yield as it is risk-free and allows to insure against consumption volatility in $t = 2$.

[24] This return spread is assumed to be fixed and independent of the relative quantities of money and bonds. While this represents a substantial simplification, it leaves the qualitative results of the model unchanged (Stein, 2012, p. 63).

Investment is carried out by banks since they possess specific skills in operating investment projects. Banks invest an amount I in risky projects delivering a state-dependent payoff in $t = 2$. In the good state, which occurs with probability p, the project payoff is given by some concave function $f(I) > I$. In the bad state, occurring with probability $1 - p$, expected output diminishes to $\lambda I < I$ and is either given by $\lambda I/q$ with probability q or zero with probability $1 - q$. The actual state is revealed in the intermediate period $t = 1$ in which banks have the possibility to sell assets to outside investors. However, this is only possible with a fire-sale discount $0 \leq k \leq 1$ (more on this below), implying that selling a fraction Δ of the original investment amount in the bad state yields total proceeds of $\Delta k \lambda I$.

Banks entirely rely on external funding. They can issue long-term debt maturing in $t = 2$, which is risky due to the positive probability of a zero project payoff. They can also issue short-term debt maturing in $t = 1$ whose payoff is independent from the actual state. Insofar, it is essentially risk-free and should be interpreted as an amount of (private) money M delivering non-pecuniary benefits to its owners (see Equation 4.27). Money is risk-free because banks can sell assets in the bad state such that depositors get paid off in any case. Money is a senior claim whereas long-term bonds are a junior claim.[25]

If a bank finances a share m of I by issuing short-term debt, the repayment obligation in $t = 1$ is $mIR^M = M$. This repayment obligation has to be met in every state. Selling assets yields $\Delta k \lambda I$ and the case of $\Delta = 1$ implies selling the entire portfolio, i.e., it denotes the maximal non-state-contingent repayment amount in $t = 1$. This pins down the maximally feasible fraction of short-term funding m^{MAX} since it has to hold that

$$k\lambda I = m^{MAX} I R^M \quad \Leftrightarrow \quad m^{MAX} = \frac{k\lambda}{R^M}. \tag{4.30}$$

The maximally feasible share of short-term debt m^{MAX} varies with the fire-sale discount k, the expected payoff λ per unit of investment in the bad state and is inversely related to the interest rate on money R^M. If banks issued relatively more short-term

25 To obtain new funding in $t = 1$ is impossible due to a debt overhang problem. Newly issued claims have to be subordinated to long-term debt, which implies that their value is clearly below the amount which has to be refinanced in the bad state. Note also that selling assets in the good state is not necessary. Since risk is removed in the good state, households are willing to postpone their withdrawals until $t = 2$, as they do not wish to consume in $t = 1$ anyway.

debt, it would lose its no-risk property since selling assets would yield insufficient revenues in the bad state.

In $t = 1$, banks can sell assets to patient outside investors (POIs). POIs are endowed with resources of W which they can either use to buy distressed assets from banks or to invest in "late-arriving" investment projects which yield a concave payoff $g(W)$ in $t = 2$. The amount of assets banks are obliged to sell in the bad state amounts to M, since this is the amount which is required to pay off short-term depositors. If POIs buy them, their investment in technology g decreases to $W - M$. No-arbitrage considerations imply that investing in distressed bank assets needs to yield the same return as late-arriving investment projects, which endogenously pins down the fire sale discount to

$$\frac{1}{k} = g'(W - M) \tag{4.31}$$

since the marginal return of buying bank assets $1/k$ (their fair value in $t = 1$ is λI and they trade at $k\lambda I$) has to equal the marginal return of the alternative investment project. Importantly, the fire sale discount increases in M. The larger the amount of assets being sold in $t = 1$, the less is invested in late-arriving investment projects. However, the marginal return $g'(W - M)$ increases in M due to the concavity of g, which implies that buying distressed assets has to yield a higher return, which is in turn achieved by a decline of k. The key assumption is that banks do not internalize this mechanism and thus their own contribution to fire-sale dynamics in adverse states. They regard k as an exogenous parameter. It is subsequently shown that this coordination failure produces a decentralized market equilibrium which is welfare-inferior compared to the social planner solution. Banks excessively rely on short-term debt, which gives rise to fire-sale dynamics and crowding-out of outsider projects in the bad state.

4.3.2.2 Decentralized Market Equilibrium

Banks seek to maximize expected profits Π while facing the funding constraint $m \leq m^{MAX}$. The Lagrangian $\mathscr{L}^B$ for this problem is given by

$$
\begin{aligned}
\mathscr{L}^B &= [pf(I) + (1-p)\lambda I - IR^B] \\
&\quad + mI(R^B - R^M) \\
&\quad - (1-p)zmIR^M - \eta(m - \frac{k\lambda}{R^M}),
\end{aligned} \tag{4.32}
$$

where the term in the first line denotes expected bank profits if financing were entirely bond-based, the term in the second line captures additional profits driven by reduced financing costs in the case of short-term funding and the terms in the third line represent the fire sale-related losses in the bad state and finally the rearranged constraint multiplied with its shadow price η.[26] Banks thus need to trade off cheaper funding costs and the possibility of fire sale losses in the bad state. Taking the first-order condition (FOC) with respect to m yields

$$
\begin{aligned}
\frac{\partial \mathscr{L}^B}{\partial m} &= I[(R^B - R^M) - (1-p)zR^M] - \eta \stackrel{!}{=} 0 \\
&\Leftrightarrow I[(R^B - R^M) - (1-p)zR^M] = \eta.
\end{aligned} \tag{4.33}
$$

If $\eta > 0$, the short-term financing constraint is binding and the corner solution $m = m^{MAX}$ is the optimum. If $\eta = 0$, the constraint is non-binding and banks optimally choose some interior value $m < m^{MAX}$. The value of the Lagrange multiplier critically depends on the spread between R^B and R^M. The left-hand side of Equation (4.33) increases in $R^B - R^M$, implying that a large spread causes banks to exhaust short-term funding possibilities to the maximally feasible extent, which makes the constraint binding and yields a positive shadow price $\eta > 0$. In contrast, in a low-spread regime banks are satisfied with some medium amount of short-term funding and the constraint is hence non-binding. If short-term financing is relatively cheap, banks maximize its amount within their funding mix at the expense of a potential aggravation of fire-sale dynamics. The FOC with respect to I is given by

[26] Fire-sale losses are in fact a wealth transfer from banks to patient investors. By defining $z = \frac{1-k}{k}$ as the net excess return for patient investors, they can be expressed as the transfer of this excess return z multiplied with the amount mIR^M of sold assets.

$$\begin{aligned}\frac{\partial \mathscr{L}^B}{\partial I} &= pf'(I) + (1-p)\lambda - R^B + m(R^B - R^{M)} - (1-p)zmR^M \overset{!}{=} 0 \\ &\Leftrightarrow pf'(I) + (1-p)\lambda - R^B = -\Big(m(R^B - R^{M)} - (1-p)zmR^M\Big).\end{aligned} \tag{4.34}$$

Substituting Equation (4.33) into (4.34) allows to simplify the FOC to

$$\frac{\partial \mathscr{L}^B}{\partial I} = pf'(I) + (1-p)\lambda - R^B = \frac{-\eta m}{I}. \tag{4.35}$$

For $\eta = 0$ and $m \leq m^{MAX}$, the amount of I equals optimal investment if financing were entirely based on bonds.[27] For $\eta > 0$ and hence $m = m^{MAX}$, it follows that $pf'(I) + (1-p)\lambda < R^B$ which implies an increase in I and a consequent decline in $f'(I)$. Thus, the privately optimal amount of investment in the presence of a high-spread regime (if $R^B \gg R^M$ and thus $\eta > 0$ as well as $m = m^{MAX}$), is higher than in the low-spread regime. This is due to the fact that banks cannot increase their reliance on short-term funding by simply rearranging their liability structure while keeping the balance sheet size fixed. In that case, money would lose its no-risk property since the constant amount of assets would be insufficient to guarantee complete repayment of short-term depositors in the bad state. In order to back short-term debt with sufficient collateral, I has to be expanded instead. Short-term debt M and investment I have to increase jointly in order to satisfy the collateral constraint.

4.3.2.3 Social Planner Solution

In the next step, it is shown that the decentralized equilibrium features excessive reliance on short-term debt in the case of $R^B \gg R^M$. For that purpose, the decentralized equilibrium is compared to the optimization problem of a benevolent social planner. The crucial difference is that the social planer recognizes the endogeneity of the fire-sale discount k as well as the crowding-out of late-arriving investment projects in the bad state, which implies a loss of potential output. The social planner seeks to maximize utility of the representative agent. In Appendix A.2 it is verified that social utility can be expressed as:

[27] If financing is entirely bond-based, it holds that $m = 0$ and the FOC simplifies to $\frac{\partial \mathscr{L}^B}{\partial I} = pf'(I) + (1-p)\lambda - R^B \overset{!}{=} 0$, which states that the expected (marginal) return of investment has to equal (marginal) funding costs R^B.

$$
\begin{aligned}
U = {} & [pf(I) + (1-p)\lambda I - IR^B] + M\frac{(R^B - R^M)}{R^M} \\
& pg(W) + (1-p)[g(W-M) + M] - WR^B.
\end{aligned} \tag{4.36}
$$

Importantly, the social planner does not account for fire-sale losses z since the welfare implications of the associated wealth transfer net out in the aggregate. However, the social planner accounts for crowding-out effects. If POIs acquire existing bank assets instead of investing in their own project, aggregate output is diminished. This is the key inefficiency the social planner seeks to address. The collateral constraint remains the same and the Lagrangian $\mathscr{L}^P$ for the problem becomes

$$
\begin{aligned}
\mathscr{L}^P = {} & [pf(I) + (1-p)\lambda I - IR^B] + M\frac{(R^B - R^M)}{R^M} + pg(W) \\
& + (1-p)[g(W-M) + M] - WR^B - \eta^P(m - \frac{k\lambda}{R^M})
\end{aligned} \tag{4.37}
$$

Appendix A.2 shows that the FOC with respect to m implies that

$$
I\{(R^B - R^M) - (1-p)zR^M\} = \eta^P(1 - \frac{g''(\cdot)}{(g'(\cdot))^2}\lambda I). \tag{4.38}
$$

Furthermore, the FOC with respect to I is given by

$$
pf'(I) + (1-p)\lambda - R^B + m(R^B - R^M) - (1-p)zmR^M = -\eta^P\frac{g''(\cdot)}{(g'(\cdot))^2}\lambda m. \tag{4.39}
$$

Now private and social optimality conditions can be compared. In the low-spread setting where $m \leq m^{MAX}$ and hence $\eta = \eta^P = 0$, the private and the social optimum coincide. This can be easily verified by the comparison of the respective FOCs. Comparing (4.33) and (4.38) shows that both FOCs are perfectly equivalent for $\eta = \eta^P = 0$. The same holds when comparing (4.34) and (4.39). Hence, if the spread between R^B and R^M is sufficiently small, banks choose the socially optimal amount of both M and I.

However, this result no longer holds in the high-spread case with $m = m^{MAX}$. Equation (4.39) shows that with $\eta^P > 0$, the right-hand side of this Equation becomes positive since it holds that $g''(\cdot) < 0$ as $g(\cdot)$ was defined to be concave. Hence, the left-hand side has to increase. This is only possible if I is reduced, since $f'(I)$ is decreasing in I. The social planner thus chooses a *lower* amount of I and automatically also a lower amount of M, since $M = m^{MAX} R^M I$. Put differently, the decentralized equilibrium is characterized by a *socially inefficient* amount of investment I and short-term debt M. Banks conduct too much investment and issue too much short-term debt. They do not internalize that the fire-sale discount is endogenous and crowds out outsider investment as a higher-order effect.

Internalization can be achieved via a simple cap on short-term funding, whose socially optimal amount can easily be deduced from Equations (4.38) and (4.39). The observation of banks' investment opportunities $f(I)$ might be impossible though. The desired levels of I and M can nevertheless be implemented by a cap-and-trade approach, akin to the issuance of tradable carbon emission certificates. The regulator grants permits to banks which allow them to issue a certain amount of money. The market price P of the permission to issue one unit of short-term debt corresponds to the shadow price of the short-term funding constraint. Even without knowing the exact functional form of $f(I)$, the shadow price of short-term funding in the social optimum can be calculated (Stein, 2012, pp. 76-78). As a result, the regulator only has to gradually adjust the quantity of permits upwards until the permit price P coincides with the socially optimal shadow price of the collateral constraint.

Other authors have developed similar models where banks' non-internalization of the adverse effects of fire-sales lead to constrained inefficient equilibria. In Korinek (2011), banks likewise rely excessively on debt, making fire sales in adverse states particularly devastating. He shows that taxing debt issuance can lead to successful internalization. Similarly, Lorenzoni (2008) shows that non-internalization of fire-sale risks leads to ex-ante overinvestment and excessive borrowing. Giavazzi and Giovannini (2010) relate the model of Stein (2012) to a discussion of monetary policy. They argue that if social inefficiency arises only in regimes in which the spread between long-term bond rates R^B and short-term rates R^M is large, the central bank should constantly compress the term spread to ensure a low-spread regime.

Regarding empirical evidence, Ramcharan and Rajan (2014) document contagious fire sales for US banks before and during the Great Depression. Cappiello and Supera

(2014) simulate fire-sale scenarios for the Euro Area banking sector and find that they would lead to a substantial decline in its aggregate equity position. Coval and Stafford (2007) detect fire-sale discounts in US equity markets for cases in which mutual funds are forced to liquidate positions due to large outflows of customer deposits. Campbell et al. (2009) argue that the default of Lehman Brothers triggered massive fire sales of collateral, especially inflation-protected treasuries. For the non-financial sector, Acharya et al. (2007) find that firm defaults produce lower recovery rates if there is industry-wide distress, implying that inside investors cannot act as potential buyers and assets have to be sold to outsiders at a loss.

4.4 Liquidity Externalities

Liquidity externalities emerge if banks' individually rational decisions on how to manage liquidity exacerbate systemic risk. There are several models studying the systemic implications of bankers' individual liquidity management policies. They point out various channels through which individual liquidity management can have adverse systemic repercussions.

4.4.1 Liquidity Hoarding

Gale and Yorulmazer (2013) provide a model of *liquidity hoarding*. Bank assets are composed of cash and an illiquid asset. Banks are subject to idiosyncratic liquidity shocks. If available liquidity is insufficient, illiquid assets have to be sold at secondary markets, typically with a fire-sale discount. If selling assets generates insufficient revenues, banks are forced into costly bankruptcy. Hence, every bank trades off returns from investing in illiquid assets against the risk of fire-sale losses and bankruptcy in the worst case. There are two motives for banks to hold cash: First, they hold cash for *precautionary* reasons in order to protect themselves against future liquidity shocks. Second, banks hold liquid reserves for *speculative* reasons since the possibility of acquiring illiquid assets at fire-sale prices offers an opportunity to generate large excess returns.

The key result is that these individual incentives prevent the efficient provision and redistribution of liquidity in the aggregate. Banks with a liquidity surplus tend to be reluctant to lend to banks experiencing a liquidity shock, both for precautionary and speculative reasons. Banks subject to a liquidity shock consequently face difficulties to obtain cash on the interbank market which implies their default in the worst case. Illiquid assets provide a zero payoff in the default state. Banks with a liquidity surplus do not internalize this inefficiency and aggregate payoffs in the market equilibrium turn out to be lower than compared to a social planner solution with efficient liquidity redistribution. The social planner solution can also be implemented by the central bank with a lender-of-last-resort policy. In that case, however, the private market for liquidity entirely breaks down and the central bank becomes the only provider of liquidity.

Diamond and Rajan (2011) show how liquidity hoarding in conjunction with risk-taking incentives under limited liability can lead to a constellation in which banks do not insure themselves against liquidity shocks, even though it would be possible. Banks choose to pursue a strategy of *strategic illiquidity*. The setup is as follows: In the initial period $t = 0$, banks hold illiquid financial assets paying off in $t = 2$. Funding is obtained via deposits. In $t = 1$, banks potentially face a stochastic liquidity shock leading to a partial withdrawal of deposits. Banks can raise liquidity by selling their assets to outside investors. In contrast to other models, outside investors are assumed to be able to extract full payoffs. Banks can sell assets in $t = 0$, thereby achieving insurance against a possible liquidity shock. Alternatively, they can sell assets in $t = 1$ if they are hit by the liquidity shock. Outside investors face the opportunity to either buy assets in $t = 0$ or to buy assets at fire-sale prices in $t = 1$. Given this choice, outside investors already demand a discount in $t = 0$ because they can alternatively rely on speculative hoarding to buy assets with a discount at $t = 1$. In this constellation, banks do not sell assets in $t = 0$ at all. Hence, even though banks have the possibility to sell assets in $t = 0$ and to thereby achieve insurance against liquidity shocks in $t = 1$, they are reluctant to do so. The reasoning is as follows: If the liquidity shock does not materialize, the asset pays off regularly in $t = 2$ and shareholders make profits. If the shock occurs, the bank is forced to conduct a fire sale in $t = 1$ and may finally become insolvent. Depositors bear the lion's share of the associated losses. After all, banks find it preferable to remain exposed to the liquidity shock since liquidity risk is mostly borne by depositors.

This allocation is inefficient for two reasons. First, banks expose themselves to avoidable liquidity risks. Second, financial fragility creates special return opportunities for outside investors and investment in new projects is crowded out just as in Stein (2012). Public intervention can be conducted in various ways. For example, the regulator could subsidize market prices in $t = 0$ to incentivize trading with outside investors.

Alternatively, outside investors can be endowed with additional liquidity in $t = 1$ to avoid fire-sale discounts and crowding-out effects.

Regarding empirical evidence, several authors detected liquidity-hoarding patterns in the recent financial crisis. Acharya and Merrouche (2013) analyze liquidity demand of UK banks during the immediate aftermath of the interbank market disruptions in August 2007. They find that demand increased strongly even though market activity had been restored, which points towards precautionary hoarding behavior to protect against future liquidity shortages. Similarly, Berrospide (2013) documents precautionary hoarding for US commercial banks in the recent crisis. Hoarding is found to be increased in anticipation of future losses and liquidity outflows, measured by unrealized write-downs, loan-loss provisions and unused credit lines, respectively. Finally, Heider et al. (2009, 2015) argue that elevated uncertainty with respect to counterparty risk after the demise of Lehman Brothers has led to liquidity hoarding by Eurozone banks.

4.4.2 The Interplay of Market Liquidity and Funding Liquidity

Brunnermeier and Pedersen (2009) put forward the concepts of market liquidity and funding liquidity. They are interdependent and may act in a mutually reinforcing, destabilizing way. In Brunnermeier and Pedersen (2009, p. 2201), *market liquidity* is defined as a property of an asset and reflects "the ease with which it is traded." *Funding liquidity* is defined as "the ease with which [market participants] can obtain funding." In what follows, I highlight the essence of their model with the help of a stylized example.

Market participants (henceforth traders) invest in risky assets and finance themselves via capital and collateralized debt. Traders can for instance be interpreted as investment banks who pledge risky assets as collateral to outside financiers and in turn receive funding. In order to protect themselves against losses, financiers require the establishment of a wedge between the current asset price and its collateral value, i.e., they demand a *haircut* $h \in [0, 1]$. If traders want to raise an amount D of collateralized debt, they have to pledge an amount $D/(1 - h)$ of assets as collateral. For example, if a trader wants to raise 100\$ of debt and the haircut is $h = 0.2$, he needs to pledge assets which are currently worth $100\$/(1 - 0.2) = 125\$$. The asset can consequently decline in value by 20%, but the financier would still be able to recover the lending amount

Assets	Liabilities
Asset 125	Collateralized Debt 100
	Capital 25

Table 4.3: *Balance Sheet with Collateralized Funding*

by seizing the collateral. Put differently, the haircut is the maximum percentage-point decline of the asset price before the collateral value falls short of the lending amount.

The prevailing haircut determines the feasible balance-sheet structure of traders. It determines both the maximally feasible leverage ratio as well as the maximum size of the balance sheet given an initial capital endowment. The capital ratio always needs to equal the haircut as a very minimum. Consider an example with a capital endowment of $C = 25\$$ and $h = 0.2$ for illustration. Market participants are able to buy the risky asset and obtain the necessary funding by its simultaneous collateralization. The difference between market price and collateral value has to be covered by capital. The maximally feasible size of the balance sheet is denoted by S and is given by

$$\frac{C}{S} = h \Leftrightarrow S = \frac{C}{h} = 125\$. \tag{4.40}$$

The amount of collateralized funding D is given by

$$D = \frac{C}{h}(1-h) = 100\$. \tag{4.41}$$

Table 4.3 depicts the emerging balance sheet structure. An asset position of $S = 125\$$ is sufficient to support collateralized funding of $D = 100\$$, and the residual needs to be covered with capital.

Financiers set haircuts in order to protect themselves against losses. Suppose that they finance an amount D_t in period t, which is collateralized by an amount of assets being worth $P_t = D_t/(1-h)$. If the trader repays, the financier receives D_t. If the trader defaults, the financier seizes the collateral at its next-period price P_{t+1}. In order to avoid losses in any state, it needs to hold that

Assets	Liabilities
Asset 100	Collateralized Debt 75
	Capital 25

Table 4.4: *Balance Sheet after Haircut Increase to $h^{'}$*

$$\begin{aligned} P_{t+1} &\geq D_t \\ P_{t+1} &\geq P_t(1-h) \\ P_{t+1} - P_t &\geq -hP_t \\ \frac{P_{t+1} - P_t}{P_t} &\geq -h, \end{aligned} \tag{4.42}$$

implying that the price change of the risky asset must not be lower that the negative haircut. If $h = 0.2$, the asset price can decline by 20% before financiers incur losses in the case of traders defaulting on their obligations. These considerations clarify that prudent financiers vary the required haircut positively with the riskiness of the collateralized asset, i.e., with its volatility. If volatility is high, haircuts are tightened to avoid scenarios in which the collateral value falls short of the lending amount. Hence, funding liquidity declines with asset price volatility.

In the model, price volatility can increase due to stochastic supply and demand shocks. Importantly, it is assumed that financiers cannot observe whether the rise in asset-price volatility is due to a stochastic and temporary shock or whether the asset has indeed become riskier. Financiers thus react by raising required haircuts. Recall the balance sheet in Table 4.3 and suppose that the required haircut is increased to $h^{'} = 0.25$. Both the maximally feasible balance sheet size and the maximally possible leverage ratio decrease. Market participants consequently need to deleverage. If deleveraging occurs collectively, market liquidity will be impaired to a great extent. The initial decline in market liquidity has led to a decline in funding liquidity which in turn leads to a further decline in market liquidity.

Table 4.4 depicts the new balance sheet. The required capital ratio has increased to 25%, in line with the haircut, implying that the balance sheet has to be shrunk to an amount of 100$. External funding of 75$ has to be collateralized by an asset worth 100$, and assets worth 25$ must be sold compared to the constellation in Table 4.3.

The pressure to sell assets triggers two amplification mechanisms: The *Haircut Spiral* and the *Loss Spiral*. Selling assets puts downward pressure on their market prices such

Assets	Liabilities
Asset 90	Collateralized Debt 75
	Capital 15

Table 4.5: *Balance Sheet after Asset Price Decline*

Assets	Liabilities
Asset 30	Collateralized Debt 15
	Capital 15

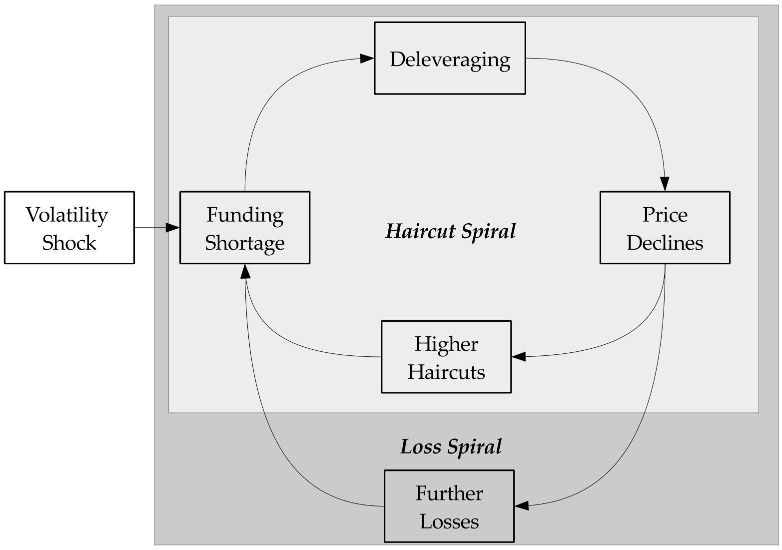
Table 4.6: *Balance Sheet after Deleveraging and Further Haircut Increase to h''*

that their volatility is likely to increase further. Hence, financiers respond with a further increase of required haircuts, which gives rise to an adverse feedback loop between rising asset-price volatility and rising haircuts. Moreover, declines in asset prices produce direct losses and lead to a decline in capital. The decline in capital requires further deleveraging which produces further losses and further deleveraging.

With respect to the example, suppose that initial asset sales of 25$ trigger a price decline of 10%. Hence, starting from Table 4.4, the value of assets declines. The new balance sheet is displayed in Table 4.5. Capital has been diminished to 15$ and the capital ratio is consequently lower than required by financiers, i.e., $15\$/90\$ < 0.25$. In order to restore the acceptable leverage ratio, further assets need to be sold. Suppose additionally that financiers increase the haircut to $h'' = 0.5$ due to the rise in asset price volatility. Then, the balance sheet needs to decline massively and is finally given by Table 4.6. Clearly, the necessity to sell assets worth 60$ puts further downward pressure on prices and enhances volatility. Both spirals act in a self-reinforcing way in the subsequent rounds of necessary balance sheet adjustment.

As a result, both market and funding liquidity are inherently fragile. Single traders or single financiers do not internalize that selling assets or tightening funding conditions exacerbate systemic stress. Importantly, funding and market liquidity are inextricably interlinked and reinforce each other. Even small shocks to asset prices and/or funding conditions can trigger powerful feedback loops which finally lead to a complete market collapse due to the massive decline in traders' balance-sheet capacity. Figure 4.6 depicts the interrelations of the haircut spiral and the loss spiral.

The initial volatility shock leads to an increase in haircuts and thus to a decline in funding liquidity. Traders with a given capital endowment are no longer able to



Source: Adapted from Brunnermeier/Pedersen (2009, p.2204).

Figure 4.6: *Destabilizing Interplay of Market and Funding Liquidity*

obtain collateralized funding for their current asset positions and experience a funding shortage. They need to scale back their balance sheet to satisfy the required capital ratio. This deleveraging process and the associated excess supply of assets trigger price declines. Decreasing prices have two effects: First, they enhance asset price volatility further such that financiers tighten haircuts even more (haircut spiral). Second, selling assets with a loss eats into the capital of traders so that they need to deleverage further (loss spiral). A disruption of funding liquidity almost inevitably leads to a collapse in market liquidity (and vice versa).

The empirical relevance of this mechanism during the recent crisis has been inter alia documented in Gorton (2009), who shows that haircuts for subprime-related securities skyrocketed after August 2007 so that the ability of intermediaries to raise collateralized debt via repurchase agreements (repos) was severely impaired. The significance of repo markets is documented by Hördahl and King (2008). They estimated their pre-crisis volume to be roughly \$10 trillion for the US and €6 trillion for the Euro Zone, respectively. Gorton and Metrick (2012) present evidence that US repo markets shrunk drastically in the crisis, especially due to the retreat of foreign financial institutions which were no longer willing to provide repo finance to the US intermediation sector.

4.5 Adverse Selection

The concept of adverse selection was pioneered by Akerlof (1970) and highlights the inefficiencies which may arise from private information. It is applicable to virtually any economic situation that suffers from asymmetric information and consequently also (and maybe especially) to financial markets.

In a well-known paper, Stiglitz and Weiss (1981) highlight that adverse selection can severely impair the functioning of loan markets. If the credit quality of borrowers is their own private information, lenders charge interest rates dependent on the average riskiness of the entire borrower population. Hence, solid borrowers have to pay higher interest rates than under full information whereas risky borrowers can borrow at lower rates. This implies that risky borrowers impose an externality on solid borrowers. Importantly, this information problem can lead to a market breakdown. If solid borrowers perceive that the interest rate based on average riskiness is too high, they exit the market which leaves lenders with an adversely selected pool consisting of risky borrowers only. If lending to risky borrowers is deemed unprofitable, no lending will occur at all, such that profitable investment projects do not receive funding.

Adverse selection may also become an issue if banks are selling assets whose quality is private information. Investors who fear to buy "lemons" are only willing to acquire assets at a discount. If the discount is large, banks trying to sell solid assets will no longer participate in the market. Put generally, adverse selection can impair the functioning of important financial-market segments which creates inefficiencies of various forms and contributes to systemic risk.

4.5.1 Multiple Equilibria on Interbank Markets

Heider et al. (2009, 2015) adapt the concept of adverse selection to interbank markets and show that asymmetric information may give rise to multiple equilibria with different properties in terms of efficiency. In their model, heterogeneous banks are subject to both idiosyncratic liquidity shocks and shocks to credit quality. Idiosyncratic liquidity shocks lead to the emergence of an interbank market, which allows banks facing unexpected liquidity needs to borrow from banks with surplus liquidity. The functioning of the interbank market is impaired by adverse selection, which is present because shocks to credit quality are private information. Interbank lenders will consequently charge an interest rate which compensates for the average credit risk of all banks.

If the equilibrium interbank rate is too high, banks with good credit quality and a liquidity shortage do not borrow on interbank markets but prefer costly liquidation of their assets. If lending to the adversely selected pool of interbank borrowers is deemed unprofitable, the interbank market entirely breaks down and banks with a liquidity surplus rely on hoarding. The level of the interbank rate and thus the market constellation is critically determined by both the level and the dispersion of counterparty risk. The higher the general level of counterparty risk and the higher the differences in credit quality, the more likely becomes a market breakdown.

Importantly, the model exhibits the possibility of multiple equilibria for a certain (reasonable) range of parameter values. Banks choose their portfolio composition, i.e., the shares of liquid and illiquid assets, conditional on the expected interbank market constellation in the future. If banks expect that every bank will participate in the interbank market, portfolios are chosen to be relatively liquid in order to exploit profitable interbank lending opportunities. Conversely, if banks expect adverse selection, they choose relatively illiquid portfolios and future interbank activity is low or entirely absent. The expected market constellation thus emerges in a self-fulfilling fashion. Given the fact that market breakdowns trigger costly and inefficient liquidation, policy interventions are desirable. For example, imposing liquidity requirements acts as a coordination device which ensures full participation.

Figure 4.7 depicts market constellations as a function of counterparty risk p and its dispersion Δp.[28] For high levels of p and a low level of Δp, full participation represents the unique equilibrium. If Δp increases, the full participation equilibrium co-exists with an adverse selection equilibrium, in which solid banks with liquidity shortages rely on costly asset liquidation instead of interbank lending. For very high levels of Δp, full participation co-exists with a hoarding equilibrium, in which banks with a liquidity surplus are reluctant to lend to adversely selected borrowers. If p decreases, adverse selection becomes the unique equilibrium. For higher levels of Δp, the hoarding equilibrium sets in, and if Δp increases further, even risky banks stop demanding interbank loans which is called the no-borrowing constellation.

[28] Formally, p denotes the repayment probability of the risky and illiquid investment project of banks. Hence, counterparty risk declines in p. The dispersion of counterparty risk Δp is the difference of repayment probabilities between banks experiencing favorable and adverse shocks to credit quality.

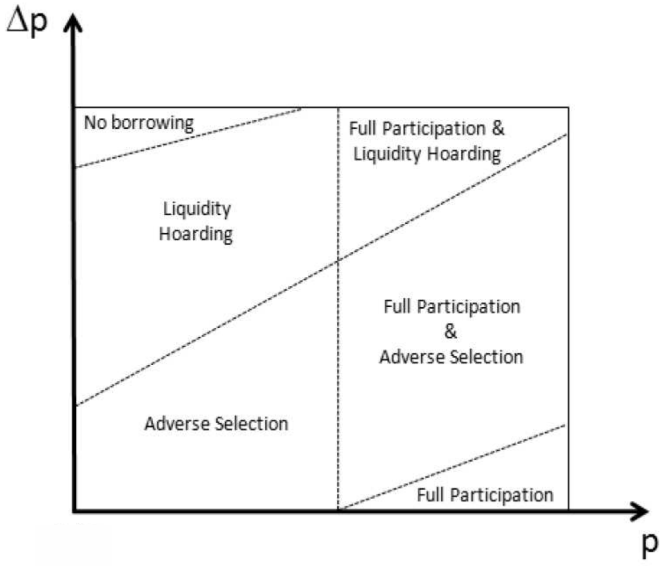


Figure 4.7: *Counterparty Risk and Interbank Market Constellations*

The behavior of interbank markets during the recent crisis is depicted in Figure 4.8 and can be analyzed through the lens of the model. Before August 2007, markets were characterized by the perception of low risk, and consequently spreads for unsecured interbank lending were very narrow.[29] This constellation corresponds to the full-participation equilibrium in which asymmetric information is regarded as a minor problem because of negligible counterparty risk. In August 2007, however, spreads rose and remained elevated until September 2008. At this time, several European banks started to report losses on mortgage-related securities, which probably caused a reassessment of both the level and the dispersion of counterparty risk. In September 2008, spreads rose to unprecedented highs and banks started to hoard liquidity as reflected by the dramatic increase of recourse to the ECB deposit facility, which was essentially zero before. The demise of Lehman Brothers in September 2008 seemingly led to a drastic upward revision of perceived counterparty risk and its dispersion. The increase in interbank rates mirrors an almost complete collapse of unsecured interbank markets,

[29] The Figure is adapted from Heider et al. (2015). Data was obtained from Datastream and the ECB. The interbank spread is calculated as the monthly average of the difference between the EURIBOR rate for unsecured interbank lending and the Repo Rate for secured interbank lending (both with a maturity of three months). Hence, the spread should almost exclusively reflect perceived interbank credit risk.

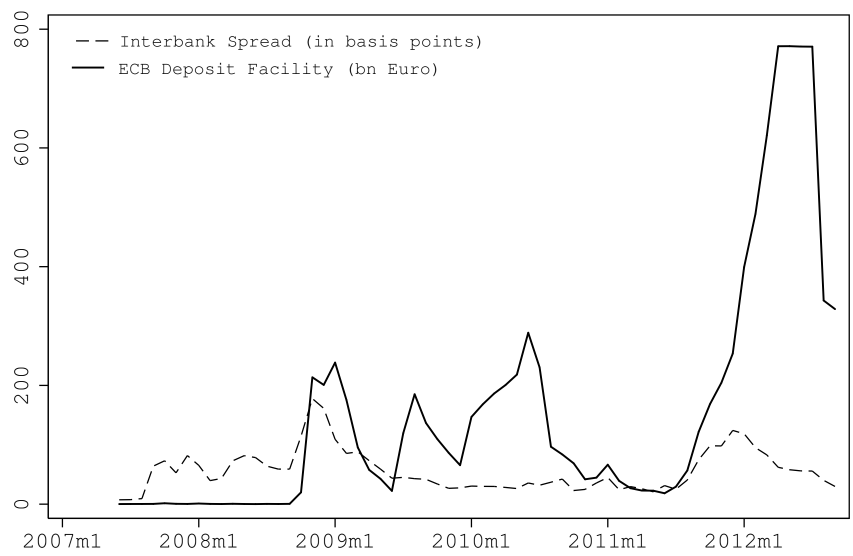


Figure 4.8: *Euro Area Interbank Market since 2007*

which corresponds to the model's constellation of liquidity hoarding in the wake of elevated counterparty risk. Spreads started to narrow in 2009 whereas recourse to the ECB deposit facility remained on a relatively high level. With the intensification of the government debt crisis in mid-2011, both spreads and deposit-facility recourse increased again.[30]

4.5.2 The Impairment of Secondary Markets for Opaque Assets

Bolton et al. (2011) analyze how adverse selection can impair secondary markets for opaque assets. Their model consists of short-term investors (henceforth STIs) and long-term investors (henceforth LTIs) with a longer time horizon. STIs should be regarded as banks whereas LTIs can for instance be interpreted as pension funds. LTIs can either invest in riskless long-maturity assets or they can hold cash. Returns from holding cash are zero per se, but under certain circumstances, cash can be used to acquire assets from STIs at potentially favorable prices. These cash balances are referred to as *outside*

[30] However, recourse to the ECB deposit facility cannot be explained exclusively within the model. For example, the ECB conducted several longer-term refinancing operations (LTROs) to reduce liquidity risk for a dangerously weakened banking system in the years after the Lehman failure. Apparently, banks obtained funding from LTROs and parked these funds in the ECB deposit facility instead of lending to other banks or to the non-financial sector. Hence, the ECB created a special opportunity for precautionary liquidity hoarding which is absent from the model.

liquidity. STIs can either hold cash (*inside liquidity*) or invest in risky assets. The latter are subject to two types of risk. First, payoffs may be delayed. Second, they might become zero.

Since STIs value early consumption more than LTIs, there is a secondary market for risky assets. STIs seek to sell assets with delayed payoffs to LTIs in order to obtain liquidity for early consumption. However, this secondary market is subject to an adverse selection problem. LTIs cannot observe whether the asset has only delayed payoffs or whether the asset is worthless in the sense that its payoff will be zero. Thus, assets trade at a discount. Nevertheless, asset trades between STIs and LTIs are generally welfare-enhancing. Since only STIs have access to the generally superior investment technology of the risky asset, it is socially desirable to maximize the amount which is invested into the latter. Put differently, liquidity needs of STIs are most efficiently satisfied by the provision of outside liquidity. However, if the adverse selection problem is severe, obtaining outside liquidity carries prohibitive costs for STIs and the market for outside liquidity collapses. Hence, STIs shift towards inside liquidity and aggregate investment in the risky technology declines.

Chapter 5

The Concept of Macroprudential Regulation

5.1 Theoretical Foundations of Macroprudential Regulation

The previous Chapters have offered two explanations for an excessive level of systemic risk: First, systemic risk may be driven by behavior which departs from strict rationality. Second, systemic risk can become inefficiently high due to the presence of systemic externalities. Given the outlined shortcomings of the limited rationality approach, it appears more promising to ground macroprudential regulation with its scope to contain systemic risk on the concept of systemic externalities.

5.1.1 Mitigation of Systemic Externalities

In theory, the ultimate objective of macroprudential regulation is to mitigate systemic externalities such as to ensure an adequate level of systemic risk. The models discussed in the previous Chapter consistently demonstrate that systemic risk can reach socially inefficient levels in the absence of regulatory intervention. Put differently, the presence of systemic externalities makes financial crises more likely and also more costly.

However, the considered models are highly stylized. While they highlight key mechanisms leading to excessive systemic risk, they are without doubt too simplistic to serve as guidance for real-world macroprudential policy measures. Moreover, in a real-world setting, externalities may occur jointly and interact with each other, whereas most models treat specific externalities in isolation. In this respect, Derviz (2013, p. 12) states that "financial intermediation theory [...] relies on toy models which provide only very indirect, if any, empirical guidance."

Hence, the mapping of theoretical results into practical policy measures is inherently difficult. For example, it is barely possible to confront the models with real-world data to obtain socially optimal capital and liquidity requirements. Nevertheless, the theory of systemic externalities delivers important conceptual underpinnings for practical macroprudential regulation. Even though the latter offers no quantitative guidance, each measure can be analyzed qualitatively regarding its likely contribution to the mitigation of systemic externalities. De Nicoló et al. (2012, p. 10) argue that macroprudential policy should be viewed "as a tool to correct externalities that create systemic risk. This approach gives more structure to the definition of systemic risk, and introduces economic rationale into the discussion of macroprudential policy."

5.1.2 Analysis of Potential Instruments

Table 5.1, which closely follows De Nicoló et al. (2012), provides an overview of potential macroprudential instruments. The first column depicts the five different forms of systemic externalities which were discussed in the previous Chapter. The five columns to the right list potential instruments. *X* indicates whether the respective policy instrument is able in principle to achieve internalization of the externality under consideration. Policy instruments are split into five categories: Capital requirements, liquidity requirements, restrictions on activities, assets and liabilities (henceforth RAALs), Pigouvian taxation and other measures.[1]

Externalities related to interconnections can be tackled with stricter capital requirements. If banks operate with higher capital cushions, they are more capable to absorb losses from interbank exposures such that higher-order propagation effects become limited to a great extent. Alternatively, interbank lending can be quantitatively restricted

[1] RAALs can take different forms. First, it is conceivable to impose quantitative limits on exposures against specific borrowers (or more generally on exposures against specific sectors) and on the issuance of certain types of liabilities. Second, RAALs can be qualitative in a sense that lending standards become subject to some minimum requirements. Third, some activities may be prohibited altogether.

with size limits which equally reduces contagion risk. As a last alternative, the formation of interbank linkages could be subject to (Pigouvian) taxation, which potentially dis-incentivizes banks from forming financial linkages which exacerbate systemic risk.

Strategic complementarities can be mitigated by higher capital requirements which make correlated investment strategies unattractive. Moreover, quantitative restrictions on asset allocation could limit common exposures. With respect to competition dynamics and procyclical lending standards, countercyclical capital requirements which tighten during the boom appear promising. As a complement, regulatory requirements on lending standards (qualitative RAALs) could be varied countercyclically, for example by lowering acceptable debt-to-income ratios of potential borrowers during a boom. As shown in Acharya et al. (2010b), strategic complementarities can also be mitigated by charging variable deposit insurance premia (see Section 4.2), which is subsumed under other measures here.

The risk of fire sales can be likewise contained via capital requirements. If banks have a sizable capital cushion, they can absorb losses without an impairment of debt claims. Hence, there is less need to sell assets in adverse states. Moreover, a stronger capital base makes banks more resilient against adverse valuation effects. Since fire sales typically arise from a liquidity mismatch, i.e., short-term creditors withdrawing their funds in the wake of bad news, liquidity requirements may also help to avoid fire-sale dynamics. Similarly, taxing short-term debt issuance may contribute to the implementation of a socially efficient amount of maturity transformation.

Liquidity externalities can be tackled with liquidity requirements. If banks are required to hold sufficient liquidity buffers, they can withstand adverse scenarios without relying on socially inefficient hoarding behavior or strategic illiquidity. Alternatively, liquidity mismatches could be subject to taxation so that their contribution to systemic risk becomes internalized (Perotti and Suarez, 2011).

Adverse Selection effects can be mitigated by more restrictive capital requirements. If banks are more capable to withstand losses, it becomes relatively less important that their individual solvency is private information. If their capital position is strong enough to render default risk negligible, adverse selection on interbank markets as in Heider et al. (2009, 2015) should be effectively contained. Alternatively, measures which enhance market transparency can contain adverse selection problems. For example, the involvement of rating agencies in assessing the value of opaque assets can avoid adverse-selection issues on secondary markets as in Bolton et al. (2011).

Type of Externality	*Internalization Strategies*				
	Capital Requirements	Liquidity Requirements	RAALs	Pigouvian Taxation	Other Measures
Interconnectedness	X		X	X	
Strategic Complementarities	X		X		X
Fire Sales	X	X		X	
Liquidity Externalities		X		X	
Adverse Selection	X				X

Table 5.1: *Internalization Strategies*

Which internalization strategies are best equipped for practical policymaking? It is apparent that capital requirements can contribute to the mitigation of each externality except the ones related to liquidity. Pigouvian taxation is also promising from a theoretical point of view, yet the proper calibration of such taxes is likely to be difficult and subject to political constraints. Liquidity requirements are well-suited to deal with liquidity externalities. RAALs seem appropriate to limit common exposures and the procyclicality of lending standards. In any case, macroprudential regulation should rely on a set of instruments. There is no single tool which is capable to mitigate every form of systemic risk. For example, capital requirements may fail to provide a binding constraints during booms. Rising asset prices and low default rates tend to increase capital positions, which facilitates credit expansion even in the case of relatively tight capital requirements. Hence, they should be augmented with a countercyclical element or by RAALs which ensure that lending booms are contained.

To sum up, I consider a combination of capital requirements, RAALs and liquidity requirements to be a more or less comprehensive toolkit to tackle the issue of excessive systemic risk. Potential forms of these instruments and the stage of their practical implementation are discussed in the following Section.

5.2 Practical Implementation

The recent crisis has triggered a substantial rethinking of policy aimed at financial stability. The crisis clarified that the attempt to secure individual soundness with microprudential measures is not a sufficient condition for systemic stability (Blanchard et al., 2010). Tarullo (2015, p. 2) even claims that "we are all macroprudentialists now." However, bridging the gap between theory and practice is exceptionally difficult. While market failures are relatively well understood on the theoretical level, it represents a substantial challenge to transfer these insights into robust policy frameworks.

Macroprudential regulation is still in its infancy. Its institutional structure, its objectives and their operationalization as well as its potential instruments and their correct calibration represent issues which still lack of a definitive answer.[2] Nevertheless, most advanced countries have created macroprudential regulation authorities which are equipped with specific instruments. It is likely that the experiences yet to be made will trigger further adjustments and refinements of the setup of macroprudential regulation. In what follows, I briefly discuss the current state of macroprudential supervision in the Euro Area.

5.2.1 Setup and Objectives of Macroprudential Policy in the EMU

Figure 5.1 depicts the institutional structure of macroprudential supervision in the European Monetary Union (henceforth EMU). Generally, macroprudential supervision is located at the level of member states. Most member states have assigned macroprudential authorities to their national central banks, while some have decided to allocate this task to separate national supervision authorities.

Macroprudential regulation is conducted in line with the Capital Requirements Directive (CRD IV) and the Capital Requirements Regulation (CRR), which were passed by the European Parliament in 2014. The CRD IV and the CRR basically transfer the international Basel III agreement on the future of banking supervision into European law. Moreover, national supervisors are able to implement further measures based on national law (flexibility clause). Importantly, policy decisions by national supervisors can be overruled by the Single Supervisory Mechanism (SSM). The SSM is the newly founded supervisory body for large banks within the Euro Area which operates under the roof of the European Central Bank. If the SSM seeks to implement a more restrictive policy stance than national supervisors, the latter have to comply with SSM recommendations.

[2] Various academic and policy-oriented papers have contributed to the debate on practical implementation. See for instance Aikman et al. (2013), Bank of England (2009, 2011), Claessens (2014), Galati and Moessner (2013), Hanson et al. (2011), Hellwig (2014) and IMF (2013b). IMF (2011) and Bruno et al. (2015) provide first empirical assessments of macroprudential policies primarily conducted in emerging markets.

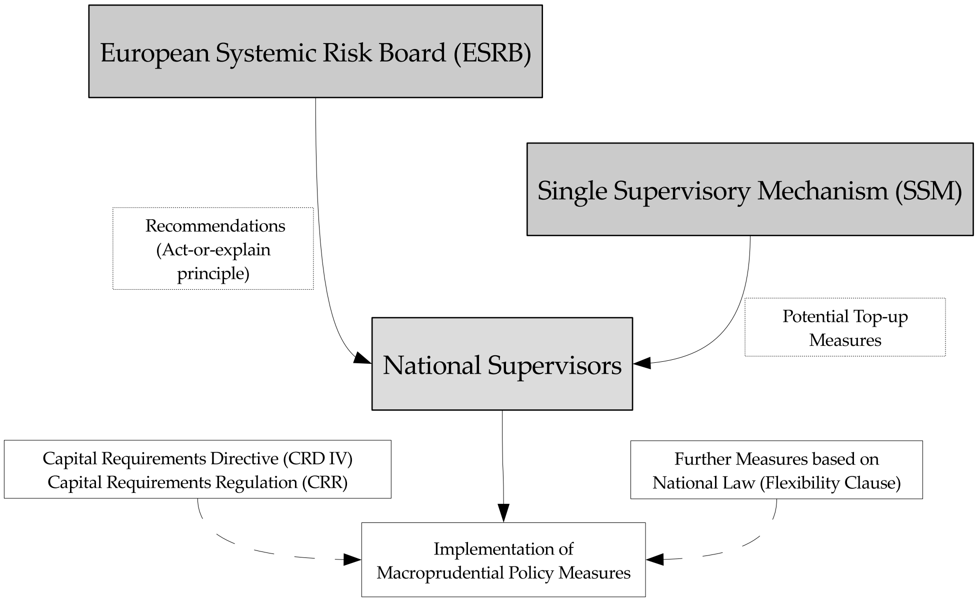


Figure 5.1: *Institutional Setup of Macroprudential Regulation in the EMU*

The European Systemic Risk Board (ESRB) is affiliated to the European Central Bank. It issues recommendations for and opinions on macroprudential policies in the EMU. They are not legally binding, but national supervisors have to deal with these recommendations on an act-or-explain basis. If they do not comply, they have to convincingly explain the reasons for deviating from ESRB recommendations.

Of course, the obvious objective of macroprudential policy is to reduce systemic risk by internalizing systemic externalities. However, the precise operationalization of this ultimate objective is difficult. With respect to the Euro Area, the ESRB has issued guidelines on potential macroprudential objectives and instruments. In ESRB (2013, p. 1), the ultimate objective of macroprudential regulation is defined as follows:

> "The ultimate objective of macro-prudential policy is to contribute to the safeguard of the stability of the financial system as a whole, including by strengthening the resilience of the financial system and decreasing the build-up of systemic risks, thereby ensuring a sustainable contribution of the financial sector to economic growth."

Hence, macroprudential regulation should promote the structural resilience of the financial system, i.e., its capability to withstand adverse shocks. Moreover, macroprudential policy is supposed to mitigate the build-up of systemic risk during booms by appropriate countercyclical measures. ESRB (2014b, p. 7) defines four mandatory intermediate objectives to operationalize the ultimate objectives from above. These intermediate targets are:

- Prevention of excessive credit growth and leverage
- Prevention of excessive maturity mismatch and market illiquidity
- Limiting direct and indirect exposure concentrations
- Limiting the systemic impact of misaligned incentives (moral hazard)

These intermediate objectives can be loosely traced back to the theoretical goal of correcting systemic externalities. For example, preventing excessive maturity mismatches is certainly useful to correct fire-sale and liquidity externalities. Limits on exposure concentrations may help to reduce externalities arising from excessive interconnections. Probably the most important factor is limiting leverage (or, equivalently, raising capital requirements) as such measures contribute to the mitigation of several systemic externalities at the same time.

5.2.2 Macroprudential Instruments in the EMU

There are various potential instruments at the disposal of macroprudential supervisors to achieve their intermediate objectives. Figure 5.2 provides a non-exhaustive list. In what follows, I will give a brief explanation of these measures.

Prevention of Excessive Credit Growth and Leverage: An important instrument is the so-called Countercyclical Capital Buffer (CCB). National authorities can increase capital requirements by up to 2.5% of risk-weighted assets if credit growth within the national financial system is deemed excessive.[3] A potential indicator of excessive credit growth is the deviation of the credit-to-GDP ratio from its historical trend, as measured by a

[3] Capital surcharges are related to *risk-weighted assets*. To obtain a measure for risk-weighted assets RW, an asset position X has to be multiplied with an appropriate risk weight r. Of course, risk weights vary with the riskiness of assets. Risk weights can be obtained from the so-called standard approach or by applying internal risk management models. The standard approach maps publicly available

Prevention of Excessive Credit Growth and Leverage

- Counter-cyclical capital buffer
- Leverage Ratio
- Loan-to-value requirements (LTV)
- Loan-to-income requirements (LTI)

Prevention of Excessive Maturity Mismatch and Market Illiqudity

- Liquidity coverage ratio
- Net stable funding ratio
- Loan-to-deposit ratio
- Margin and haircut requirements

Limiting direct and indirect Exposure Concentrations

- Large exposure restrictions

Limiting the Systemic Impact of Misaligned Incentives (Moral Hazard)

- Capital Surcharges for Systemically Important Financial Institutions (SIFI)

Source: ESRB (2013, 2014)

Figure 5.2: *Selected Macroprudential Instruments in the EMU*

one-sided Hodrick-Prescott filter (ESRB, 2014a, p. 37). The CCB is complemented by the leverage ratio, defined as the ratio of total *non* risk-weighted assets to capital. It must not exceed a value of 33. Equivalently, the ratio of capital to total assets must not be below 3%. The leverage ratio serves as a backstop, since accumulating large positions of assets with low or zero risk weights can lead to a dangerous build-up of leverage which is not reflected in risk-weighted capital adequacy measures, especially if risk-weights turn out to be undersized (Bundesbank, 2011). Loan-to-value requirements (LTV) are mainly directed towards residential real-estate financing and stipulate that the loan amount must not exceed a certain percentage of the property value (for instance 80%). Loan-to-income requirements restrict the loan amount to not exceed a certain multiple

ratings into specific risk-weights. For example, government bonds issued from countries with an AAA-rating have a zero risk weight $r = 0\%$. Conversely, a claim on a company rated below BB- has a risk weight of $r = 150\%$. Each asset has to be multiplied with an appropriate risk weight to arrive at an aggregate measure of risk-weighted assets. Banks consequently have to fund a certain share of risk-weighted assets with capital. The Basel III standards, which are supposed to be implemented until 2019, require banks to fund 10,5% of risk-weighted assets with capital (see for instance Bundesbank (2011, p. 19)). Macroprudential motivated surcharges will be added to this measure.

of borrower income.

Prevention of Excessive Maturity Mismatch and Market Illiquidity: As inter alia specified in Bundesbank (2011), the liquidity coverage ratio (LCR) is defined as

$$LCR = \frac{\text{Highly Liquid Assets}}{\text{Net Outflows under pre-defined Stress Scenario in 30 days}} \geq 100\% \tag{5.1}$$

which aims to contain the risks of banks experiencing liquidity shortages under adverse market conditions. It is directed towards short-term liquidity risk management. Cash and government bonds count as highly liquid assets, whereas private sector assets can contribute to the enumerator only with a steep haircut. The net stable funding ratio (NSFR) seeks to contain maturity transformation by requiring a certain amount of stable long-term funding for long-term assets. The Basel Committee on Banking Supervision (henceforth BCBS) defines the NSFR as

$$NSFR = \frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \geq 100\% \tag{5.2}$$

where the enumerator is defined "as the portion of capital and liabilities expected to be reliable over the time horizon considered by the NSFR, which extends to one year." (BCBS, 2014, p. 2) The denominator is defined to be "a function of the liquidity characteristics and residual maturities of the various assets held by that institution as well as those of its off-balance sheet (OBS) exposures." (BCBS, 2014, p. 2) The precise definitions of the involved balance-sheet items are still subject to regulatory debates. In any case, the NSFR seeks to ensure that funding stability is achieved over a one-year-horizon. Loan-to-deposit ratios are designed to limit the reliance of banks on potentially fragile funding sources such as repos and unsecured interbank loans. Along similar lines, haircuts on collateralized financing could become subject to minimum requirements.

Limiting direct and indirect exposure concentrations: Supervisors can implement restrictions on large exposures. For example, interbank loans could be restricted to not exceed a certain share of capital and/or total assets. The same principle could be applied to exposures towards national governments or large firms. It is also conceivable to limit sectoral exposures, for instance in the field of real-estate finance.

Limiting the systemic impact of misaligned incentives: Supervisors have the possibility to impose additional surcharges on systemically important financial institutions (SIFIs).

Institutions which are systemically relevant on a global level have to hold additional capital in the range of 1% and 3,5% of risk-weighted assets (BCBS, 2013).[4] It is also possible to impose capital surcharges of up to 2% of risk-weighted assets on institutions which are systemically relevant from a domestic perspective. Moreover, there is a flexible systemic risk buffer of up to 3% of risk-weighted assets which can be applied to all or to a subset of banks. SIFI surcharges are designed to limit the adverse incentives emerging from the well-known too-big-too-fail problem. Moreover, these surcharges increase the resilience of SIFIs and contain the risk of potentially disastrous higher-order propagation effects in case of their default.

The implementation of the aforementioned instruments is an ongoing process. For example, both the leverage ratio and the liquidity coverage ratio will not be fully operational before 2019. The same holds for SIFI capital surcharges. The net stable funding ratio will become a binding standard from 2018. There are various reasons for these large implementation lags. First, international standard-setting amounts to a difficult bargaining problem due to often diverging interests of national jurisdictions. Moreover, banks should have the possibility to adjust gradually towards the new regulatory environment. Furthermore, the definitions of certain measures are still subject to international consultation. For instance, there are ongoing debates which balance-sheet items should count as regulatory capital.[5]

5.3 Systemic Risk Measurement

The macroprudential toolkit in the EMU and in other jurisdictions will consist of various instruments and their proper calibration requires precise measurement techniques for systemic risk. For this purpose, systemic risk is usually divided into two categories. The *time dimension* seeks to track the development of aggregate systemic vulnerabilities over time, whereas the *cross-sectional dimension* analyzes how systemic risk is distributed within the system at a given point in time (Caruana, 2010; Galati and Moessner,

4 As of 2014, Deutsche Bank is considered to be the only SIFI in Germany with a recommended additional capital requirement of 2% of risk-weighted assets (Financial Stability Board, 2014).

5 Instruments also differ with respect to their legal basis. Some have been implemented via EU law, whereas others are proposals whose usage is mainly at the discretion of national authorities. An introduction to legal details along with legislative references is provided by Angeloni (2014) and ESRB (2013, 2014b).

2013). In what follows, I provide a brief and selective overview on measurement techniques for both dimensions.[6]

5.3.1 Measurement in the Time Dimension

The development of systemic risk in the time dimension can be analyzed with the help of early-warning models, as first proposed in Kaminsky et al. (1998) and Reinhart and Kaminsky (1999). Generally speaking, early-warning models seek to find macro-financial indicators which predict future financial distress. Alessi and Detken (2011) provide an early-warning model which tries to identify indicators which predict costly asset price booms by using data from 18 OECD countries between 1970 and 2007. An asset price boom is generally defined as a constellation in which an aggregate asset price index comprising deflated equity and property prices exceeds its recursive Hodrick-Prescott trend by 1.75 times its recursive standard deviation for three consecutive quarters.[7] An asset price boom is defined as costly if cumulative real GDP growth in the subsequent three years is three percentage points below potential.

An indicator's performance is assessed on the basis of its ability to issue a warning signal up to six quarters in advance of costly asset price booms. An indicator issues a signal if its value exceeds a certain pre-specified threshold. The authors use real and financial variables such as GDP, investment, different asset prices and interest rates as well as several types of monetary and credit aggregates as potential indicators. These variables are also assessed in various transformations, such as year-on-year growth rates and recursive Hodrick-Prescott trend deviations.

As depicted in Table 5.2, an indicator can generate four outcomes at a certain point in time. Outcomes A and D imply that the indicator issues correct signals. However, the indicator might miss a future crisis and fail to issue a warning signal, which is called type-I error (outcome C in the Table). On the other hand, an indicator can issue a warning signal even if no crisis occurs in the future, which is labeled as type-II error and corresponds to outcome B. Alessi and Detken (2011) subsequently define a loss function of

[6] For a much more comprehensive review of systemic risk measures, the reader is referred to Bisias et al. (2012).

[7] The Hodrick-Prescott (HP) Filter generally decomposes a time series into a trend component and a cyclical component ("gap"). See Neusser (2009) for a textbook treatment. The recursive HP filter applied in period t only applies current and past values instead of using the entire sample. This procedure is designed to mimic real-time conditions in period t, where future values of the time series are unknown.

	Costly boom-bust cycle	No costly boom-bust cycle
Signal issued	A	B
No Signal Issued	C	D

Table 5.2: *Behavior of Early Warning Indicators*

$$L = \theta \frac{C}{A+C} + (1-\theta)\frac{B}{B+D}, \tag{5.3}$$

where the first term $C/(A+C)$ measures how often the indicator fails to issue a warning signal in relation to the total number of signals issued before a costly asset price boom. Put differently, this term depicts the relative share of type-I errors. The second term $B/(B+D)$ displays the relative share of type-II errors, where the indicator issues a signal despite no costly asset price boom takes place. The parameter θ captures preferences of policymakers. If θ is high, policymakers rather care about missing a future crisis than receiving false alarms. Vice versa, if θ is low, policymakers are primarily concerned with the risk of false alarms, where a non-justified tightening of the macroprudential policy stance would unnecessarily restrict lending and finally economic activity.

The loss function is minimized conditional on the value of θ by choosing an appropriate threshold for which the indicator issues a warning signal. For example, suppose that the deviation of the credit-to-GDP ratio from its long-run trend is used as an indicator. If θ is high, the optimal loss-minimizing threshold will be low. That is, a warning signal will be issued already for relatively small upward trend deviations of the credit-to-GDP ratio. Small upward deviations are not necessarily predicting a crisis with sufficient probability, yet policymakers care less about type-II errors and more about the risk of missing a crisis. Conversely, if θ is low, the threshold will be high. Policymakers are more concerned with type-II errors, therefore trend deviations of credit need to become sufficiently large before a warning signal is issued in order to minimize false alarms. The usefulness U of an indicator is expressed as

$$U = \min[\theta; 1-\theta] - L. \tag{5.4}$$

The policymaker can always realize a loss of $\min[\theta; 1-\theta]$ by disregarding the indicator. If $\theta < 0.5$, the indicator is ignored in such a way that no crisis signals are received, i.e., $A = B = 0$ which would imply a loss of θ according to (5.3). If $\theta > 0.5$, the policy-maker acts as if the signal is issued in any period, such that $C = D = 0$ and $L = 1 - \theta$. If utilizing the indicator yields to a loss $L < \min[\theta; 1 - \theta]$, its usefulness increases. Put differently, an indicator's usefulness increases with the reduction of losses compared to the case when it is disregarded.

Alessi and Detken (2011) find that upward deviations of credit aggregates from their Hodrick-Prescott trend (henceforth HP-trend) are the most useful indicators for the majority of countries, followed by upward trend deviations of monetary aggregates.[8] Interestingly, it is the global gap of private credit-to-GDP which delivers the most accurate results. This could reflect the fact that asset price booms often occur jointly across countries. As a general observation, it is easier to obtain useful indicators if policymakers have relatively balanced preferences, i.e., if θ is close to 0.5. If preferences are asymmetric, it is barely possible to find useful indicators. The authors additionally conduct an out-of sample exercise, with thresholds calibrated on a sub-sample ranging from 1970 to 2002. It is then examined how the indicators perform in predicting the recent financial crisis. Again, the global gap of private credit-to-GDP performs best whereas monetary aggregates broadly fail to issue any reliable warning signal. Regarding practical applications, Behn et al. (2013) assess early-warning models with respect to their usefulness in calibrating the countercyclical capital buffer and obtain encouraging results.

Borio and Drehmann (2009) perform a methodologically similar analysis which focuses on the prediction of banking crises instead of boom-bust cycles of asset prices. They find that upward trend deviations of credit-to-GDP ratios, especially when occurring jointly with property price gaps, are reliable predictors of banking crises with a forecast horizon of up to three years. Moreover, Drehmann (2013) shows that incorporating credit aggregates which also capture non-bank loans leads to a further improvement of forecast performance. Hahm et al. (2013) and Shin (2013) demonstrate that pronounced growth of Non-Core Liabilities of banks is an equally promising early-warning indicator. Non-Core Liabilities such as repos and interbank obligations are typically of a short-term nature and inherently fragile. If banks increasingly rely on the latter, they are more susceptible to funding shortages, which may ultimately give rise to liquidity externalities and fire sales.

To sum up, there are various reliable early-warning indicators. Most authors emphasize the special role of upward trend deviations of credit-to-GDP ratios in this re-

[8] A detailed breakdown of results can be found in the working-paper version of their publication (Alessi and Detken, 2009).

spect. Figure 5.3 plots credit-to-GDP gaps for selected countries.[9] The horizontal line depicts an early warning threshold, i.e., if the gap exceeds 4%, a warning signal would be issued. The threshold corresponds to the average of the values employed by Borio and Drehmann (2009), who varied the latter between 2% and 6%.

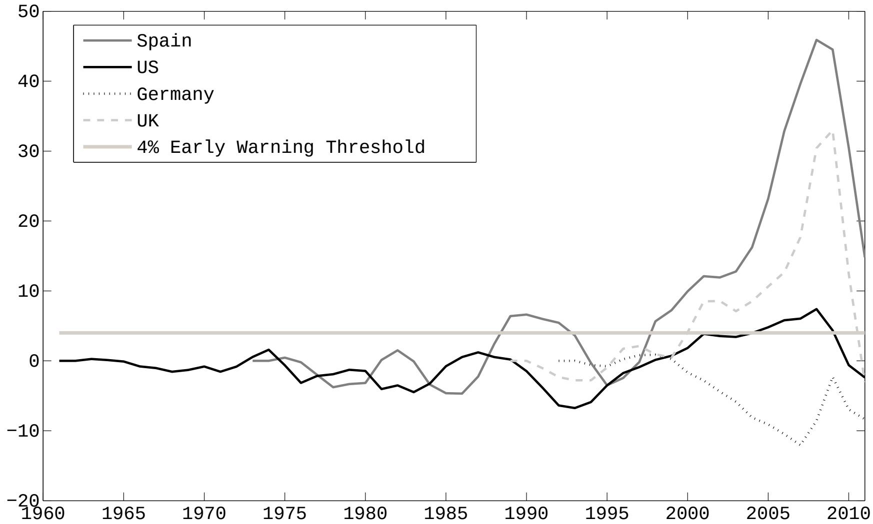


Figure 5.3: *Bank Credit-to-GDP Gaps for Selected Countries*

Apparently, credit gaps would have issued (strong) warning signals in the run-up to the crisis. Especially UK and Spain realized unprecedented credit gaps prior to 2007. For the US, the gap appears less spectacular, but a warning signal would have been issued as early as 2004 nonetheless.[10] It is somewhat surprising that credit expansion in the US appears to have been relatively mild. The potential reason is that the credit aggregate under consideration tracks commercial banks only, and therefore does not cover the enormous increase in credit granted via the shadow banking system. It is

[9] Gaps were obtained by de-trending the ratios of outstanding private bank credit to GDP using a recursive HP-filter with a smoothing factor of $\lambda = 1600$, as proposed in Borio and Drehmann (2009). Data was obtained from FED FRED and is on a yearly basis. Recursive HP-filtering was conducted with a MATLAB routine provided by Meyer-Gohde (2010).

[10] Of course, HP-filtered estimates from small samples should be analyzed with caution, especially given the fact that the HP-filter suffers from low precision at the end of the sample (St-Amant and van Norden, 1997). As a partial remedy, the sample could be enlarged by using quarterly data and a higher smoothing factor (ESRB, 2014a, p. 37). Here, I nevertheless stick to the approach of Borio and Drehmann (2009) and use yearly data (which is also more readily available). The problems associated with HP-filtering notwithstanding, the observed pattern is remarkably clear and is therefore likely to be robust against applying different de-trending methods.

also interesting to observe that there would have been no warning signal for Germany, which is at odds with the crisis experience, namely that several banks required government assistance. This can be attributed to the fact that German banks accumulated large cross-border exposures, especially towards the US housing market, which are not mirrored in a domestic credit aggregate. Indeed, Borio and Drehmann (2009) argue that credit aggregates should be adjusted for cross-border exposures, which is unfortunately very difficult because of data availability constraints.

5.3.2 Measurement in the Cross-Sectional Dimension

Measuring systemic risk in the cross-sectional dimension tries to capture the individual contributions of financial institutions to systemic risk at a given point in time. While measurement in the time dimension targets aggregate vulnerabilities, measurement in the cross-section ideally allows to assess the systemic importance of single institutions such that institution-specific measures like SIFI capital surcharges can be adequately calibrated.

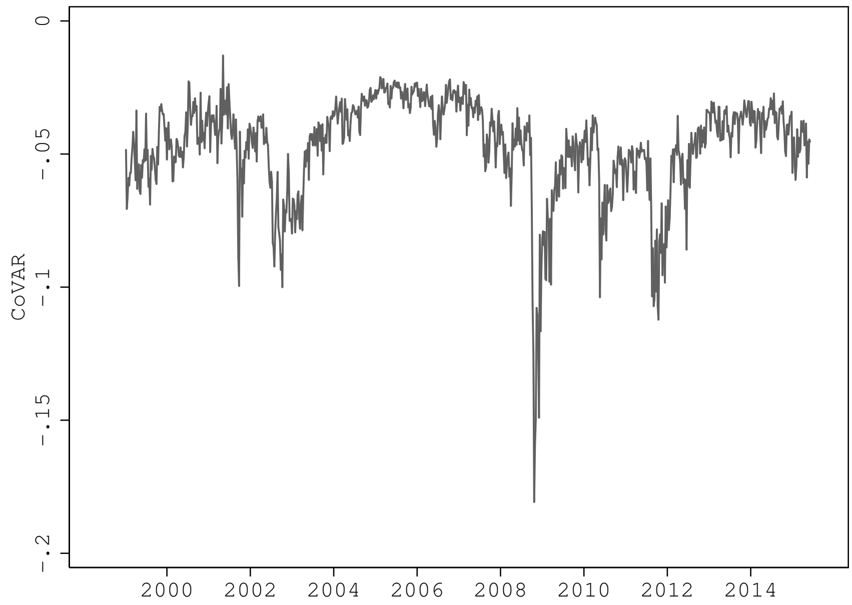
Adrian and Brunnermeier (2011) propose a systemic-risk metric called $CoVaR$, which grounds on the Value-at-Risk (VaR) methodology briefly discussed in Section 3.2.2. As a first step, the authors estimate the VaR of the weekly growth rate of total assets of financial intermediaries. If the 95%-VaR of a certain institution in that respect is given by -5%, this means that total assets will not shrink by more than 5% with a probability of 95%.[11] Focusing on the growth of total assets seeks to capture the risk of shrinking balance-sheet capacity and thus the risk of deleveraging with its potential consequences (such as fire sales).

The $CoVaR_{i,q}$ of a single institution i measures the q%-VaR of the growth rate of total assets for the entire financial sector *conditional* on institution i being in distress.[12] The lower the $CoVaR_{i,q}$ realization, the higher the risk that distress of institution i will give rise to systemic deleveraging. In this sense, $CoVaR_{i,q}$ serves as a measure of the individual contribution of institution i to systemic risk. Consider a numerical example

[11] Weekly data on the evolution of total assets is proxied by multiplying current market capitalization with book leverage, where the latter is defined as the ratio of total assets to equity at book values. Both VaR and CoVaR are estimated making use of quantile regressions. See Adrian and Brunnermeier (2011, pp. 13-16) for details.

[12] Financial distress is defined as an event in which the growth rate of total assets of institution i is lower or equal to its own q%-VaR, i.e., it is an event in which institution i experiences an abnormally high decline in total assets.

for illustration: If $CoVaR_{i,q}$ = - 10%, the weekly growth rate of total assets of the financial sector decreases by less than ten percent with a probability of q if institution i is in distress. Hence, the further the $CoVaR$ moves into negative territory, the more likely it becomes that distress at institution i will give rise to system-wide declines in balance-sheet capacity.



Source: ESRB Risk Dashboard

Figure 5.4: *Average CoVaR for European Banks*

Figure 5.4 depicts the average $CoVaR$ for European Banks. Bank-specific data is not made public for confidentiality reasons and to avoid stigma. Nevertheless, it becomes apparent that the average $CoVaR$ declines drastically during a crisis, as for instance during 2008. Hence, the potential for adverse spillovers and systemic deleveraging is especially pronounced during a crisis. This result is certainly not surprising. Interestingly, the individual $CoVaR$ of an institution can be reliably predicted by its balance-sheet characteristics, especially its size, its leverage and the degree of maturity transformation at a two-year time horizon. It might thus be possible (in principle) to infer the individual contribution of a single institution to systemic risk from its balance-sheet characteristics, which may finally help to calibrate macroprudential measures geared towards the internalization of individual systemic risk contributions on an ex-ante-basis.

There is an increasing amount of further cross-sectional systemic risk measures. For example, Acharya et al. (2010a) propose an alternative measure of cross-sectional systemic risk called *Systemic Expected Shortfall* (SES), which measures whether individual institutions tend to experience capital shortfalls in times of systemic stress. The authors emphasize its use for calibrating a macroprudential tax. Drehmann and Tarashev (2013) propose a measure which relates the systemic importance of individual banks to the losses they impose on non-bank creditors in a systemic crisis. Chan-Lau (2010) provides an example for network analysis techniques based on individual balance-sheet data, which seeks to assess systemic risk arising from interconnectedness.

5.4 Unresolved Issues

Even though macroprudential supervision starts to be operational in most of the advanced countries, there are several unresolved issues which cast serious doubt on the ability of current arrangements to effectively contain systemic risk. In what follows, I will outline various shortcomings of the current state of macroprudential supervision.

5.4.1 Regulatory Arbitrage

An important yet unresolved problem is the risk of regulatory arbitrage. Macroprudential supervision is primarily directed towards the banking system. However, stricter regulation of banks may trigger a shift of intermediation activities into less regulated financial market segments or less regulated jurisdictions, respectively.[13] Adrian (2014) argues that regulatory arbitrage is a key motivation for shadow banking activities, meaning that commercial banks accumulate exposures via off-balance-sheet vehicles which are subject to less regulatory scrutiny. However, the regulation of shadow banking activities is still in its infancy. Hence, macroprudential regulation may succeed in containing systemic risk which arises from traditional banking operations, but vulnerabilities might continue to develop in other areas of the financial system.

[13] Regulatory arbitrage for banks across jurisdictions has been empirically documented by Houston et al. (2012). Moreover, Aiyar et al. (2012) show for the UK that tightening capital requirements for domestically regulated banks does not help to restrict aggregate credit supply, since foreign banks not affected by tighter regulation increase their lending activities in that case.

5.4.2 Too-Big-Too-Fail Problems

The problem that some institutions are too big and too interconnected to fail continues to be a pressing concern. While SIFI capital surcharges are a step in the right direction, they are very likely to be undersized. Haldane and Booth (2014) estimate that SIFI capital surcharges should be at least in the area of about 7% of risk-weighted assets, which would correspond to doubling the maximally conceivable amount under current regulation. Furthermore, if an institution is officially declared to be systemically important, this essentially boils down to an explicit government guarantee, especially given the ongoing lack of global resolution procedures for multinational and highly interconnected banks. Various authors have found that this translates into a sizable implicit subsidy which manifests itself in substantially lower funding costs even in an environment of tighter regulation. For example, the IMF (2012) estimates the amount of this subsidy for global SIFIs to be in the area of 60-80 basis points while Noss and Sowerbutts (2012) detect sizable subsidies for banks in the UK. Generally, government guarantees tend to weaken monitoring incentives and may spur risk-taking (Kareken and Wallace, 1978; Keeley, 1990). It therefore appears unfortunate that the share of bank liabilities enjoying either explicit or implicit government backing has increased in trend during the last decades. For the US, Marshall et al. (2015) estimate that the share of guaranteed liabilities rose from roughly 45% in 1999 to 60% in 2013. These results strongly suggest that externalities resulting from interconnectedness and the too-big-too-fail problem in general are not adequately internalized by the current supervision framework. Hence, banking supervision continues to suffer from a fundamental time-inconsistency problem, especially with respect to large and interconnected institutions.

5.4.3 Political Constraints

Macroprudential regulation is countercyclical in its nature. Ideally, the policy stance should be tightened during the boom and relaxed during the bust. However, tightening the policy stance during booms may turn out difficult because of political constraints. The public opinion towards countercyclical measures justified by concerns about systemic risk is likely to be negative, especially since the nature of systemic risk is arguably more difficult to understand than for example the benefits of price stability. Baker (2015, pp. 19-23) summarizes this problem as follows:

> "It is that countercyclical measures are most required from the perspective of the system as whole at precisely the point when there is least political and social appetite for them, because they appear to the majority, from an individual perspective, to be unnecessary due to perceived low risks. [...] The benefits of macroprudential [regulation] relate to reducing the hidden long term costs generated by systemic risk and financial instability. These are much more difficult to articulate and communicate in terms of near term individual benefits."

A strict rule-based application of macroprudential instruments would greatly alleviate this problem. However, there is no widely accepted rule for calibration so far. Indeed, ESRB (2014a) recommends basing macroprudential policy on the principle of "guided discretion." Given the relative inexperience with systemic-risk measurement, quantitative recommendations should always be supplemented with supervisory judgment. This will make it difficult to conduct macroprudential policy free of political influence.[14] Put bluntly, it will be tough to take a stand in a debate against politicians and industry representatives armed with a one-sided HP filter as the main argument. Hellwig (2009, pp. 189-191) additionally stresses the risk of "regulatory capture," meaning that supervisors might tend to act in the interest of banks instead of society, for instance motivated by political preferences for large domestic banking groups ("national champions"). Hence, it remains to be seen whether countercyclical policies can be applied with sufficient rigor. Moreover, policies may be complicated by time lags in data collection and implementation.

5.4.4 Fundamental Procyclicality

Bank balance sheets behave procyclically by nature. If assets are valued at market prices and liabilities have a fixed nominal value, asset price fluctuations will translate into fluctuations of the equity base. During an asset price boom, banks' equity positions are strengthened almost mechanically, which facilitates an expansion of balance sheets and

[14] The advantages of rule-based over discretionary policies have been formalized in an influential contribution by Kydland and Prescott (1977). See also Barro and Gordon (1983) as well as Taylor (2012) for applications of their insights to monetary policymaking. However, the operating environment of macroprudential supervision is characterized by enormous complexity and uncertainty. This makes discretion unavoidable to some extent, at least until policymakers have gained reliable experience regarding the impact of their instruments.

further asset price increases (Adrian and Shin, 2010b). Tighter capital regulation can dampen the amplitude of such effects, but it cannot fully eliminate them. For this reason, Shin (2013) and Cochrane (2014) propose taxing balance-sheet expansions during asset price booms, especially when funded via inherently fragile Non-Core Liabilities such as repos and interbank debt. These proposals have not entered the supervisory toolkit to date.

5.4.5 Flawed Risk-Weighting

The practice of imposing capital requirements based on risk-weighted assets is subject to increasing criticism. First, risk-weighting makes capital regulation inherently procyclical (Kashyap and Stein, 2004; Hellwig, 2009). During a boom, credit ratings of borrowers tend to improve which reduces their risk weight and hence the required capital cushion. In the bust, credit ratings deteriorate, which automatically raises risk weights and capital requirements precisely when they are most difficult to fulfill. Moreover, risk weights for some asset classes are regarded to be inadequately low. For example, domestic government bonds need to backed with zero capital in most jurisdictions. As emphasized by Weidmann (2012), this very practice made banks within the Euro Area very vulnerable to solvency problems of governments. It arguably strengthened the adverse feedback loop between declines in government solvency and increasing banking distress associated with the need for fiscal support, which is regarded as one of the key issues in the EMU sovereign debt crisis (Shambaugh, 2012). Furthermore, Scopelliti (2014) documents that capital requirements for asset-backed securities have been very low prior to the crisis.[15] Another issue is that banks are allowed to calculate risk weights according to internal risk-management models. While this practice is useful in general, Mariathasan and Merrouche (2014) as well as Begley et al. (2015) provide evidence for strategic under-reporting of risks, that is, banks exploit discretionary leeway in internal risk modeling to obtain artificially low risk weights for the purpose of capital requirement minimization. Hence, it has to be concluded that the inherent deficiencies of the risk-weighting approach allow banks to accumulate too much risk with too little capital.

[15] An AAA-rated asset-backed security (ABS) had to be funded with roughly 1% of capital, which (at least with the benefit of hindsight) appears clearly undersized.

5.4.6 Excessive Leverage

The risk-weighting approach allows banks to operate with inadequately thin capital cushions. The Basel III framework addresses this issue by imposing a leverage ratio, i.e., the ratio of total *non*-risk-weighted assets to capital must not exceed 33. Put differently, roughly 3% of total assets have to be funded with capital. Various authors consider this requirement to be drastically insufficient. Most prominently, Admati et al. (2010) and Admati and Hellwig (2013) make the case for a ratio in the range of 20-30%.[16] Miles et al. (2013) conduct a cost-benefit analysis of capital requirements and conclude that optimal capital ratios should be much higher than envisaged under Basel III. Specifically, they find that the optimal capital ratio is between 7-10% of total risk non-weighted assets. However, Hoenig (2015) documents that average capital ratios of global SIFIs were just below 5% at the end of 2014. Angelini et al. (2015) estimate the costs of an increase in capital requirements by employing calibrated dynamic stochastic general equilibrium models (henceforth DSGE-models) for the EMU and the US, and find that a one percentage point increase leads to a small decline of about 0.1% in the steady state GDP level. However, they do not account for the indirect benefits of reduced crisis risk. Hanson et al. (2011) demonstrate that there is no historical correlation between bank capital ratios and lending spreads. Haldane and Madouros (2012) show that banks' non-risk-weighted leverage ratios have been a more reliable predictor of failure during the crisis that the risk-weighted capital ratio. Moreover, the majority of banks which failed during the crisis operated with leverage ratios well below the new regulatory benchmark of 33. Consistent with this, the IMF (2010) estimates that the recent financial crisis forced the global banking system to conduct cumulative write-downs amounting to about 4% of their total assets. To sum up, there are very convincing theoretical and empirical arguments suggesting that banks are still allowed

[16] Moreover, they debunk various claims pertaining to the optimality of high bank leverage. For example, it used to be a widely shared position that high leverage is beneficial as it allows banks to maximize the creation of liquid money-like liabilities. However, their liquidity would actually be improved if banks become safer by holding more equity (see Admati and Hellwig (2013, ch. 10) and the references therein). Another popular argument is that holding capital is costly. Raising capital requirements would raise banks' funding costs and thus leads to more restrictive lending conditions which would harm economic growth. However, the cost of capital is not constant. The riskiness of bank equity decreases with declining leverage, and so does the required return on equity (Admati and Hellwig, 2013, ch. 7). A counterargument against a strict leverage ratio is brought forward by Burghof and Müller (2014), who show that leverage ratios tend to reduce specialization in the banking sector which can lead to correlated portfolios. The latter outcome can adversely affect systemic risk, as it was discussed in Section 4.2.

to operate with excessive leverage. Unfortunately, these insights have had very little policy impact so far.

Hence, I arrive at an unpleasant conclusion: The current state of macroprudential regulation is insufficient to guarantee the resilience of the financial system and to mitigate its inherent procyclicality. Put differently, systemic risk remains excessive and the associated externalities are not fully mitigated. This result brings off the first part of my thesis. Given the insufficiency of macroprudential supervision, systemic risk ultimately becomes a concern for monetary policy. The subsequent part explores the nexus between monetary policy and systemic risk.

Part II

The Nexus of Monetary Policy and Systemic Risk

Chapter 6

Why is Systemic Risk a Challenge for Monetary Policy?

Systemic risk materializes in the form of a severe financial crisis and spillovers to the real economy can adversely affect the central bank's capability to pursue its essential objectives. The primary objective for monetary policy is to deliver price stability. Some emphasis is also put on the stabilization of output and employment, but usually only to the extent that there is no interference with the primary objective. If macroprudential regulation fails to mitigate the build-up of systemic risk, the associated risks to price and output stability inevitably become a concern for monetary policy.

Monetary policy objectives are prominently anchored within central bank laws. With respect to the European Central Bank, Article 127(1) of the Treaty on the Functioning of the European Union stipulates that "[t]he primary objective of the European System of Central Banks [...] shall be to maintain price stability." Regarding the Federal Reserve System, Section 2A of the Federal Reserve Act defines "the goals of maximum employment, stable prices, and moderate long-term interest rates."

The actual operationalization of the price stability objective is left to central banks themselves. The ECB (2014) states that she "aims to maintain inflation rates below, but close to, 2% over the medium term," where inflation is measured by "a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area." The Federal Reserve contends in a statement by the Federal Open Market Committee (2014) that "inflation at the rate of 2 percent, as measured by the annual change in the price index for personal consumption expenditures, is most consistent over the longer run with the Federal Reserves statutory mandate."

With respect to output and employment stabilization targets, central banks generally do not provide any explicit guidance. Nonetheless it is often assumed that monetary policy seeks to keep GDP growth close to the growth rate of potential output as a secondary objective. This holds similarly (and to some extent interchangeably) for employment, where monetary policy is thought to minimize deviations between the actual and the "structural" unemployment rate.

Price stability is considered as desirable since inflation produces considerable economic and social costs (Fischer and Modigliani, 1978), whereas an output stabilization objective can be justified theoretically with household preferences for consumption smoothing (Woodford, 2003). Accordingly, an approach of simultaneously targeting inflation and (to a lesser extent) the output gap has become the dominant theoretical doctrine of monetary policymaking before the financial crisis. It is usually referred to as *flexible inflation targeting*.[1]

Theoretical treatments of monetary policymaking usually assume that central banks seek to minimize a loss function by appropriately using their policy instrument. A standard central bank loss function for a period t is given by

$$L_t = (p_t - p^*)^2 + \lambda(y_t - y^*)^2 \tag{6.1}$$

where losses depend on squared deviations of inflation p_t from its target p^* and on squared differences between actual (y_t) and potential (y^*) growth rates of output, while λ denotes the relative weight of output stabilization. Whereas this type of loss function is often imposed in an ad-hoc fashion, Woodford (2003) shows that it can be explicitly derived from a microfounded New-Keynesian model where monetary policy maximizes social utility for a representative agent. Figure 6.1 provides loss estimates on a yearly basis for the ECB, the Federal Reserve and the Bank of England from 1996 up to 2013.[2]

[1] See Svensson (1997) for an early exposition of the inflation targeting approach and Goodfriend (2007) for a description of the pre-crisis consensus view on monetary policy.

[2] Each central bank is assumed to have an inflation target of $p^* = 2$, and the weight on output stabilization λ is set to 0.5. Data on inflation and output gaps was obtained from OECD Economic Outlook, Eurostat and FED FRED.

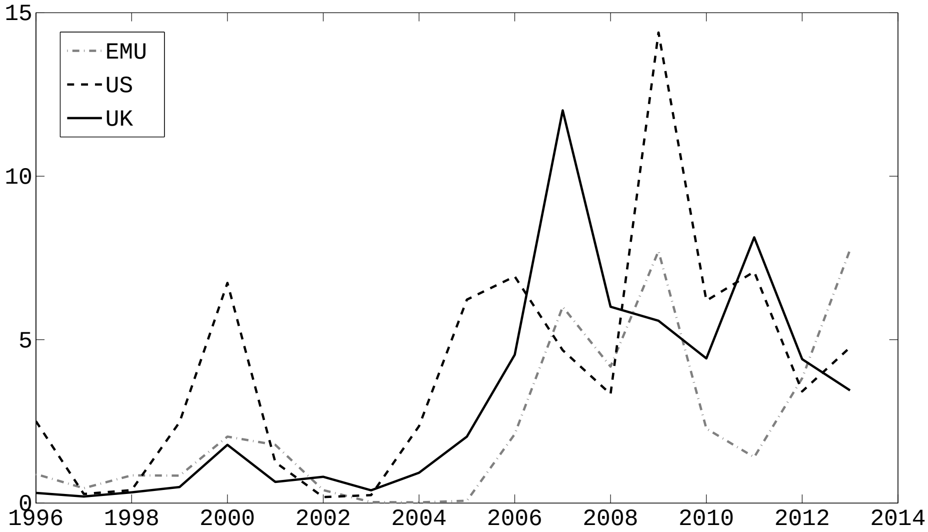


Figure 6.1: *Central Bank Loss Estimates 1996-2013*

It is apparent that losses increased considerably with the onset of the financial crisis in 2007. The fatal and self-reinforcing interplay of increasing financial distress and declining economic activity translated into large output gaps persisting for several years. Moreover, inflation rates temporarily fell below target in the US and the Euro Area.

Given these adverse environments, policymakers embarked on unconventional policy measures to an unprecedented extent. Since short-term rates as the traditional policy instrument had quickly become constrained by their zero lower bound, central banks tried to stimulate the economy by means of large-scale asset purchases and explicit commitments to a prolonged period of very low interest rates.[3] Empirical assessments generally attribute some success to the efforts undertaken in the sense that they prevented a further intensification of the ongoing recessions (Gambacorta et al., 2012; Moessner, 2013). The beneficial short-run effects notwithstanding, some observers claim that unconventional policy may have unintended and unfavorable consequences for financial stability, fiscal discipline and central bank independence in the long run (White, 2012).

As illustrated by Figure 6.1, financial crises may drastically compromise the ability of central banks to achieve their objectives. Thus, there should be a vital interest in

[3] A useful overview on unconventional policy measures is provided by Borio and Disyatat (2010).

ex-ante-prevention. As argued in Section 5.4, the current state of financial supervision is likely to leave excessive systemic risk as a mostly unresolved issue. The task of regulating systemic risk therefore ultimately becomes a concern of the central bank, and it remains unclear whether monetary policy is able to perform this task without neglecting its other goals. The question of how monetary policy affects systemic risk is thus of utmost importance and calls for a careful reconsideration of the transmission process of monetary policy.

Indeed, there has been a lively debate on the question whether US policy rates have been "too low for too long" in the years prior to the crisis. Most prominently, Taylor (2007) argues that the level of the US Federal Funds Rate has been inadequately low between 2002 and 2005 which, in his view, contributed to the boom-bust cycle on US housing markets. This view is disputed by Bernanke (2010) and Greenspan (2010), who mainly blame insufficient financial regulation and additionally point out that the prolonged period of low rates prior to the crisis was justified by downside risks to inflation.

In general, the transmission of monetary policy impulses has been an important research topic for decades. Broad consensus has been achieved on the existence of several transmission channels linking monetary impulses to adjustment processes on financial markets and finally to aggregate demand and inflation (Mishkin, 1995). Until recently, however, the established theory on monetary transmission paid little attention to effects of the policy stance on risk-taking behavior within the financial sector. The relatively new concept of a *risk-taking channel* (Borio and Zhu, 2012) sheds light on these issues, and argues for a nexus between monetary policymaking and the evolution of systemic risk on financial markets. In the remainder, I will first outline the traditional understanding of monetary policy transmission. After that, I will extensively discuss the concept of the risk-taking channel on both a theoretical and an empirical basis. Eventually, I will highlight potential needs to adjust monetary policy frameworks.

My key hypothesis is that the existence of a risk-taking channel in conjunction with the insufficient regulation of systemic risk creates a new and challenging policy environment in which the central bank faces additional trade-offs. While pre-crisis wisdom usually suggested that central banks automatically foster financial stability by delivering price stability (Schwartz, 1995; Issing, 2003), the crisis experience suggests otherwise. Central banks not only have to trade off inflation and output variability. Financial stability considerations - and their feedback to the former two aspects - may impose an additional constraint on monetary policy. Under some circumstances, the central bank could become forced to accept a higher degree of macroeconomic volatility in the short run for the sake of medium-term financial market stabilization.

Chapter 7

Traditional Understanding of Monetary Policy Transmission

The consensus view of monetary transmission implies that nominal rigidities enable the central bank to exert short-term influence on real variables (Mishkin, 1995; Taylor, 1995). It is assumed that wages and prices show some degree of stickiness which allows the central bank to influence real interest rates by varying nominal short-term rates (Taylor, 1999). Changes in real interest rates ultimately affect agents' spending decisions, aggregate demand and eventually inflation.

Importantly, modern frameworks explain nominal rigidities with frictions in the wage and price-setting process instead of assuming some type of adaptive expectation formation and/or money illusion.[1] This allows to reconcile the sticky behavior of nominal variables with the assumptions of rational expectations and optimizing agents. The current workhorse model of monetary policy analysis is the so-called New-Keynesian Model, which is strongly devoted to the idea of microfoundation, that is, macroeconomic dynamics are understood as the aggregation of optimal decisions made by representative firms and households. The introduction of wage- and price-setting frictions of various forms gives rise to inflation and output persistence and monetary non-neutrality in the short run.[2]

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1 Popular models of staggered price setting have been developed by Calvo (1983) and Rotemberg (1982). A wage setting model in a similar spirit has been proposed by Taylor (1980).

2 See Gali (2008), Goodfriend (2002) and Woodford (2003) for detailed expositions of the New-Keynesian paradigm.

The actual transmission of monetary policy impulses takes place via various channels. In general, changes in short-term interest rates affect the set of (relative) prices on financial markets which triggers adjustments in agents' spending behavior and eventually in aggregate consumption, investment and in the current account. The associated variation in aggregate demand ultimately affects inflation dynamics.

It is common to categorize transmission channels with respect to their view on the properties of financial markets. Henceforth, I borrow the terminology of Boivin et al. (2010) and distinguish between channels which assume perfect financial markets (*neoclassical channels*) and channels which recognize the presence of financial frictions (*non-neoclassical channels*). The subsequent discussion of neoclassical transmission channels will be comparably brief. Non-neoclassical transmission channels will be covered in greater detail, as they represent the natural starting point for an analysis of the risk-taking channel.

7.1 Neoclassical Transmission Channels

Monetary policy influences interest rates and thus the cost of investment. Standard neoclassical investment theory derives optimal investment behavior from the intertemporal maximization of firm value (Jorgenson, 1963). One of the key determinants of investment in that respect is the *user cost of capital* u_c, which, according to Boivin et al. (2010), can be expressed as

$$u_c = p_c[\{(1-\tau)i - \pi^e\} - \{\pi_c^e - \pi^e\} + \delta], \tag{7.1}$$

where p_c denotes the relative price of new capital, i the nominal interest rate, π_e expected inflation, π_e^c the expected rate of change in the price of the capital asset, δ is the capital asset's depreciation rate and τ is the marginal tax rate which enters the formula to account for tax deductibility of interest rate expenses. Equation (7.1) can be decomposed into (i) the opportunity costs of holding capital, which are given by the real tax-adjusted interest rate $(1-\tau)i - \pi^e$, (ii) expected real capital gains $\pi_c^e - \pi^e$ and (iii) the depreciation rate δ.

User costs and the marginal profitability of investment have to be equal in optimum. Consequently, the effect of a policy-induced change in the interest rate i on user costs

u_c triggers an adjustment of the capital stock to restore the optimum. For example, if the interest rate declines, user costs decrease as well. Firms respond with an increase of their capital stock and its marginal productivity decreases. This process continues until the optimality condition is restored. Hence, a decline in interest rate triggers additional investment.

Given the longer-term nature of most investment projects, the actually relevant interest rate in Equation (7.1) is likely to be a long-term rate. Since the instrument of traditional monetary policymaking is a short-term rate, an additional concept linking short and long rates is required: The *expectation theory of the term structure* (ETTS). In its purest form, the expectation theory links rates of different maturities in a no-arbitrage condition, that is, a long-term fixed income investment must yield the same return as a revolving investment in short-term securities. As a consequence, the long-term rate approximately equals the average value of current and expected short-term rates (see for example Romer (2012, pp. 518-520)). If the central bank manipulates current and/or expected short rates, the long-term rate is pushed into the same direction.[3]

Another closely related mechanism which enhances the inverse relationship between interest rates and investment is the *q-theory* of Tobin (1969). Tobin's q is the ratio of the actual market value of capital compared to its replacement costs, that is, the relative price of new capital or investment.[4] The value of q guides the decision of a firm whether to increase its capital stock via the acquisition of existing capital or by investment in new capital. Monetary policy indirectly affects q and hence aggregate investment. If the central bank lowers interest rates, capital asset prices rise for two reasons. First, lower interest rates reduce the discount factor applied to the valuation of future cash flows. Second, lowering the yields on fixed income assets triggers portfolio substitution, which increases demand for capital assets and hence their prices.[5]

[3] This treatment of ETTS is of course incomplete and merely designed to illustrate the proposition that policy-induced changes of short-term rates do have a concurrent effect on long-term rates. More sophisticated treatments of ETTS and term structure theories in general can be found for example in Geiger (2011), Russell (1992) and Shiller and McCulloch (1990).

[4] It should be noted that the relative price of capital also figures prominently in the user cost formula (7.1). This is not a coincidence. Hayashi (1982) shows that the user cost approach and the q-theory can be reconciled in a generalized framework for optimal investment.

[5] This argument is regarded as crucial in the monetarist view of monetary transmission, which emphasizes that policy interventions perturb the optimal portfolio choice of households by their effect on relative yields across the entire spectrum of assets (Meltzer, 1995). For example, a decline in the policy rate decreases yields on fixed-income assets. Households respond with a reallocation of wealth towards stocks, which can be simplistically regarded as residual claims on profits from owning and employing capital assets. If demand for stocks increases, stock prices will rise. So does Tobin's q, which renders investment conditions more favorable.

If capital asset prices increase, q increases as well. Installation of new capital becomes relatively cheaper and investment consequently increases.

A different avenue for monetary transmission is based on the impact of central bank operations on consumption via wealth effects, which can be formalized in the life-cycle model of consumption by Ando and Modigliani (1963). If individuals have the desire to achieve a steady level of consumption over their lifetime they smooth consumption across periods, for example with the accumulation of retirement savings. Hence, if asset prices and thus the value of savings increase due to a decline in the policy rate, a higher level of (current) consumption becomes affordable.

Another important mechanism similar in spirit is the intertemporal substitution effect, which figures prominently in the New-Keynesian Model (see for instance Gali (2008, ch. 2-3)). If interest rates decrease, consuming today becomes more attractive relative to saving for the sake of future consumption. The optimal trade-off between consumption now and in the future is determined by the Euler Equation of consumption

$$u_t^c = \beta(1 + r_t)u_{t+1}^c, \tag{7.2}$$

implying that disutility from giving up a marginal amount of consumption u_t^c today needs to equal the utility from possible future consumption, which is the marginal utility of consumption in the next period u_{t+1}^c multiplied with the gross real interest rate on savings $(1 + r_t)$ corrected for the gross time preference rate β. If, other things equal, r_t decreases, agents optimally respond with an increase of current consumption, which in turn decreases marginal utility u_t^c and restores the optimum.

Monetary impulses also affect relative yields of domestic and foreign assets which may have implications for the exchange rate and the current account (Mishkin, 1995). If the central bank decreases interest rates, investors respond with portfolio shifts towards foreign assets. The associated capital outflows go hand in hand with an exchange rate depreciation, which ultimately benefits the current account and aggregate demand. This so-called exchange rate channel gains in relevance with increasing openness towards trade and capital flows.

The empirical relevance of the aforementioned channels has been documented extensively. Indeed, it is a common and generally undisputed finding that variations in the policy rate inversely affect macroeconomic aggregates as well as the inflation rate.[6]

7.2 Non-Neoclassical Transmission Channels

7.2.1 Incomplete Information and Credit Constraints

The theory of non-neoclassical transmission channels incorporates concepts from the literature on financial intermediation under incomplete information. In such a setting, lender-borrower relationships between banks and firms or households are complicated by various agency problems. The presence of agency problems makes obtaining external funding more costly than internal financing and commands an external finance premium (Bernanke and Gertler, 1989). In the extreme, external finance may become completely unavailable. As famously shown by Stiglitz and Weiss (1981), this constellation of *credit rationing* may emerge as an equilibrium phenomenon, implying that some borrowers do not receive credit despite they are willing to pay the market interest rate. Especially small firms and households usually cannot fall back on capital market funding. They are dependent on bank loans as their only source for external finance.[7] Thus, the presence of agency problems implies that obtaining external funding is particularly costly or even infeasible. In the latter case, firms and households may become credit-constrained.

Agency problems on loan markets are closely related to the special incentive structure associated with limited liability. Limited liability acts like a put option in the sense that losses of the borrower are limited to his equity stake and/or the amount of pledged collateral (Jensen and Meckling, 1976). If losses are limited, borrowers can increase their expected profit by taking on more risk. Particularly good outcomes generate high profits whereas the losses in adverse states are mainly borne by lenders. In the extreme,

[6] See Bernanke et al. (2005), Christiano et al. (1999), Mojon et al. (2002) and Romer and Romer (1989) among others.

[7] Diamond (1991) shows that firms without an established reputation have difficulties to receive funding on capital markets. An alternative reason for a lack of capital market access is an insufficient equity base (Holmstrom and Tirole, 1997). In both cases, severe agency problems prevent the issuance of debt securities. Instead, financing is only possible by banks who mitigate agency problems with the help of specific screening and monitoring capabilities. A rather practical argument is that presence on capital markets carries fixed costs, such as rating fees or costs for building an investor-relations team. These costs may be prohibitively high for small and medium-sized firms.

it may hold that borrowers prefer a high-risk project with low expected return over a low-risk project with high returns. In a nutshell, limited liability creates a global (and often socially inefficient) risk-taking incentive.

The provision of collateral acts as a disciplining device which may align the incentives of borrowers and lenders, such that the aforementioned agency problems are mitigated to a great extent. In general, risk-taking incentives are attenuated if the borrower has enough "skin in the game." The mere possibility that collateral is seized by the lender in the case of default acts as a sufficiently strong deterrent from taking excessive risk. Collateral is either of explicit or implicit form: Explicit collateral takes the form of specific assets such as real estate or government bonds which are handed to the lender in the case of default. Implicit collateral is the equity position on the borrower's balance sheet. The equity position reflects discounted future profits which are lost in the case of default. Hence, a strong equity base or, equivalently, a low debt-equity ratio tames risk-taking incentives since future profits only accrue if the firm survives. The difference between the sum of explicit and implicit collateral and outstanding liabilities is usually referred to as the net worth of a firm.

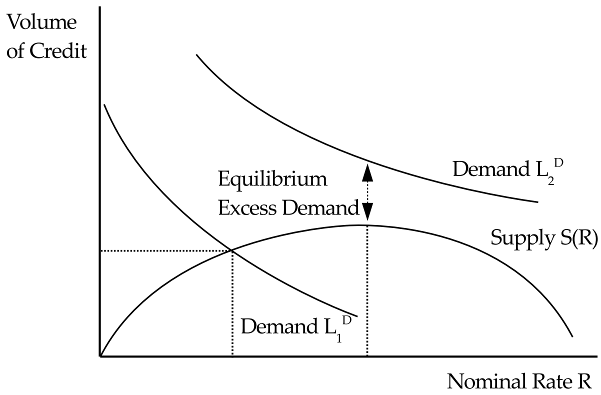
Importantly, banks are not only lenders. They are borrowers as well. The refinancing of modern banking groups heavily relies on non-insured capital market funding. Hence, banks will likewise be judged with respect to their risk-taking incentives and their net worth. If the net worth of both firms and banks is reduced, agency problems may intensify. The possibility of credit rationing reemerges and the external finance premium likely rises. *Both* the ability to lend and to borrow decline.

Monetary policy affects the lending capacity of financial intermediaries and the borrowing capacity of firms and households in a procyclical fashion. A rise in interest rates decreases both the net worth of firms and the net worth of banks, aggregate credit consequently contracts and so does credit-financed spending, i.e., especially investment and durable consumption. The impact of monetary policy goes beyond the effects of neoclassical transmission theory. The presence of financial market imperfections *amplifies* the response of aggregate demand to a policy change. In what follows, I briefly discuss the role of collateral in preventing rationing equilibria. Subsequently, I outline several approaches linking the stance of monetary policy to the net worth of economic agents, which determines their ability to lend and to borrow and thereby influences aggregate spending.

7.2.2 Credit Rationing and the Mitigating Role of Collateral

Information asymmetries between lenders and borrowers can lead to the problem of credit rationing. If lenders are unable ex ante to evaluate the riskiness of a potential borrower and his investment project, a classical problem of *adverse selection* emerges and credit rationing may occur as an equilibrium outcome (Stiglitz and Weiss, 1981). If lenders are uncertain about the true riskiness of a potential borrower, they charge an interest rate based on the average riskiness of all borrowers.

Under the presence of limited liability, risky borrowers are willing to pay higher interest rates. As argued above, the expected payoff for borrowers increases in risk, which makes a higher interest rate affordable. However, lending to risky borrowers is less profitable for banks. Hence, the willingness to supply credit starts to decrease for higher interest rates. Indeed, credit supply may become backward-bending as in Figure 7.1. If loan demand is sufficiently strong, the market does not clear and excess demand emerges as an equilibrium phenomenon even though every borrower is willing to pay the demanded interest rate.



Source: Adapted from Freixas and Rochet (2008, p. 174)

Figure 7.1: *Credit Rationing as an Equilibrium Phenomenon*

Another variety of credit rationing may occur due to *ex post* problems related to *moral hazard* (Bester and Hellwig, 1987). It is assumed that borrowers may alter the riskiness of their investment project after they have received funding. They are able to choose between a safe project and a risky project which yields a very high payoff if successful but nevertheless has a lower expected profit. It is shown that borrowers choose the risky project after the required loan rate exceeds a certain threshold (which is inefficient). Again, the risk-taking incentive of limited liability serves as an explanation. The moral hazard problem equally gives rise to a backward-bending loan supply schedule and the possibility of credit rationing in equilibrium.

Moral hazard and adverse selection problems can be mitigated with the help of collateral as a disciplining device. With respect to moral hazard, the risk of losing collateral to the lender if payoffs are insufficient may induce borrowers to refrain from choosing the risky project. With respect to adverse selection, Bester (1985) shows that if lenders offer different contracts where collateral requirements and interest rates vary, this may act as a self-selection mechanism where borrowers' choices automatically reveal their type. Riskier borrowers prefer higher interest rates and lower collateral requirements than safer borrowers. Each type of contract ensures that banks recoup their funding costs and make zero profits in a competitive equilibrium. Thus, the credit market clears and the rationing problem vanishes.

7.2.3 Borrowing Constraints and the Financial Accelerator

Credit market imperfections imply that some borrowers end up being financially constrained if information asymmetries cannot be overcome by pledging a sufficient amount of collateral. The occurrence of credit rationing may severely diminish aggregate investment and hence economic activity in general.

In that respect, a simple yet insightful model is laid out in Freixas and Rochet (2008, ch. 6).[8] It considers a firm which transforms input x into output $f(x)$ with diminishing marginal returns. Input and output prices are both normalized to unity. The firm finances the acquisition of inputs out of their given wealth position W and an additional loan L supplied at the interest rate of r. Profits are maximized by the choice of L. With complete information, the optimization problem becomes

$$\max_L f(L+W) - (1+r)L. \tag{7.3}$$

The first-order condition is

[8] The model originally goes back to Bernanke et al. (1996). The important role of collateral constraints for macroeconomic dynamics has also been highlighted by Kiyotaki and Moore (1997).

$$f'(L+W) = (1+r), \tag{7.4}$$

which yields the result that the level of production is chosen such that marginal productivity equals the interest rate of the loan. This condition can be regarded as a simplified corollary of neoclassical investment theory. If r increases, optimality requires that $f'(L+W)$ has to increase as well, which can only be achieved by reducing "investment" in inputs, which in turn establishes a negative link between interest rates and investment. Under complete information, firms can obtain as much loans as necessary to implement the optimal level of investment as determined by Equation (7.4).

Now assume that agency problems call for full collateralization of loans. The repayment value of the loan $(1+r)L$ must not exceed the firm's wealth W, which is expressed as the volume of the firm's asset K multiplied with their price q. The investment decision is now subject to a collateral constraint of the form

$$L \leq \frac{qK}{1+r}, \tag{7.5}$$

which states that the maximum loan value is given by the present value of the firm's assets. The new optimization problem is given by

$$\begin{aligned} \max_{L} \quad & f(L+W) - (1+r)L \\ \text{s.t.} \quad & L \leq \frac{qK}{1+r}. \end{aligned} \tag{7.6}$$

Taking the first order condition of the respective Lagrangian gives the optimality condition

$$f'(L+W) = 1 + r + \lambda, \tag{7.7}$$

where λ denotes the Lagrange multiplier, i.e., the marginal increase of profits given a marginal relaxation of the collateral constraint. If the constraint is binding, λ is positive and can be regarded as the shadow cost of the collateral constraint. The presence of a binding collateral constraint leads to credit rationing and decreases investment compared to the unconstrained optimum: Principally profitable investment opportunities are foregone. Agency problems hence impose a substantial deadweight loss.

Alternatively, Bernanke and Gertler (1989) consider a model in which borrower net worth does not determine the availability of external finance per se, but rather its price.[9] The key friction is that the outcome of the borrower's investment project is private information. Hence, the borrower has the incentive to falsely report a bad outcome in order to reduce repayments. Lenders can only observe the true project outcome if they incur verification costs. The presence of this verification cost drives a wedge between the costs of internal and external funding, the so-called *external finance premium* (EFP). Importantly, the EFP is inversely related to borrowers' net worth. This is due to the fact that higher net worth reduces the probability of bad outcomes and the associated verification cost.[10] If the EFP declines, more entrepreneurs find it worthwhile to invest and aggregate demand increases.

What is the role for monetary policy in these frameworks? As argued by Bernanke and Gertler (1995), monetary policy inversely affects borrower net worth via both direct and indirect channels. Rising interest rates reduce asset prices and therefore directly lower the value of potential collateral. Moreover, interest rate expenses go up which impairs profitability. Finally, since a tighter policy stance decreases aggregate demand, business conditions and firm profits may deteriorate further.

With its influence on borrower net worth, monetary policy critically affects both the availability as well as the price of external finance. Monetary policy exerts influence on investment *beyond* its effect on user costs, and changes in the policy rate are amplified by their effects on collateral values and borrowing capacity. The outlined mechanisms are usually referred to as the *financial accelerator*. They are certainly not limited to firms, but to any borrower within the private sector. Thus, they may apply equally to households and financial intermediaries themselves.

7.2.4 The Traditional Bank Lending Channel

Monetary policy not only affects the borrowing capacity of firms and households but also the lending capacity of financial intermediaries which gives rise to a *bank lending*

[9] Indeed, the empirical relevance on quantity rationing is mixed. While Bernanke (1983) emphasizes the important role of rationing in the aggravation of the Great Depression, Berger and Udell (1992) find no significant macroeconomic effect of credit rationing for the US economy between 1977 and 1988. On the other hand, Ivashina and Scharfstein (2010) document rationing behavior in the recent financial crisis. However, it is difficult to assess whether this is due to deteriorating balance sheets of borrowers or due to liquidity and solvency concerns in the banking sector itself.

[10] Bernanke and Gertler (1989) show in detail that the optimal financing contract implies that lenders pre-commit to stochastic verification in the bad state with some probability p. This ensures that borrowers do not have the incentive to underreport.

channel of monetary policy transmission. In its traditional form, the bank lending channel has been analyzed by Bernanke and Blinder (1988), who augment the IS-LM model with a market for bank loans. Banks raise deposits subject to a minimum reserve requirement from the public and can invest in bonds as well as in loans to the private sector. The actual portfolio allocation is governed by the relative yields of both investment opportunities. Importantly, loan demand is modeled to be relatively inelastic, reflecting the notion that some borrowers have difficulties in accessing capital markets. This assumption provides a simple device for an implicit incorporation of agency problems. Unlike in the IS-LM model which assumes that all sorts of external financing occur on some generic bond market, bonds and bank loans are treated as imperfect substitutes.

The presence of a minimum reserve requirement implies that banks are subject to a balance sheet constraint. Suppose that banks are obliged to keep a share τ of deposits as minimum reserve. If equity and the possibility to hold excess reserves are neglected, the balance sheet identity reads

$$L_t + B_t + R_t = D_t, \tag{7.8}$$

where L_t denotes loans, B_t denotes bonds, R_t is the stock of reserves and D_t stands for deposits. The minimum reserve requirement stipulates that $R_t = \tau D_t$, so that (7.8) becomes

$$L_t + B_t = (1 - \tau) D_t. \tag{7.9}$$

Monetary policy uses the level of bank reserves as its policy instrument. For example, a tightening of the policy stance is achieved by contractionary open market operations. The central bank sells bonds in exchange for reserves, which reduces reserves and deposits to the same extent. This has two effects: First, excess bond supply leads to a decline in bond prices and a corresponding increase in (effective) interest rates on bonds as in the IS-LM model. Moreover, the decrease in bank reserves tightens banks' balance sheet constraint.

If R_t declines, the minimum reserve requirement is violated. Hence, banks need to shrink the size of their balance sheet. Specifically, the necessary adjustment ΔD_t after a change in the level of reserves ΔR_t is given by

$$\Delta D_t = \Delta(B_t + L_t) = \frac{1}{\tau}\Delta R_t, \tag{7.10}$$

implying that banks must reduce deposits and asset holdings overproportionally. The reduction of loan supply tightens credit conditions. Bank-dependent borrowers cannot substitute bank loans with capital market funding. The decrease in investment and spending is consequently stronger than implied by the mere increase in bond rates. The bank lending channel thus acts as an additional amplifier of monetary policy variations on the lenders' side of the credit market.

This form of the bank lending channel has drawn severe criticism. Romer and Romer (1990) argue that banks can insulate their loan supply from the policy stance by relying on funding sources without reserve requirements such as time deposits. However, since alternative funding is typically not covered by deposit insurance, the issuance of non-insured, risky liabilities may be complicated by the very same agency problems which impede the borrowing capability of firms and households. For instance, Stein (1998) shows that non-insured bank liabilities command an external finance premium if the quality of bank assets is non-observable for potential bank creditors. As a result, the policy-induced drain in deposits cannot be fully offset and their substitution is costly (if possible at all) which reduces the incentive to lend.[11]

Notwithstanding the dispute over the Romer-Romer argument, there are other objections against the Bernanke-Blinder conception of the bank lending channel. Most importantly, adjusting the quantity of bank reserves is no longer a key instrument in modern monetary policymaking which, as an exact opposite, is characterized by an elastic reserve supply. Modern central banks use the interest rate on reserve borrowing by commercial banks as their main policy tool (Disyatat, 2008). In line with this, the importance of minimum reserve requirements as an instrument of regulation has been greatly reduced. In that respect, an insightful statement has been given by Tucker (2004, p. 364), who describes policy implementation at the Bank of England as follows (emphasis added):

[11] Kashyap and Stein (1995) and Kishan and Opiela (2000) try to confirm this argument empirically by showing that small, less liquid and weakly capitalized banks' loan supply is particularly responsive to changes in the policy stance. On the other hand, Oliner and Rudebusch (1993) do not find evidence of a bank lending channel when analyzing changes in the composition of firm debt after a monetary contraction. They also point out that the empirical distinction between bank lending channel mechanisms and financial accelerator effects is hard to accomplish.

> "In terms of the overriding objective of stabilising ultra-short interest rates [...], the key is to ensure that we are both the marginal supplier and taker of "reserves." In theory, there are two possible ways of achieving this. One is to use OMOs [open-market operations] to adjust the quantity of reserves to bring about the desired short-term interest rate, implicitly or explicitly drawing on an identified demand schedule. *Neither in the past nor in the current review have we even briefly entertained the notion that this is realistic.* The alternative way for the central bank to establish itself as the rate-setter is to be prepared to supply (or absorb) whatever liquidity the market demands at its chosen rate(s). The most precise way of doing this is through so-called standing facilities in which *the central bank lends (secured) whatever is demanded at a fixed rate or takes on deposit whatever is supplied at a fixed rate*."

Under such a regime, the level of deposits or, more generally, monetary aggregates are determined endogenously. Banks are essentially able to *create* deposits by extending credit to households and firms, whereas eventually arising reserve needs are readily satisfied by the central bank at the policy rate. As noted by Spahn (2012, p. 24), the development of monetary aggregates therefore follows loan market dynamics, which inverts the direction of causality underlying the Bernanke-Blinder model. This position is neatly summarized by Jakab and Kumhof (2014, p. 4), who claim that

> "[i]n the real world, the key function of banks is the provision of financing, or the creation of new monetary purchasing power through loans, for a single agent that is both borrower and depositor."

Hence, one is tempted to conclude with Disyatat (2011, p. 716) that "[t]here is no quantitative constraint as such," which would render the Bernanke-Blinder view of the bank lending channel essentially irrelevant.[12]

However, monetary policy potentially influences bank lending behavior even in the absence of quantitative constraints. Changes in the monetary policy stance affect the opportunity costs of holding deposits. Rising levels of interest rates may induce

[12] The entire controversy hinges on the question whether the availability of deposits is a precondition for granting loans, or, more fundamentally, whether saving is a precondition for investment. This issue has been at the center of macroeconomic debates for decades. Yet a coverage of this discussion is beyond the scope of this work. Jakab and Kumhof (2014, 2015), Spahn (2014) and the references therein provide an overview.

households to reallocate their wealth in favor of higher-yielding assets, which leads to a drain in deposits. As argued by Spahn (2014, pp. 3-4), this is unconvincing: Under most circumstances, deposits cannot decline in aggregate. Individual efforts of portfolio substitution lead to a mere redistribution of deposit balances. For example, if a depositor switches to holding corporate debt securities, the deposit balances of the corporate sector rise while the aggregate level of deposits remains unchanged. Again, arguing with quantities appears to be misguided.

Nevertheless, there is still a price-theoretic argument. Consider an initial equilibrium where the rate on deposits i_D is equal to the policy rate i. An increase in the policy rate to i' makes central bank funding more expensive ($i' > i_D$). Banks with refinancing needs will now try to attract deposits from other banks. The competition for deposits causes banks to bid up the deposit rate until it holds that $i_D = i'$.[13] Due to maturity transformation, yields on bank assets are relatively sticky. Thus, the average intermediation margin is compressed. Banks will react by raising lending rates on new loans so as to pass on higher funding costs to their borrowers (Ehrmann et al., 2001, p. 20). Hence, even in the absence of reserve constraints, monetary policy continues to affect the terms of lending via its influence on the cost of banking.

Yet the borrowing ability of banks depends on a different quantitative constraint: its equity position. Capital regulation and/or market discipline determine the maximally feasible loan supply as a multiple of the given stock of bank capital. By their very nature, banks act simultaneously as borrowers and lenders. For similar reasons like households and firms, banks are required by their lenders to be endowed with a certain net worth. Hence, the logic of the financial accelerator equally applies to the banking sector. Monetary policy systematically influences the capital base of financial intermediaries through various channels, which gives rise to a distinct *bank capital channel*, as emphasized by Van den Heuvel (2002, 2006).

First, a tighter policy stance compresses the intermediation margin which diminishes future profits and thus the market value of bank equity. Second, a rise in interest rates triggers price declines of assets which are marked-to-market. The adverse valuation effect causes an immediate decrease of the capital position. Third, a policy-induced

[13] Indeed, strength and speed of the pass-through of policy rate changes on both loan and deposit rates are positively correlated with the degree of competition in the banking sector, as highlighted by van Leuvensteijn et al. (2013) for the Eurozone.

decline of economic activity may lead to elevated default rates in banks' loan portfolios. Decreasing capital forces banks to cut back loan supply, be it because the capital constraint becomes binding or because of the mere risk of getting there.[14]

7.2.5 The Revisited Bank Lending Channel

A very insightful reformulation of the bank lending channel has been proposed by Disyatat (2011). Importantly, his setup recognizes the endogenous nature of deposit creation and links loan supply decisions exclusively to funding cost and net worth considerations, instead of relying on the notion of a quantitative constraint on reserves or deposits, respectively. The model features three types of agents in equal number: Households, banks and firms. Firms require bank loans to finance production, since households demand the payment of wages before production takes place. After receiving wage payments, households keep them as deposits within the banking sector. At the end of the period, households use their deposits to purchase and consume produced goods. Deposits are consequently transferred back to the firm sector which enables the final repayment of loans. Hence, the level of deposits is exclusively determined by the equilibrium quantity of credit. While deposits change hands, they do not leave the banking system as such and remain constant in level. They circulate between the various sectors of the economy and serve as means of payment.

Firms produce output with labor as the only production factor. They are risky in the sense that they may end up with zero output due to an adverse productivity shock. Their production function is given by

$$y = N^{\beta}(1+\epsilon) \tag{7.11}$$

with N representing units of labor employed and $0 < \beta < 1$. There is an aggregate productivity shock ϵ whose distribution follows

$$\epsilon = \begin{cases} 0 & \text{w. p.} \quad \theta \\ -1 & \text{w. p.} \quad (1-\theta) \end{cases} \tag{7.12}$$

[14] A counterargument is that banks can issue additional equity claims. However, equity issuance may be complicated by agency problems and is therefore very costly (if feasible at all). See Section 4.3 for a short discussion of this issue.

implying that output becomes zero with a probability of $(1-\theta)$. In that case, the firm defaults on its bank obligations. Hence, bank lending is subject to non-diversifiable credit risk. The output price P and unit labor costs P_N are treated as constant. The bank lending rate is denoted by r_L. Thus, expected firm profits are given by

$$\Pi^e = \theta(PN^\beta - (1+r_L)P_N N). \tag{7.13}$$

Firms maximize profits by optimally choosing N. As shown in Appendix A.3, taking the FOC yields optimal labor demand:

$$N^* = \left(\frac{\beta P}{(1+r_L)P_N}\right)^{\frac{1}{1-\beta}}. \tag{7.14}$$

By assumption, labor is elastically supplied by households at P_N. A rise in the loan rate r_L decreases N^* and thus aggregate output, since financing of the production process becomes more expensive. The actually required loan amount is given by $L^D = P_N N^*$.

Banks are initially endowed with a capital position of ω, which is subject to a uniformly distributed shock in the interval $[\underline{u}, \overline{u}]$ with $-1 < \underline{u} < 0 < \overline{u}$ at the end of the period.[15] Net worth at the end of the period is thus given by

$$\psi = \omega(1+u). \tag{7.15}$$

If the firm is hit by the adverse productivity shock, the bank receives a zero payoff but still has to repay its depositors, i.e., households. Repayment is only possible if the capital position is sufficiently large. Specifically, it needs to hold that

$$\psi = \omega(1+u) > (1+R)L, \tag{7.16}$$

where R is the interest rate on deposits. The critical value u^* for the net worth shock is then given by

15 Disyatat (2011, p. 719) explains the motivation for this assumption as follows: "The idea is that banks are subject to risks, such as operation risk and risk associated with existing assets and liabilities, in addition to the marginal risk inherent in new lending. This will be captured by the variable u[.]" In what follows, the terms capital and net worth will be used interchangeably.

$$u^* = \frac{(1+R)L}{\omega} - 1. \tag{7.17}$$

By applying the cumulative distribution function of the uniform distribution, the *conditional* default probability of a bank given the failure of its debtor firm can be written as

$$\begin{aligned} q &\equiv \Pr(\psi < (1+R)L) \\ &= \Pr(u < u^*) \\ &= \frac{u^* - \underline{u}}{\overline{u} - \underline{u}}. \end{aligned} \tag{7.18}$$

The *unconditional* probability of bank default is the product of the probabilities that (i) the debtor firm fails and (ii) net worth is insufficient to pay off depositors, implying that

$$1 - x \equiv (1-\theta)q, \tag{7.19}$$

where x is the probability of repayment. As the model assumes perfect competition, the lending rate banks charge from firms is determined by a zero-profit condition. Revenues from extending loans have to equal funding costs plus expected costs of default. Hence, it holds that

$$\theta(1+r_L)L = x(1+R)L + (1-x)\psi^e, \tag{7.20}$$

where the left-hand-side denotes expected revenues from loan repayments, $x(1+R)L$ denotes funding costs in the no-default case which accrue with probability x, and ψ^e is expected net worth in the default case, which has to be transferred to borrowers with probability $(1-x)$. The expected net worth in the default scenario is given by

$$\psi^e = \omega\left[1 + \frac{\underline{u} + u^*}{2}\right], \tag{7.21}$$

since default implies that the realization of the net worth shock must lie in the interval $[\underline{u}, u^*]$. The mean of the shock is easily obtained by taking the average of the interval's boundaries.

In a last step, household behavior needs to be specified. Households are either able to hold deposits or to invest into some risk-free asset yielding $(1 + r_f)$, where r_f is set by the central bank. The indifference condition which equalizes expected returns reads

$$(1 + r_f)L = x(1 + R)L + (1 - x)(\psi^e - cL), \tag{7.22}$$

which states that risk-free gross returns need to equal the expected value of repayments from the bank. Importantly, it is assumed that depositors cannot seize bank net worth to the full extent. Its liquidation entails contract enforcement costs of amount c, which are proportional to the loan volume L.[16] The existence of liquidation costs and default risks implies that deposits need to carry a premium in order to fulfill (7.22). Hence, it holds that $R > r_f$.

The loan supply schedule of the bank can be derived in several steps. First, the household indifference condition needs to be rearranged. Appendix A.3 shows that this yields

$$\frac{(1-\theta)\omega(\overline{u} - \underline{u})}{2} q^2 + \left[(1-\theta)cL - \omega(\overline{u} - \underline{u})\right] q - \omega(1 + \underline{u}) + (1 + r_f)L \equiv 0. \tag{7.23}$$

From Equation (7.23), one can infer the conditional default probability q of banks for a given amount of loans L and a given amount of initial capital ω. Put differently, it is possible to derive the critical value of L for which q becomes non-zero. If L rises relative to capital ω, the leverage of the bank increases. Hence, at some level of L, the capital position may turn out to be too small to pay off depositors if the firm is defaulting. This critical value L_L is obtained by setting $q = 0$ in Equation (7.23), which is subsequently solved for L:

$$L_L = \frac{\omega(1 + \underline{u})}{(1 + r_f)}. \tag{7.24}$$

As soon as $L > L_L$, the bank will default on deposits with a positive probability conditional on the failure of the firm. Put differently, it cannot be ruled out that firm

[16] Disyatat (2011, p. 720) notes that this assumption "captures the costs associated with bankruptcy proceedings to claim the net worth of the defaulting bank and can be thought of also as the degree of financial market imperfection." For example, depositors may face costs for legal counseling.

bankruptcy in conjunction with a possibly adverse shock to bank capital renders the bank insolvent. Not surprisingly, L_L rises in ω. A stronger capital position can absorb more losses even when subject to a possible adverse shock, which allows extending more loans without exposing depositors to default risk.

Equivalently, it is possible to derive the upper threshold for loans by setting $q = 1$. If $q = 1$, banks always default on deposits if the firm declares bankruptcy. Solving (7.23) for $q = 1$ yields

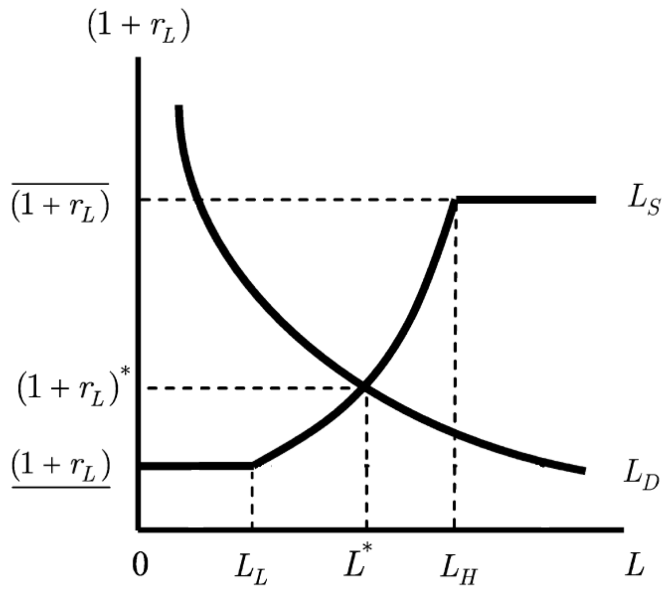
$$L_H = \frac{\omega(1+\underline{u}) + \omega(\overline{u} - \underline{u}) - \dfrac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}}{(1+r_f) + (1-\theta)c}. \tag{7.25}$$

If $L_L < L < L_H$, q increases in L for a given ω. As demonstrated in detail within Appendix A.3, this result gives rise to a non-linear loan supply schedule of the following form:

$$(1+r_L) = \begin{cases} \dfrac{(1+r_f)}{\theta} + \dfrac{(1-\theta)c}{\theta} & \text{for} \quad L \geq L_H \quad \text{and} \quad q = 1 \\ \dfrac{(1+r_f)}{\theta} + \dfrac{(1-\theta)c}{\theta}q & \text{for} \quad L_L < L < L_H \quad \text{and} \quad 0 < q < 1 \\ \dfrac{(1+r_f)}{\theta} & \text{for} \quad L \leq L_L \quad \text{and} \quad q = 0 \end{cases} \tag{7.26}$$

If $q = 0$, deposits are not exposed to default risk and are consequently remunerated at the risk-free rate $(1 + r_f)$. Since expected bank profits are zero in equilibrium, the loan rate $(1 + r_L)$ equals the deposit rate, corrected for the repayment probability of the firm. Hence, loans are supplied elastically at $\frac{(1+r_f)}{\theta}$ for $L \leq L_L$. If $0 < q < 1$, deposits are no longer risk-free, and funding costs increase in the expected costs of default for depositors. Default costs are given by the product of the relative default probability of firms $\frac{(1-\theta)}{\theta}$, the default probability of banks conditional on firm failure q and the contractual enforcement cost c. The increase of funding costs is fully reflected in the loan rate. The loan supply curve thus becomes upward-sloping. If $q = 1$, the loan rate becomes constant, albeit on an elevated level, and the supply curve is horizontal again (Figure 7.2).

Loan demand of firms is determined by their optimal labor demand and decreases in $(1 + r_L)$, since rising loan rates increase the cost of production. The loan demand function is given by



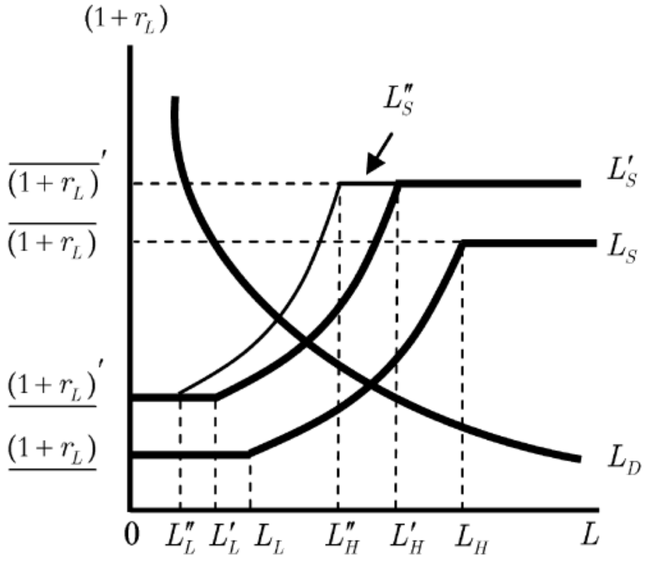
Source: Disyatat (2011, p. 722)

Figure 7.2: *Loan Market Equilibrium*

$$L^D = P_N N^* = P_N \left(\frac{\beta P}{(1+r_L)P_N} \right)^{\frac{1}{1-\beta}}, \tag{7.27}$$

which establishes a negatively sloped demand schedule. Figure 7.2 depicts a graphical exposition of the loan market, where $\underline{(1+r_L)}$ corresponds to the loan rate in the $q = 0$ regime and $\overline{(1+r_L)}$ to the loan rate which arises if $q = 1$. Loan market equilibrium is given by L^* and $(1+r_L^*)$. Loan demand behaves straightforward and decreases in $(1+r_L)$. Loan supply is horizontal if q equals zero or unity, and positively sloped in the intermediate cases.

How, then, is monetary policy supposed to affect the loan market outcome? Recall the assumption that the central bank sets r_f. Equation (7.26) shows that an increase in r_f uniformly increases loan rates for any quantity of loans. Put differently, loan supply exhibits an upward shift. A rise in r_f raises funding costs, and banks subsequently charge higher loan rates, as already argued by Ehrmann et al. (2001, p. 20). Yet there is an additional effect: An increase in r_f decreases L_L (and L_H), that is, deposits become



Source: Disyatat (2011, p. 724)

Figure 7.3: *Effect of a Policy Tightening*

exposed to default risk at a lower threshold level of loans. This is due to the fact that repayment obligations to depositors increase in r_f, which, other things equal, implies that q becomes positive for a lower level of loans (at a given net worth ω). The effect of a policy tightening is depicted in Figure 7.3.

The loan supply curve changes to $L_S^{'}$. As a result, the equilibrium loan rate increases and the equilibrium quantity of loans declines. Note also that the loan threshold level has decreased to $L_L^{'}$ (and $L_H^{'}$). Thus, a tightening of the policy stance leads to a supply-driven decline in aggregate credit and ultimately to a contraction of aggregate output.

An additional amplification mechanism emerges when assuming that bank net worth ω is inversely related to the policy rate $(1 + r_f)$, which would be tantamount to the inclusion of a bank capital channel. Lower net worth implies that the loan threshold level declines further to $L_L^{''}$, since given an erosion of the capital cushion, depositors start to become exposed to default risk for an even lower quantity of loans. Loan supply exhibits an additional shift to $L_S^{''}$ and credit as well as output consequently contract even further.

A possible objection against the outlined mechanisms is the claim that in reality, deposit insurance removes default risk for depositors. However, the share of deposits in total bank liabilities decreases. Figure 7.4 depicts the ratio of deposits to total assets for both the US commercial banking system and the sector of monetary financial institutions (MFI) in the Euro Area.[17] It is apparent that the share of deposits in banks' funding mix has undergone a secular decline, even though US data shows that deposits have regained some importance in the aftermath of the financial crisis.

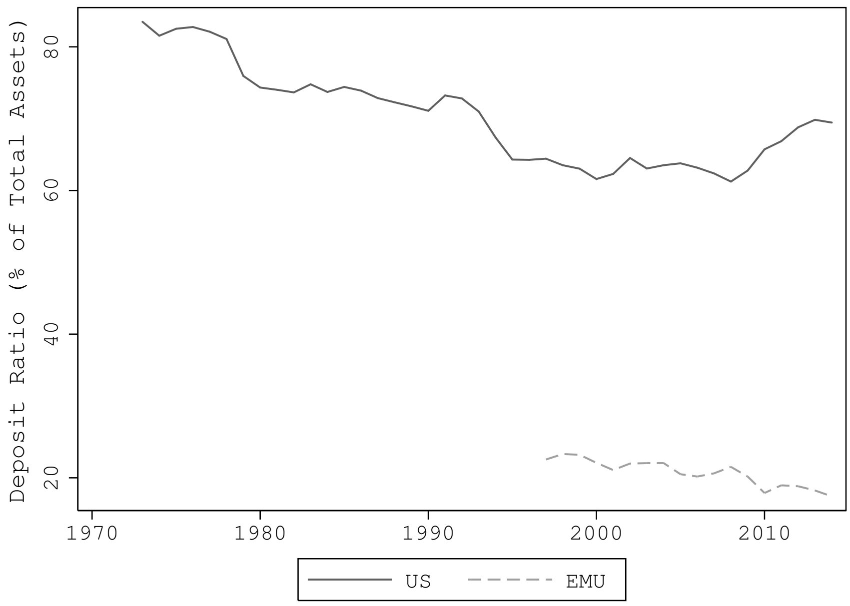


Figure 7.4: *Commercial Bank Deposit Ratios in the US and the Euro Area*

These days, banks obtain a sizable amount of funding by issuing non-insured liabilities on capital markets. Being unprotected from default risk, investors will scrutinize the financial health of banks who seek to obtain funding. To speak within the model, they will try to estimate q conditional on bank net worth ω and the loan volume L and will, accordingly, demand an adequate risk premium.[18] Hence, in contrast to Romer

[17] Data on total assets and outstanding deposits was taken from FED FRED for the US and the ECB Statistical Data Warehouse for the Euro Area. The substantial difference of deposit shares can be possibly explained with the different structure of banking markets. The Euro Area is dominated by large universal banking groups which a strong reliance on capital market funding. Conversely, the US banking system consists to a large extent of smaller banks with a stronger retail deposit base.

[18] Disyatat (2011, p. 716) puts it as follows: "[Banks'] marginal source of funding invariably comes from the market, where credit risk matters."

and Romer (1990), the bank lending channel becomes more (not less) relevant if the capital market reliance of the banking system increases.

Chapter 8

The Risk-Taking Channel of Monetary Transmission

8.1 Definition

The aforementioned theory of non-neoclassical transmission channels assumes that risk attitudes of financial intermediaries are constant. More specifically, the presented models usually presuppose the presence of risk neutrality. This assumption needs to be relaxed. Instead, it is more plausible to presume that decisionmaking of financial intermediaries is governed by aversion towards risk, and that the general risk attitude is likely to vary over time.

The risk-taking channel of monetary policy transmission explicitly recognizes the importance of fluctuations in risk attitudes. It is noteworthy that the concept of a risk-taking channel has started to develop not long ago, i.e., only when Borio and Zhu (2008), in a pioneering contribution, first highlighted its potential relevance. Hence, it was mainly neglected in the pre-crisis understanding of monetary policy transmission. Its key hypothesis is that monetary policy systematically affects risk attitudes within the financial sector in a procyclical manner. If the policy stance is relaxed (tightened), risk attitudes become looser (more conservative). In that respect, Borio and Zhu (2012, p. 237) define the risk-taking channel as "the link between monetary policy and the perception and pricing of risk by economic agents." If risk attitudes respond in a procyclical fashion to monetary impulses, the impact of monetary policy on lending dynamics is even stronger than predicted by the theory on the financial accelerator and the bank lending channel.

In order to precisely describe the risk-taking channel, it is useful to analyze policy transmission in a graphical exposition of the loan market.[1] Taking into account the previous discussion of the financial accelerator mechanism, loan demand can be expressed by

$$L_D = L_D(r_L, \Phi(i_t), \eta), \tag{8.1}$$

where r_L denotes the loan rate, Φ is the net worth position of borrowers (inversely related to the policy rate i_t), and η is a parameter measuring the stringency of collateral requirements, which is treated as constant for now. Loan demand is downward-sloping in r_L while variations of Φ and η will trigger shifts of the curve as such.

Loan supply is characterized in the spirit of Disyatat (2011) and takes the following form:

$$L_S = L_S\left(r_D(i_t, \frac{L}{\omega(i_t)}, \alpha)\right), \tag{8.2}$$

where r_D denotes funding costs of the bank sector. More specifically, r_D should be viewed as the interest rate banks need to offer financiers when issuing non-insured (short-term) liabilities. Funding costs r_D vary proportionally with the policy rate i_t, since the latter represents the benchmark short-term interest rate. Moreover, they increase in the default probability of banks, which is in turn determined by the ratio of loans L to net worth ω. Similar to borrower net worth, ω is assumed to be inversely related to the policy rate. A rising volume of (risky) loans at a given net worth ω increases the probability of bank distress, since net worth is less likely to provide a sufficient protection for bank financiers. The parameter α measures the required marginal increase in r_D for a marginal increase in leverage L/ω and can be regarded as a proxy for the risk tolerance of bank financiers. To sum up, default probabilities within the banking sector increase in leverage and thus in L. Hence, loan supply is upward-sloping as the costs of lending increase in L. The slope is given by α, which denotes the marginal cost of additional leverage.[2]

[1] Woodford (2010) pursues a similar approach.
[2] It is equally conceivable to explain the positively sloped loan supply curve with banks' profit-

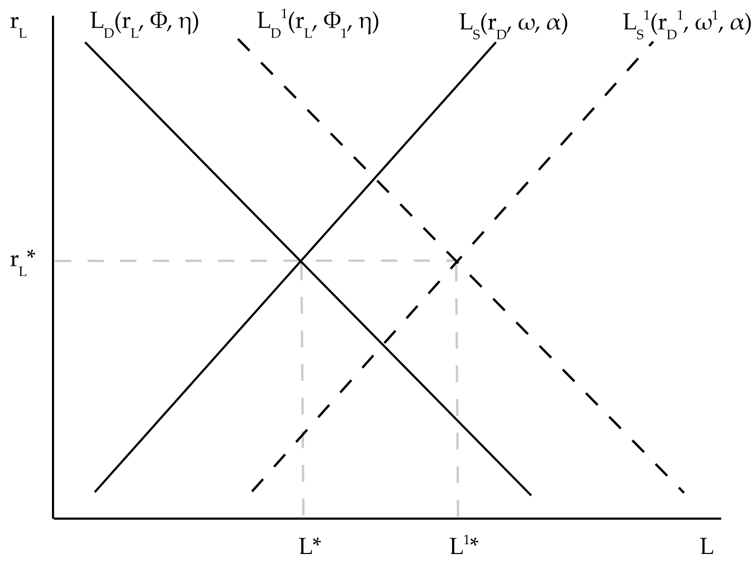


Figure 8.1: *Traditional Policy Transmission on the Loan Market*

Figure 8.1 depicts the effect of a decrease in the policy rate as indicated by the theory on non-neoclassical transmission channels. An easing of the policy stance causes a rise in borrower net worth from Φ to Φ_1. The increasing amount of collateral renders some additional borrowers eligible for a loan, whereas they were collateral-constrained before the decrease in the policy rate. Hence, loan demand shifts to the right, primarily due to the financial accelerator effect. With respect to loan supply, a decrease in i proportionally lowers r_D. Moreover, it triggers an increase in net worth from ω to ω_1. Thus, bank leverage declines with an increase in ω, which further reduces r_D as lending to banks becomes less risky. In a nutshell, banks are able to extend more loans at lower costs. Loan supply likewise shifts to the right. As a result, the equilibrium lending volume increases, and so does credit-financed spending.[3]

If risk attitudes are allowed to fluctuate procyclically in the spirit of the risk-taking channel, the impact of monetary impulses on lending dynamics will become stronger.

maximizing behavior. If interest rates rise, banks are (ceteris paribus) willing to increase loan supply due to an increase in the intermediation margin. However, banks in the model of Disyatat (2011) operate under perfect competition and therefore make zero profits. The slope of the supply curve is thus exclusively determined by (funding) cost considerations.

3 Note that the net effect on the loan rate r_L^* depends on the relative strength of supply and demand shifts. For the sake of simplicity, I assume that they are of equal magnitude.

To capture this idea, loan demand is slightly modified such that

$$L_D = L_D(r_L, \Phi(i_t), \eta(i_t)), \tag{8.3}$$

which implies that the stringency of collateral requirements becomes endogenous. Specifically, it is assumed that η is inversely related to the policy rate. A decrease in i_t triggers looser risk attitudes within the banking sector, and collateral requirements become relaxed. For example, banks may accept collateral of lower quality and/or a lower degree of collateralization. Put simply, banks soften their lending standards. This effectively amounts to a further relaxation of borrowers' collateral constraints.

In order to analyze the implications for loan supply, I allow that α varies with the policy stance. Loan supply is then given by

$$L_S = L_S\left(r_D(i_t, \frac{L}{\omega(i_t)}, \alpha(i_t))\right). \tag{8.4}$$

I assume that $\partial\alpha(i_t)/\partial i_t > 0$. If the policy rate decreases, bank financiers loosen their risk attitudes and are willing to tolerate higher leverage in the banking system. Put differently, the required marginal risk compensation for a marginal increase in leverage declines. As a result, the supply curve becomes flatter.

Hence, the risk-taking channel can be crudely captured by modeling η and α as variables which are endogenous to the policy stance. As a consequence, the response of lending dynamics to a monetary impulse is altered. Figure 8.2 depicts comparative statics in the presence of this additional amplification mechanism. The dashed lines L_D^1 and L_S^1 correspond to loan supply and loan demand responses implied by the bank lending channel and the financial accelerator, respectively (see Figure 8.1). The inclusion of the risk-taking channel triggers a further shift of loan demand to L_D^2 (dotted line). The collateral requirement η endogenously declines to η_1, since lower policy rates motivate banks to soften their lending standards. Moreover, the loan supply becomes flatter and is now given by L_S^2 (dotted line). Risk tolerance of bank financiers increases, which implies that α decreases to α_1. As a result, lending increases more strongly and the loan rate declines to r_L^{2*}. This pattern is broadly consistent with available evidence on the risk-taking channel, which will be presented in detail in Section 8.7.

Yet this stylized exposition of the risk-taking channel leaves several important questions unanswered. For instance, the notion of a certain "risk attitude" is very fuzzy and

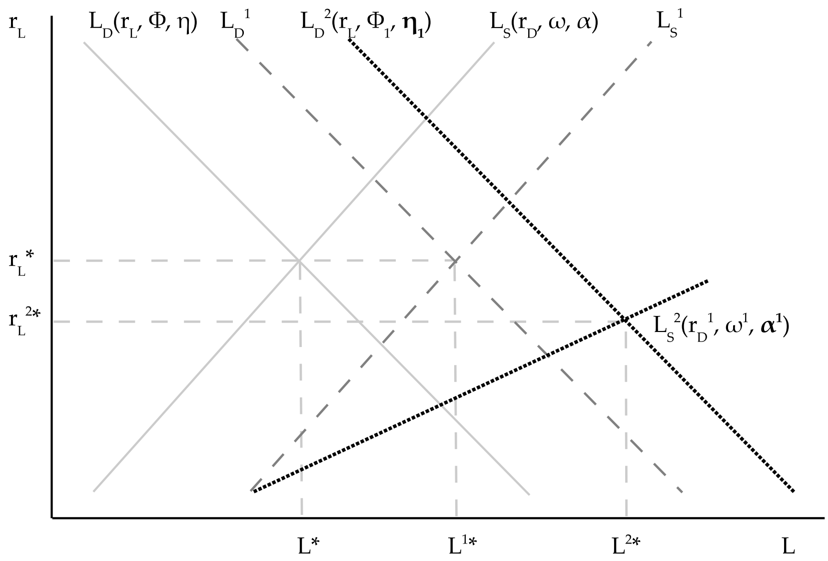


Figure 8.2: *Policy Amplification by the Risk-Taking Channel*

deserves clarification. The subsequent pages will be devoted to this task. Moreover, the supposedly procyclical response of risk attitudes to the policy stance is so far a mere ad-hoc assumption. Fortunately, detailed models of banks' risk-taking incentives and their relation to monetary policy have been developed in recent years. They will be extensively discussed in the remainder. These models consistently predict that a relaxation of the policy stance motivates banks to (i) increase their leverage, to (ii) take additional credit risk and to (iii) rely more strongly on potentially unstable funding sources. Hence, the qualitative implications of the stylized exposition of the risk-taking channel above tend to be in line with more sophisticated approaches.

8.2 General Determinants of Risk Attitudes

8.2.1 The Semantics of Risk

In order to attain a precise picture of the risk-taking channel, it is necessary to clarify the determinants of attitudes towards risk on a general level. The attitude towards risk determines the desired compensation for risk-taking and thus the prices of risky assets along with their desired risk premium. A useful decomposition of the factors determining attitudes towards risk is given by Gai and Vause (2006, pp. 167-172). As a start, they define the *risk premium* of an asset as its expected excess return over some risk-free asset being required by investors to bear its additional risk. Risk premia depend on both asset-specific and general factors. They are positively related to the individual quantity of risk of a given asset - for instance measured by the volatility of its price and its payoffs - but also to the general price of a unit of risk on financial markets. The price of risk is inversely related to investors' general *risk appetite*. Risk appetite in turn is thought to decrease in *risk aversion*, which indicates the degree of dislike for uncertain outcomes, and in the level of *macroeconomic uncertainty*.[4] Following Gai and Vause (2006, p. 169), a visualization of the interplay of these factors is provided in Figure 8.3.

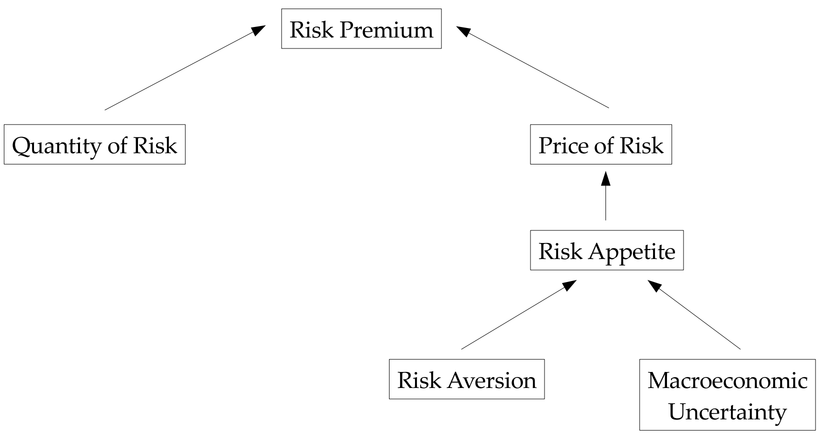


Figure 8.3: *Decomposition of Risk Premia*

At first sight, fluctuations of risk premia can occur for several reasons. However, risk aversion is usually modeled to be a "deep" parameter, which is embedded in the utility function of economic agents as a preference specification and does not vary over time. If the quantity of risk of an asset is also constant, fluctuations in its risk premium can only be explained by changes in the level of macroeconomic uncertainty and its

[4] In what follows, macroeconomic uncertainty is (sloppily) identified with macroeconomic volatility, i.e., the volatility of output and inflation. Even though this is quite common in the literature, it should be noted that uncertainty (if properly defined) is in fact a concept which is distinct from the notion of risk and volatility (Sauter, 2014).

associated impact on risk appetite and, eventually, the price of risk.

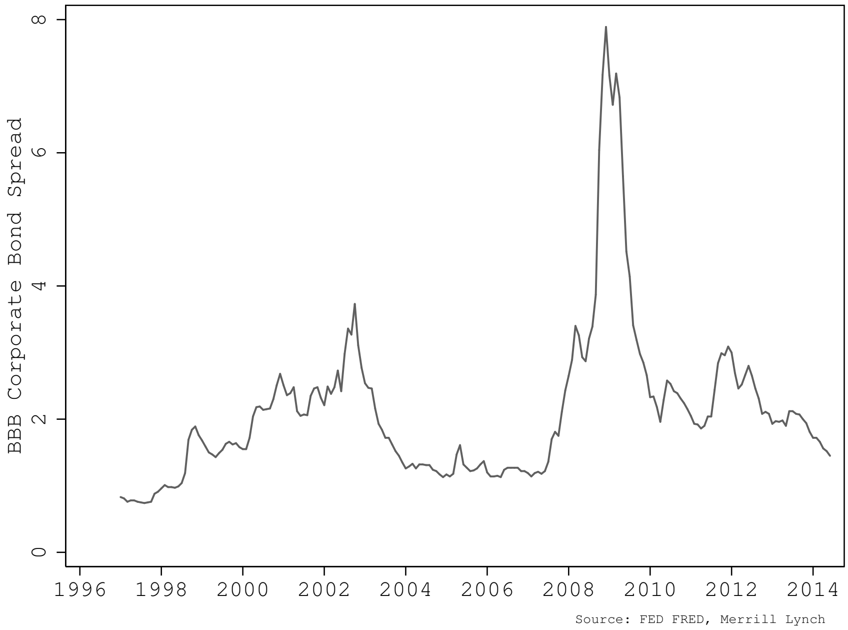


Figure 8.4: *BBB US Corporate Bond Spread over Treasuries*

However, it is unrealistic to assume that the riskiness of an asset does not vary over time. For example, default risk arguably fluctuates with the business cycle and, consequently, so will required risk premia on assets carrying credit risk. Nevertheless, Figure 8.4 tries to provide an example of a risk premium primarily driven by fluctuations in risk appetite. It depicts the spread between the Merrill Lynch index measuring the yields of BBB-rated US corporate bonds and the yield of presumably risk-free US treasuries. This spread represents the excess return and hence the risk premium which is required by investors. As an approximation, the quantity of (credit) risk of the underlying assets can be regarded as constant over time. If the credit quality of an issuer changes, its rating is adjusted and its bonds will be removed from the index. Despite an approximately constant quantity of risk, the spread shows considerable fluctuations. By elimination, they have to be driven exclusively by changes in risk appetite. If risk aversion is assumed to be constant as well, the only remaining variable is macroeconomic uncertainty. For example, spreads rose dramatically after 2008, when the Great Recession has arguably increased macroeconomic uncertainty. Put more generally, this example suggests that macroeconomic conditions affect the general price of risk and thus risk premia on any given asset. Since monetary policy critically affects macroeconomic outcomes, it might exhibit influence on the price of risk within the economy and thus on general risk attitudes of economic agents. In what follows, I will explore the possibility of such a mechanism in more detail.

8.2.2 Risk Attitudes in the Consumption-Based Asset Pricing Model

The decomposition of risk premia into asset-specific and general factors appears sensible, but calls for an explicit formal representation. This can be achieved with the help of the consumption-based asset pricing model (CCAPM) going back to Lucas (1978). In what follows, I refer to its treatment in Cochrane (2001, ch. 1).

Agents receive a stochastic endowment in each period. This endowment can be used for immediate consumption. Alternatively, agents are able to save and postpone consumption by investing into assets with different risk characteristics. In its simplest form, the model describes an exchange economy and is hence entirely formulated in real terms. Agents have intertemporal utility functions given by

$$U = E_t \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{8.5}$$

Per-period utility concavely increases in consumption and future consumption is discounted with a (gross) time preference parameter β. The concavity of the utility function implies that agents are risk averse in the sense that they prefer smooth consumption streams over volatile ones. Intertemporal optimization gives the basic pricing equation of an asset:

$$p_t = \beta \frac{u'(c_{t+1})}{u'(c_t)} x_{t+1}. \tag{8.6}$$

The pricing equation ensures that marginal disutility of foregone consumption implied by a marginal investment in the asset, which is the current asset price p_t multiplied by marginal utility of consumption $u'(c_t)$, equals the expected marginal utility gain of consumption in the next period, which is the asset's expected payoff x_{t+1} multiplied by expected future marginal consumption utility $u'(c_{t+1})$ which has to be discounted with β.[5] Simplification is possible by defining the *stochastic discount factor* (SDF) m_{t+1} as

$$m_{t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)} \tag{8.7}$$

and the pricing equation can now be written in a more compact form as

$$p_t = m_{t+1} x_{t+1}. \tag{8.8}$$

The utility function is specified as

$$u(c_t) = \frac{c_t^{1-\gamma}}{1-\gamma} \tag{8.9}$$

with $\gamma > 0$ as the coefficient of relative risk aversion. Risk aversion and hence the desire to smooth consumption streams increases in γ.[6] Calculating marginal utility from (8.9) and plugging it into (8.7) yields

$$m_{t+1} = \beta \left(\frac{c_{t+1}}{c_t} \right)^{-\gamma}. \tag{8.10}$$

The discount factor, and hence asset prices, vary positively with β. For low β, investors are impatient so that postponing consumption has to be rewarded with higher returns. Additionally, the SDF decreases in expected consumption growth c_{t+1}/c_t. This is due to the desire for consumption smoothing embedded in the utility function. If consumption growth is expected to be low or even negative, investors strongly desire to smooth out fluctuations in consumption with the help of future asset payoffs which drives up current asset prices.

Moreover, the stochastic discount factor pins down the level of the economy's gross risk-free rate R^f. To see why, consider an asset with a certain unit payoff in the next period. By use of Equations (8.6) and (8.8), it is possible to write

5 For the sake of notational simplicity, I refrain from using expectation operators when possible. Variables indexed with $t+1$ are rational expectations based on available information in the current period t, unless specified otherwise.

6 Technically, the concavity of $u(c_t)$ increases in γ. A function is concave if its first derivative declines monotonously, which holds true in this case since $u'(c_t) = c_t^{-\gamma}$ and $u''(c_t) = -\gamma c_t^{-\gamma-1} < 0$, with the latter term decreasing in γ.

$$\begin{aligned} p_t &= m_{t+1}x_{t+1} \\ p_t &= m_{t+1} \\ \frac{1}{p_t} &= \frac{1}{m_{t+1}} = R^f \end{aligned} \tag{8.11}$$

Rewriting the pricing equation using the covariance decomposition $cov(m_{t+1}, x_{t+1}) = E(m_{t+1}x_{t+1}) - E_t(m_{t+1})E_t(x_{t+1})$ allows to look at the pricing of risky assets in more detail:

$$\begin{aligned} p_t &= E_t(m_{t+1})E_t(x_{t+1}) + cov(m_{t+1}, x_{t+1}) \\ &= \frac{x_{t+1}}{R^f} + cov(m_{t+1}, x_{t+1}). \end{aligned} \tag{8.12}$$

The first term denotes the asset price under risk neutrality, which is the expected payoff discounted with the risk-free rate R^f. The second term adjusts for risk. Asset prices decrease if the SDF and the asset payoffs have a negative covariance: Equation (8.10) implies that the SDF decreases in consumption growth. Hence, if consumption growth and payoff move in line, the covariance of the SDF and the asset payoff becomes negative, which reduces asset prices. This result is again due to the desire for consumption smoothing. An asset whose payoff co-varies positively with consumption growth produces undesired volatility of the consumption stream. Therefore, investors are only willing to buy this asset at a lower price. Vice versa, assets whose payoffs are negatively correlated with consumption (implying positive covariance between SDF and payoff) trade at higher prices since they carry the additional benefit of smoothing consumption across states. Put generally, assets with procyclical payoffs command lower prices and hence higher returns than assets with countercyclical payoffs.

The risk premium of an asset i can be obtained with a further rearrangement of Equation (8.8):

$$p_t^i = E_t(m_{t+1}x_{t+1}^i). \tag{8.13}$$

Dividing by p_t^i yields

$$1 = E_t(m_{t+1}R_{t+1}^i), \tag{8.14}$$

where R^i_{t+1} denotes the asset's gross return. Making use of the covariance decomposition and Equation (8.11) gives

$$\begin{aligned} 1 &= E_t(m_{t+1}R^i_{t+1}) \\ 1 &= m_{t+1}R^i_{t+1} + cov(m_{t+1}, R^i_{t+1}) \\ R^i_{t+1} - R^f &= -R^f cov(m_{t+1}, R^i_{t+1}). \end{aligned} \tag{8.15}$$

Equation (8.15) clarifies that assets with procyclical payoffs - which implies a negative covariance of SDF and return - need to carry a risk premium such that investors are compensated for the likely increase in consumption volatility that comes with investing in this specific asset. In a final step, (8.15) is multiplied by σ^2_m/σ^2_m and σ_R/σ_R, where σ^2_m denotes the variance of the SDF and σ_R stands for the standard deviation of the asset return. This yields

$$\begin{aligned} R^i_{t+1} - R^f &= -R^f cov(m_{t+1}, R^i_{t+1}) \\ &= -\frac{cov(m_{t+1}, R^i_{t+1})}{\sigma^2_m}\sigma^2_m R^f \\ &= -\frac{cov(m_{t+1}, R^i_{t+1})}{\sigma^2_m}\frac{\sigma_R}{\sigma_R}\sigma^2_m R^f \end{aligned} \tag{8.16}$$

Exploiting the definition the correlation coefficient allows a final and insightful rearrangement of (8.16).[7] The risk premium of an asset i can be ultimately expressed as

$$\begin{aligned} R^i_{t+1} - R^f &= -\frac{cov(m_{t+1}, R^i_{t+1})}{\sigma^2_m}\frac{\sigma_R}{\sigma_R}\sigma^2_m R^f \\ &= \underbrace{-\rho_{m,R}\frac{\sigma_R}{\sigma_m}}_{\beta_i}\underbrace{\sigma^2_m R^f}_{\lambda_t} \end{aligned} \tag{8.17}$$

where the terms summarized by β_i denote the risk quantity of the asset. If the correlation of SDF and asset return $\rho_{m,R}$ is negative, the return is procyclical and the asset thus carries more risk. Additionally, the quantity of risk increases in the ratio of return volatility to SDF volatility. As indicated by (8.7), the latter depends positively on the volatility of consumption growth and can thus be interpreted as a proxy for

7 The correlation coefficient of two variables x and y is given by $\rho_{xy} = \frac{cov(x,y)}{\sigma_x \sigma_y}$.

macroeconomic volatility. In a nutshell, an asset's quantity of risk increases if returns are procyclical and if their volatility rises relative to macroeconomic volatility.

The price of risk is denoted by the terms included in λ_t. It depends on risk aversion and the degree of macroeconomic uncertainty. As argued in Cochrane (2001, p. 19), an analytical solution for λ_t can be derived under the assumption that consumption growth is log-normally distributed. It then holds that

$$\lambda = \gamma \sigma_t^2(\Delta c_{t+1}). \tag{8.18}$$

Recall that γ is risk aversion parameter in the utility function which governs the strength of the consumption smoothing motive. The term $\sigma_t^2(\Delta c_{t+1})$ is the volatility of consumption growth which proxies macroeconomic uncertainty. Since risk aversion is assumed to be constant, the price of risk co-varies positively with macroeconomic volatility. Interchangeably, risk appetite as the inverse of the price of risk (cf. Figure 8.3) is negatively related to macroeconomic volatility. To sum up, the risk premium can be formally decomposed into the product of the asset-specific quantity of risk and the general price of risk as suggested by Gai and Vause (2006). The price of risk is crucially dependent on macroeconomic volatility.

8.3 Risk Attitudes and the Role of the Monetary Regime

8.3.1 Policy Objectives, Strategies and the Price of Risk

Given the predictions of the CCAPM, monetary policy affects the pricing of risk on financial markets by its influence on macroeconomic volatility. Importantly, this holds even when risk aversion and individual riskiness of assets are regarded as being unrelated to monetary policy. Central banks critically affect risk appetite and hence the general price of risk by their preferences with respect to the relative importance of inflation and output stabilization objectives. Moreover, the price of risk is also affected by the general strategy the central bank chooses to achieve its ultimate objectives. For example, I will demonstrate that the price of risk differs depending on whether monetary policy acts under discretion or whether the central bank commits to a decision rule. Thus, the choice of the policy regime has secular consequences for the pricing of risk.

It is well-known from the literature on optimal monetary policy, that policymakers face a trade-off between inflation volatility σ_π and output volatility σ_y which is managed according to the relative importance attached to the stabilization of each measure. Taylor (1979) was first to show that optimal policy in a reduced-form rational expectations model can be formulated as the minimization of an intertemporal loss function. A central bank loss function in this spirit is

$$L_t = E_t \sum_{i=0}^{\infty} \beta^t \left((\pi_{t+i} - \pi^*)^2 + \alpha (y_{t+i} - y^*)^2 \right) \tag{8.19}$$

indicating that monetary policy seeks to minimize current and expected deviations of inflation π and output growth y from their target values (denoted with an asterisk). The relative importance of both objectives is governed by α. Stronger (weaker) preferences for relative output stabilization lead to higher (lower) inflation variability. This trade-off can be depicted by plotting the so-called efficient policy frontier (Gertler et al., 1999). Conditional on the value of α, optimal monetary policy delivers an outcome with a specific combination of inflation and output volatility (Figure 8.5).[8]

Hence, central bank preferences may exert decisive influence on output and consumption volatility. Recalling Equations (8.17) and (8.18), it is tempting to assume that a strong focus on output stabilization is likely to decrease the price of risk and hence risk premia due to the reduction of output volatility. However, nominal assets such as bonds may suffer from the associated increase in inflation volatility.

As shown by Sarte (1998) and others, the CCAPM can be extended to account for nominal assets. Unlike real assets, nominal assets deliver fixed repayments, but their real value may be impaired by unexpected inflation.[9] Thus, investors require a com-

[8] In a consistently micro-founded New-Keynesian model, the loss function emerges from the maximization of social utility of the representative household. The value of the parameter α is, inter alia, governed by the degree of risk aversion embedded into the household utility function (which is perfectly similar to the one used within the CCAPM). If risk aversion increases, the household attaches higher value to smooth consumption streams. Hence, α increases since output stabilization decreases the volatility of consumption. See Woodford (2003, ch. 6) or Gali (2008, pp. 111-112) for detailed treatments. In this sense, central bank preferences reflect the preferences of the representative household.

[9] Within the CCAPM framework, real assets are usually considered as claims on (uncertain) future consumption. Their nominal payoff varies with the business cycle but also with the price level. Hence, payoff volatility rises in output volatility but not in inflation volatility. Conversely, nominal assets deliver nominally fixed repayments which insulates them from output volatility. However, the real value of payoffs varies with inflation. For example, stocks are real assets. Their dividend streams vary with macroeconomic conditions, but their real value is protected from inflation since firms presumably adjust prices (and hence nominal profits) with the price level. Conversely, credit claims are nominal assets. The principal and coupon payments are usually fixed in value.

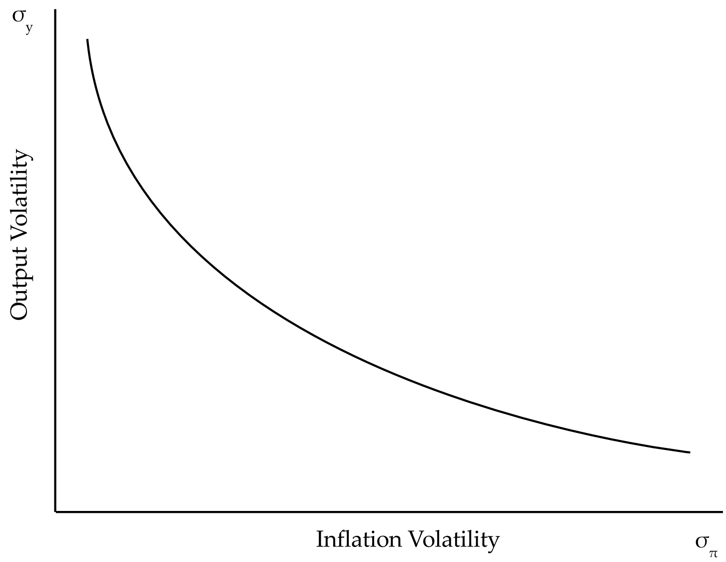


Figure 8.5: *Efficient Policy Frontier*

pensation for inflation risk. In a stylized form, the required (net) return on nominal assets i_t^N can be expressed by a slightly modified Fisher Equation and reads

$$i_t^N = r^f + E_t \pi_{t+1} + f(\sigma_\pi) \tag{8.20}$$

where r^f denotes the risk-free real return, $E_t \pi_{t+1}$ is expected inflation and the term $f(\sigma_\pi)$ with $\partial f(\sigma_\pi)/\partial \sigma_\pi > 0$ indicates that nominal assets carry an inflation risk premium which increases in inflation volatility.

A careful examination of the implications of monetary policy preferences for risk premia has been undertaken by Söderlind (2006). He derives analytical solutions for consumption and inflation volatility as a function of monetary policy preferences. It is shown that a strong preference for inflation stabilization increases the variance of output and thus risk premia on real assets. Conversely, if monetary policy focuses on the stabilization of output at the expense of heightened inflation volatility, risk premia on real assets decrease but inflation risk premia on nominal assets go up. Hence, monetary policy preferences carry important implications for the relative riskiness of nominal and real assets and their corresponding risk premia.

The policy strategy may have equally important implications for the price of risk. The choice of a certain strategy may affect the location of the efficient policy frontier and hence the feasible set of combinations for σ_y and σ_π.[10] Conditional on the characteristics of the policy strategy, the trade-off between inflation and output volatility may improve (worsen), which is reflected by a shift of the policy frontier towards (away from) the origin.

Welfare analysis based on the New-Keynesian model shows that central banks can improve the policy trade-off compared to policy based on discretion if they pursue a so-called commitment strategy (McCallum and Nelson, 2004). Under this strategy, the central bank credibly commits to a state-contingent plan. That is, the central bank credibly announces how it plans to respond to changes in macroeconomic conditions. If the central bank promises to react decisively in the wake of inflationary pressures, it achieves the stabilization of inflation expectations.[11] In this case, the policy trade-off becomes more benign. If inflation increases unexpectedly, the stabilization of inflation by a tightened policy stance may exhibit adverse effects on output. Under commitment, the mere threat of harshly increasing the policy rate in the wake of inflation shocks generates the (initial) expectation of a sharp decrease in output. To see that, consider the standard New-Keynesian Phillips Curve which is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(y_t - y^*) + \varepsilon_t^\pi \tag{8.21}$$

If an inflation shock ε_t^π hits the economy, the policy-induced expectation of weak economic activity leads to an automatic decline in expected inflation $E_t\pi_{t+1}$.[12] Since actual inflation π_t critically depends on expected inflation, the impact of the inflation shock on current inflation is mitigated. If the response of actual inflation to the inflation

---

10 Very generally speaking, a monetary policy strategy is the policy framework which is chosen by the central bank to achieve its ultimate objectives. In reality, it involves various factors such as quantitative definitions of ultimate objectives, the specification of potential intermediate targets, the choice of the policy instrument, pre-defined procedures for the evaluation of the adequate policy stance and a coherent communication policy. Comprehensive discussions of modern monetary policy strategies are given by Mishkin (2007, 2011) and Spahn (2012, ch. 5). In the subsequently discussed New-Keynesian model, policy strategies are treated in a highly simplified fashion. Essentially, the central bank chooses between discretionary and rule-based policy.

11 In order to maintain the golden thread, I do not lay out the formal properties of the commitment solution in detail. For that purpose, the reader is referred to Gertler et al. (1999), McCallum and Nelson (2004) or Gali (2008) among others.

12 Forward iteration of (8.21) in isolation verifies that inflation depends on current and expected future values of the output gap $(y_t - y^*)$ (Gertler et al., 1999, p. 1667).

shock is weakened, the central bank has to contract output by less to bring inflation back to target. Hence, the impact of the inflation shock on both output and inflation is muted. Put differently, macroeconomic volatility triggered by unexpected inflation goes down. Note that this effect is entirely due to the beneficial expectation effect implied by the commitment strategy.

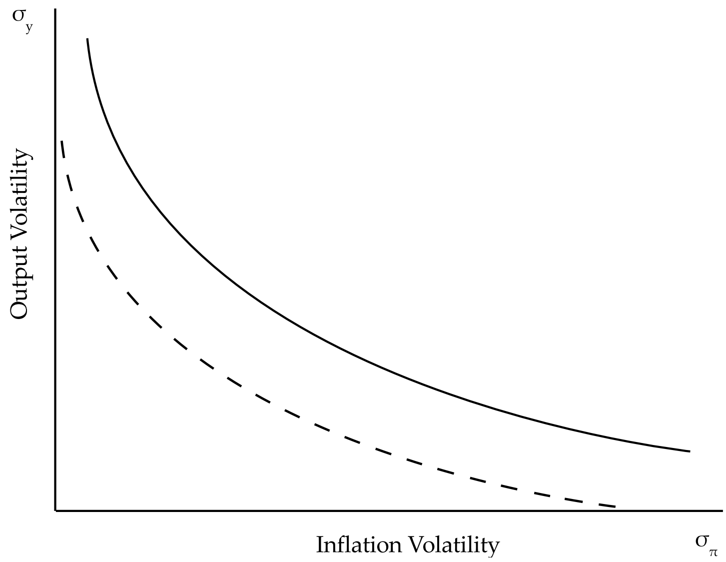


Figure 8.6: *Improvement of the Policy Trade-Off under Commitment*

Figure 8.6 depicts the implications for the policy trade-off. Commitment attenuates the impact of inflation shocks on macroeconomic volatility. Hence, for a given variance of ε_t^{π}, a switch towards the commitment strategy improves the policy trade-off. The efficient policy frontier consequently shifts towards the origin, as depicted by the dashed line in Figure 8.6. Given that both inflation and output volatility tend to decline, risk premia on nominal and real assets can be expected to decrease uniformly. Thus, the success of the policy strategy in containing macroeconomic volatility critically affects the general price of risk.

8.3.2 The Paradox of Credibility

The previous reflections help to shed light on an empirical phenomenon which could be observed from the middle of the 1980s until the beginning of the financial crisis in

2007. During this time, risk premia on equity, government bonds, corporate bonds and real estate uniformly declined in almost any advanced economy, as shown for instance in Trichet (2008). Simultaneously, the volatility of consumption and inflation along with other macroeconomic aggregates decreased markedly. These developments were documented, inter alia, by Stock and Watson (2003) for the US economy. They coined the term "Great Moderation" in that respect. The CCAPM indeed predicts a decreasing price of risk and hence falling risk premia in the wake of declining macro volatility. With respect to the sources of the Great Moderation, Stock and Watson (2003) and Benati and Surico (2009), among others, find that improvements in the practice of monetary policy have been critical.[13] Changes in both the theory and the practice of monetary policy beginning in the 1980s involved clear commitments to price stability, increased transparency with respect to intended policy actions and a growing recognition of the importance of influencing private sector expectations (Goodfriend, 2007). Hence, these developments may be interpreted as a step in the direction of the commitment solution with its beneficial effects on the policy trade-off.

But is the secular decrease of macroeconomic volatility and the price of risk during the Great Moderation unambiguously a good thing? To the extent that it can be ascribed to less severe supply shocks and improved policy practices, this question is usually answered positively. Trichet (2008, p. 11) claims that "a significant part of the decline in macroeconomic uncertainty is no windfall for modern societies: it is the fair and expected reward for institutional reform." Moreover, pre-crisis wisdom suggested that delivering price stability more or less automatically benefits financial stability. For instance, Bordo et al. (2002, p. 537) declares that "a monetary regime that produces aggregate price stability will, as a byproduct, tend to promote stability of the financial system." Similarly, Issing (2003, p. 22) states that "in general price stability fosters financial stability."

Quite to the contrary, some authors warned that the apparent success of monetary policy comes with a potential downside for financial stability. In particular, Borio and Lowe (2002) and Borio and White (2004) have argued that the very success in stabilizing inflation and the business cycle by employing a credible and transparent policy framework *promotes* the build-up of systemic risk on financial markets and increases

13 Another important contributor was the absence of severe macroeconomic shocks. This finding is equally in line with New-Keynesian models of optimal policy. In the previous example, a decline in macroeconomic volatility can also occur due to a decrease in the variance of the inflation shock ε_t^π.

the likelihood of financial crisis episodes. They dubbed this apparently contradictory hypothesis the *paradox of credibility*.

As empirically documented by Borio and Lowe (2002, p. 19), boom-bust cycles on financial markets may very well occur in the presence of subdued output volatility and low and stable inflation rates. Note that this observation drastically contradicts the CCAPM, which predicts a low and stable price of risk under calm macroeconomic conditions. Policy credibility may play an important role in the explanation of this phenomenon (Borio and Lowe, 2002, pp. 21-22). If inflation expectations are well-anchored, price and wage contracting tends to take place on a longer-term basis. In this case, inflation and wages become less sensitive to excess demand which may temporarily boost corporate profitability and hence asset prices. Thus, inflationary pressures manifest themselves in asset price increases rather than in price inflation of goods and services.

Given the relative stability of goods price inflation, there is no real reason for central banks to immediately tighten the policy stance when facing asset price inflation. Thus, booms on asset markets - often accompanied by a marked and eventually unsustainable expansion of credit - can unfold in a mostly unimpeded manner. This mechanism may be facilitated by a perceived asymmetry in the conduct of monetary policy, giving rise to moral hazard problems (Borio and Lowe, 2002, pp. 26-27). If policy does little to contain the boom but reacts with decisive support when the inevitable bust eventually threatens macroeconomic stability, this amounts to an effective protection of financial market participants from the downside of excessive risk-taking in the boom phase. This perceived insurance effect can create an upward distortion of risk-taking incentives.[14]

Moreover, if a focus on price stability makes nominal assets less risky, financing schemes may rely more heavily on debt instruments. The previous discussion of systemic risk clarified that debt, especially if issued excessively, gives rise to various forms of fragility. Hence, there may be an adverse effect on financial stability as a by-product. Albeit highly speculative in nature, this argument fits neatly with the accelerated increase of aggregate debt burdens observable in almost any advanced economy, as documented for instance in Buttiglione et al. (2014).

Hence, as noted by Borio and White (2004, p. 22), "the credibility of the central bank's anti-inflation commitment can be a double-edged sword" in the sense "that the

[14] Monetary policy in the US was explicitly committed to such a "mopping-up approach." For instance, Greenspan (1999) notes with respect to the danger of asset price bubbles that "[i]t is the job of economic policymakers to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion."

central bank can be a victim of its own success." The possibility of such an unintended by-product of successful macro stabilization calls for a modification of the policy framework, for example with a more pronounced role for proper macroprudential regulation. Moreover, as will be discussed in detail in Chapter 11, an explicit monetary policy reaction to the build-up of systemic risk might be in order.

To sum up: Risk attitudes need to be carefully decomposed into their underlying factors. The structure of monetary policy preferences and its general strategy affect the pricing of risk. Modern monetary policy frameworks may have ambiguous implications. On the one hand, as indicated by the CCAPM and the theory on optimal commitment policy, delivering price stability is beneficial for macroeconomic stability and the price of risk should thus be low and stable. On the other hand, as argued by the proponents of the paradox of credibility, rigid anti-inflation policy may have the unintended consequence of enhancing systemic risk.

However, the nexus between monetary policy and risk-taking is still incomplete. This Section discussed issues of longer-term nature, since the implementation of a certain monetary regime with its respective objectives and the corresponding strategy represents a fundamental policy choice which is unlikely to vary at short notice. Hence, the short-term link between monetary policy and risk attitudes still needs to be explored. Put differently, the question how short-term variations in the policy stance affect the (arguably cyclical) properties of risk-taking on financial markets has not been answered yet.

For that purpose, the simplified framework of the CCAPM is no longer suitable, not least because it neglects special issues related to financial intermediation.[15] Indeed, as suggested in Section 8.1, the majority of the potential responses in risk-taking to an altered policy stance are likely to take place within the financial intermediation sector. Changes in monetary conditions affect an important set of constraints and incentive schemes guiding risk-taking decisions within the latter. In order to model these mechanisms, an explicit treatment of banks is needed. The following Sections 8.4 - 8.6 aim to explore the short-term nexus between policy rate variations, risk-taking behavior

[15] The CCAPM in its basic form is useful to think about risk and risk attitudes in a macroeconomic context, yet it performs rather poorly in explaining empirical regularities of asset prices. For instance, as shown by Mehra and Prescott (1985), it cannot explain the historical risk premium on US stocks without assuming an implausibly high degree of risk aversion. Moreover, the price of risk exhibits large cyclical fluctuations in spite of relatively stable consumption growth. See Campbell (2003) and Ludvigson (2011) for insightful surveys on these empirical puzzles and the associated challenges for the CCAPM framework.

within the intermediation sector and the cyclical properties of the pricing of risk in more detail.

8.4 Risk-Taking and Active Balance Sheet Management (ABSM)

An important and powerful mechanism which links the stance of monetary policy to risk-taking behavior of financial intermediaries is the concept of *Active Balance Sheet Management* (ABSM). The ABSM concept predicts that a relaxation of the policy stance triggers a decline in required risk compensation, an increasing reliance on unstable funding sources and, under some circumstances, a higher amount of leverage within the intermediation sector. Its macroeconomic implications have been highlighted in a series of influential publications by Tobias Adrian and Hyun Song Shin (with varying co-authors). ABSM is a rather general term reflecting the notion that intermediaries actively adjust size, composition and leverage of their balance sheets in response to changing asset prices and market conditions. The various ABSM mechanisms are especially pronounced if balance sheet accounting occurs on a mark-to-market basis. The effect of the policy rate on asset prices and market conditions gives rise to a transmission channel running from policy rate variations to intermediary balance sheet adjustments and consequently their risk-taking behavior.

8.4.1 The Adrian-Shin ABSM Model

The model of Adrian and Shin (2010b) highlights a mechanism where a positive policy shock leads banks to expand their balance sheets. This goes hand in hand with a decline in the required risk compensation and a likely increase in both leverage and the share of unstable funding. The model is static and takes a partial-market perspective. There is a risky asset traded in period $t = 0$ at price p which delivers an expected payoff in the subsequent period $t = 1$. The payoff is a random variable $\tilde{w}$ which is uniformly distributed over the interval $[q - z, q + z]$. It therefore follows that mean and variance of the payoff are given by

$$E(\tilde{w}) = q \tag{8.22}$$

$$\sigma_{\tilde{w}}^2 = \frac{1}{12}[q + z - (q - z)]^2 = \frac{1}{12}(2z)^2 = \frac{z^2}{3}. \tag{8.23}$$

There is also a risk-free security paying an interest rate of i with certainty. Consider a passive and non-leveraged sector of risk-averse portfolio investors with an equity endowment e. It buys y units of the risky asset at price p and allocates the remaining endowment $e - py$ to the risk-free asset. Its expected payoff $E(W)$ is then given by

$$\begin{aligned} E(W) &\equiv qy + (1+i)(e - py) \\ &= (q - (1+i)p)y + (1+i)e \end{aligned} \tag{8.24}$$

where $(q - (1+i)p)y$ is the risky excess return and $(1+i)e$ the riskless return on equity. Passive investors seek to maximize a mean-variance utility function of the form

$$U = E(W) - \frac{1}{2\tau}\sigma_W^2, \tag{8.25}$$

which implies that utility increases in the expected portfolio payoff and decreases in its variance. The strength of the latter effect is scaled by the constant τ, which depicts investors' risk tolerance. Investors' choice variable is y, the amount of risky assets the sector is willing to hold. Plugging (8.24) into (8.25) gives

$$U = (q - (1+i)p)y + (1+i)e - \frac{1}{6\tau}y^2z^2 \tag{8.26}$$

$$= (q/p - (1+i))py + (1+i)e - \frac{1}{6\tau}y^2z^2 \tag{8.27}$$

where $(q/p - (1+i))$ is the expected excess return of investing in the risky asset.[16] The FOC delivers optimal demand y_P for the risky asset and is given by

$$\frac{\partial U}{\partial y} = (q/p - (1+i))p - \frac{1}{3\tau}yz^2 = 0 \Leftrightarrow y_P = \frac{3\tau}{z^2}(q - (1+i)p) \tag{8.28}$$

The interpretation is straightforward. Other things equal, demand for the risky asset increases in risk tolerance τ and decreases with z, which gives the width of the

[16] Note also that the portfolio variance follows from $\sigma_W^2 = y^2\sigma_{\tilde{w}}^2 = y^2\frac{z^2}{3}$.

interval of possible payoffs and hence should be regarded as a proxy for the asset's risk. Demand is also increasing in the excess return and collapses to zero as soon as $q \leq p(1+i)$, ergo if the excess return becomes zero.

Finally, there is a sector of risk-neutral active investors who operate with leverage, which are supposed to represent a stylized intermediation sector. Active investors are risk-neutral but operate under a Value-at-Risk (VaR) constraint. The VaR constraint stipulates that the equity endowment of the intermediation sector needs to be sufficiently large to ensure a zero default probability under all conceivable circumstances.[17] This carries the implication that liabilities are risk-free and thus act as a perfect money substitute. Importantly, assets enter the balance sheet with a mark-to-market valuation rather than at historical costs. Intermediaries invest an amount py in risky assets only. It is financed by the equity endowment e_b and debt issuance of the amount $e_b - py$. Their optimization problem is given by

$$\max_y E(W) \quad \text{s.t.} \quad VaR \leq e_b. \tag{8.29}$$

If it holds that $p < q/(1+i)$, the discounted payoff of the risky asset exceeds its price and delivers an excess return. Under that circumstances, the expected portfolio payoff $E(W)$ strictly increases in y, which implies that the VaR constraint is always binding. Risk neutral intermediaries seek to exploit excess return opportunities to the maximally feasible extent, i.e., they will always choose the highest possible amount of total assets.

The worst case payoff of a unit of the risky asset is $q - z$ where it is assumed that $q > z$ to ensure positive payoffs. In addition, creditors have to be repaid with the amount $p(1+i)$, since p is precisely the amount of financing required to buy a unit of the risky asset. Therefore, the VaR constraint reads

$$(p(1+i) - (q-z))y \leq e_b, \tag{8.30}$$

stating that the gap between the payment obligation to creditors $py(1+i)$ and the received worst case payoffs from the risky asset $(q-z)y$ always needs to be smaller

17 The VaR constraint is imposed ad hoc in the setting under consideration. However, in a different paper, Adrian and Shin (2013) show that VaR constraints can emerge endogenously as the optimal solution of a contracting problem under incomplete information between bank owners and bank financiers. See also Section 3.2.2 for a brief discussion of the VaR methodology.

than the equity cushion e_b, such that creditors can be repaid every time. Since the constraint always binds, (8.30) can be solved to obtain optimal asset demand of the intermediation sector as

$$y = \frac{e_b}{p(1+i) - (q-z)} \tag{8.31}$$

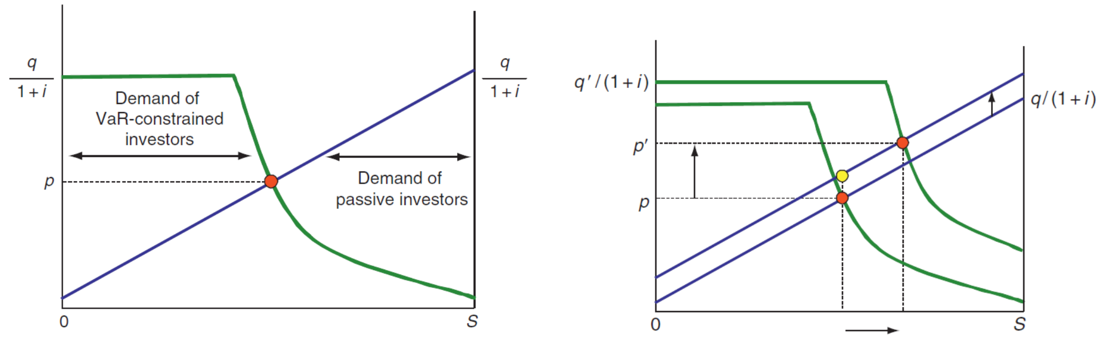
which delivers the result that asset demand increases in q and in the equity endowment e, whereas demand declines in p. Again, the analysis is straightforward. A rise in q and/or a decline in p boosts excess returns which fosters demand. So does an increase of the equity endowment e_b via a relaxation of the VaR constraint. An increase in the dispersion of payoffs, as measured by z, tightens the VaR constraint and reduces asset demand. For the same reason, demand declines in i.

Aggregate demand for the risky asset is now given by the sum of optimal demand by each sector. The risky asset is available in fixed supply S. The market clearing condition is then

$$y + y_P = S \tag{8.32}$$

The market clearing process is depicted graphically in the left panel of Figure 8.7. The intersection of sector-specific demand curves delivers the market-clearing price and determines the asset holdings of each sector. Passive investor demand is linear with an intercept of $p = q/(1+i)$ and subsequently increases with a reduction of the asset price. In line with (8.31), active investor demand is e_b/z for $p = q/(1+i)$. Demand is critically governed by the tightness of the VaR constraint. The worst possible lower deviation of the asset's payoff compared to its expected value is z. For each unit y of the asset, this potential loss has to be covered by the equity cushion. For instance, if $e_b = z$, it is only possible to demand the amount $y = 1$. A decrease of p gradually relaxes the VaR constraint and leads to a non-linear increase in demand.

It is now interesting to analyze the implication of an increase from q to q', which can be regarded as an improvement in the asset's fundamental value. It is depicted in the right panel of Figure 8.7. The demand curve of passive investors simply shifts up. The response of the intermediation sector is more complex. First, intermediaries



Source: Adrian and Shin (2010b, pp. 610-611)

Figure 8.7: *Market Clearing and Adjustment*

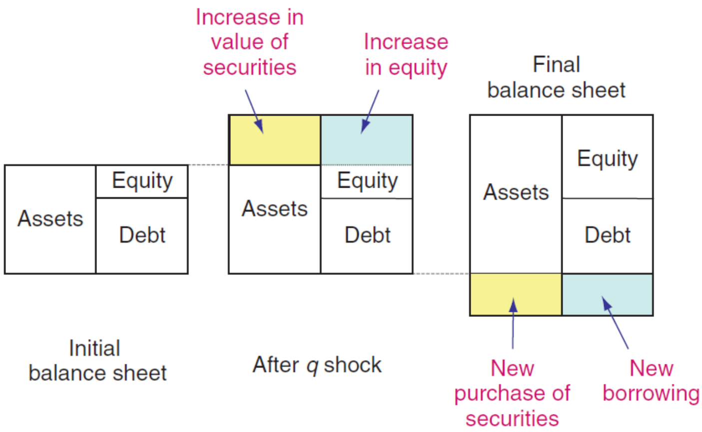
benefit from a valuation gain on their existing stock of assets. Suppose the final new market clearing price is p'. Since valuation gains directly translate into equity increases under mark-to-market accounting, Equation (8.31) allows to express the new amount of equity e_b' as

$$e_b' = (p'(1+i) - (q-z))y, \tag{8.33}$$

which corresponds to the balance sheet in the middle of Figure 8.8. The associated relaxation of the VaR constraint (and the continued presence of excess return opportunities) motivates intermediaries to increase their asset holdings until the constraint becomes binding again. The final situation after adjustment is represented by the balance sheet on the right-hand side of Figure 8.8. Specifically, it needs to hold that

$$e_b' = (p'(1+i) - (q'-z))y'. \tag{8.34}$$

Merging (8.33) and (8.34) yields



Source: Adrian and Shin (2010b, p. 611)

Figure 8.8: *Balance Sheet Adjustment after a q-Shock*

$$
\begin{aligned}
(p'(1+i)-(q'-z))y' &= (p'(1+i)-(q-z))y \\
y' &= \frac{(p'(1+i)-(q-z))}{(p'(1+i)-(q'-z))}y \\
y' &= \frac{(p'(1+i)-(q+q'-q'-z))}{(p'(1+i)-(q'-z))}y \\
y' &= \frac{(p'(1+i)-(q'-z)+(q'-q)}{(p'(1+i)-(q'-z))}y \\
y' &= y\left(1+\frac{q'-q}{p'(1+i)-q'+z}\right)
\end{aligned}
\tag{8.35}
$$

implying that intermediaries seek to extend their asset position for $q' > q$ (and vice versa). The leveraged intermediation sector amplifies the initial improvements in fundamentals.[18] A passive investor would take the increase in equity to e_b' simply as given. In stark contrast, leveraged intermediaries now find themselves with spare balance sheet capacity since the equity position e_b' exceeds the necessary VaR implied by the current asset position $p'y$. As the risky asset still promises excess returns, they

[18] The necessary condition for the existence of the amplification process is that $p'(1+i)-q'+z > 0$. This holds by assumption, since the asset price p' always exceeds the present value of its worst possible payoff $\frac{q'-z}{1+i}$. In that case, an increase in q always leads to balance sheet expansion with y' > y.

take on additional debt to purchase further assets until the VaR constraint binds again at $y' > y$. Thus, demand is increased despite an increase in the asset price.

Consider again the right panel of Figure 8.7 depicting the constellation after the increase from q to q'. While passive investors adjust demand only moderately, demand of the intermediation sector exhibits an overproportionally strong response. As a result, the asset price displays a marked increase. Moreover, relative asset holdings of the intermediation sector rise as well. This is due to the additional demand motive triggered by the relaxation of the VaR constraint.

Very importantly, it can be proven that the net effect on the risk premium is negative (Adrian and Shin, 2010b, pp. 612-613). The change in the asset price is larger than implicated by its fundamental improvement which implies that the required compensation for risk-taking decreases. This holds even though intermediaries are assumed to be constantly risk neutral. Their balance sheet adjustment nevertheless compresses the price of risk (which is equivalent to an increase in risk appetite, or to an equivalent decrease in the price of risk, cf. Figure 8.3). Note that the mere presence of a VaR constraint is sufficient to generate a procyclical response of the price of risk. There is no need to assume a variation in underlying preferences towards risk. In that respect, Adrian et al. (2010, p. 10) state (emphasis added):

> "The terminology of risk appetite is intended to highlight the apparent change in preferences of the banking sector. We say apparent change in preferences, since *the fluctuations in risk appetite are due to the constraints faced by the banks rather than their preferences as such.* However, to an outside observer, the fluctuations in risk appetite would have the outward signs of fluctuations in risk preferences of the investor."

A further inspection of Equation (8.35) shows that the strength of the amplification mechanism - measured by the size of $y' - y$ - increases for low values of z. The parameter z measures payoff dispersion and hence fundamental asset risk. A lower value of z decreases the VaR and supports a higher degree of leverage. With higher leverage, valuation gains lead to a proportionally higher increase in equity which ultimately gives rise to a stronger expansion of the balance sheets.

The decisive link to monetary policy emerges from the interpretation of the q shock as the outcome of a looser policy stance. A decreasing interest rate is likely to boost the values of both q and p, whereas the risk-free rate i is decreasing. Therefore, expansive monetary policy measures are strongly amplified by the leveraged intermediation sector. The model highlights some potential mechanics of the risk-taking channel. Easing the policy stance has four consequences: (i) Leveraged intermediaries expand their balance sheets, (ii) their outstanding level of debt increases, (iii) the required risk compensation for risky assets decreases, and (iv) intermediary leverage is likely to become procyclical. The last claim hinges on the assumption that asset risk z declines after a monetary expansion, for example due to an increase in expected economic activity and an associated decline in expected payoff volatility. Procyclicality means that leverage varies inversely with the policy rate or, put differently, that it varies positively with economic activity.

8.4.2 The Nexus of Policy Rate, Term Spread and Balance Sheet Dynamics

The discussion of the ABSM model clarified that monetary policy critically affects the pricing of risk via its influence on p and q, i.e., on the balance sheet conditions of intermediaries operating under mark-to-market accounting. Yet Adrian and Shin (2010b, pp. 636-640) highlight an additional, reinforcing effect of monetary policy on the equity endowment e. The latter can be regarded as the discounted value of future bank profits. They are not only determined by variations in q and p, but also by the profitability of maturity transformation, which is governed by the net interest margin, i.e., the difference between the average return on assets and the average cost of funding. In the model, this effect would correspond to a decline in i. Since intermediaries tend to borrow short and lend long, the term spread as the difference between some benchmark long-term rate and the policy rate provides a good indication for the profitability of banking operations. An increase in the term spread should therefore boost the value of bank equity, which further magnifies the previously discussed amplification process.

The term spread is almost exclusively determined by the policy rate. To see that, it is useful to revert to the expectation theory of the term structure. It claims that the long-term interest rate i_{nt} approximately equals the sequence of current and expected short-term rates i^e_{t+j}. Following Romer (2012, pp. 518-520), this implies that

$$i_{nt} \approx \frac{1}{n} \sum_{j=0}^{n-1} i^e_{t+j} \tag{8.36}$$

The term spread ζ_t can be expressed as

$$\zeta_t = i_{nt} - i_t = \frac{1}{n}\sum_{j=0}^{n-1} i^e_{t+j} - i_t \tag{8.37}$$

Taking the partial derivative with respect to the current short rate i_t yields

$$\frac{\partial \zeta_t}{\partial i_t} = \frac{1}{n} - 1 = \frac{1-n}{n} \tag{8.38}$$

where it holds that $\frac{\partial \zeta_t}{\partial i_t} \approx -1$ if n becomes sufficiently large. Hence, variations in the policy rate should inversely affect the term spread on an almost one-to-one basis. The level of the policy rate *per se* is thus an important driver of bank profitability via its impact on the term spread and the price of leverage.[19] This contrasts with the traditional view of monetary policy transmission, where the economic significance of short-term rates was mainly seen in the fact that they affect the actually relevant long-term rates via the term structure.

Again following an approach of Adrian and Shin (2010b), the impact of policy rate changes on the term spread can be analyzed with simple least squares regressions, in which the cumulative four-quarter change of the term spread $\Delta\zeta_{4q}$ is regressed on the cumulative four-quarter change of the policy rate Δi_{4q}. I performed this exercise for the US, the Euro Area and the UK. Results for the US and the Euro Area are displayed in Figure 8.9.[20]

The universally negative slopes of the regression lines reveal that policy rate variations inversely affect the term premium in each of the regions under consideration. This is formally confirmed when inspecting regression results in Table 8.1, where I also included the UK for comparison.

[19] It is plausible to assume that the policy rate provides the all-important benchmark for bank funding costs, since the forces of arbitrage keep money market rates always close to the policy rate. Leaving risk considerations aside, a positive spread between money market rates and the policy rate causes intermediaries to conduct refinancing mainly via central bank facilities. Money market funds are thus in excess supply, which will quickly decrease the spread.

[20] Data was obtained from Thomson Reuters Datastream. The term spread was calculated as the difference between the yield on government bonds with a maturity of ten years and the respective policy rate. For the Euro Area, Datastream provides a synthetic bond yield constructed from GDP-weighted country-specific yields. County-specific samplesizes differ due to varying data availability. While each sample ends in Q4 2014, the US sample begins in Q4 1983, the UK sample in Q3 1986 and the Euro Area Sample in Q1 1999.

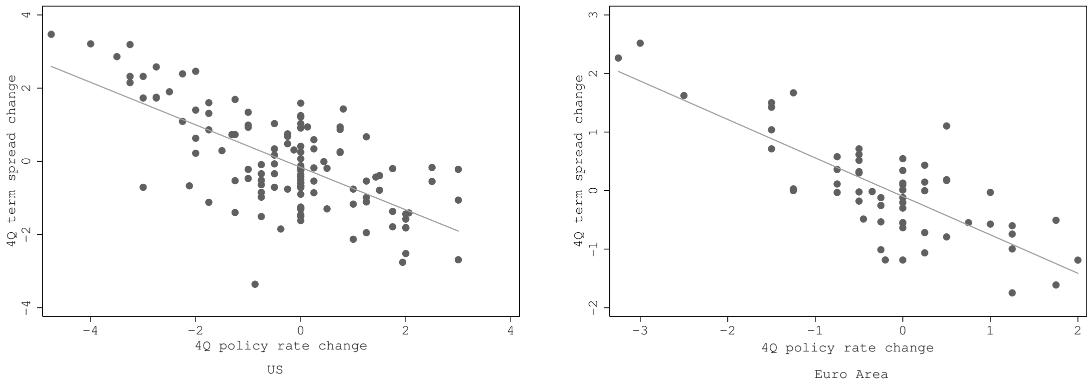


Figure 8.9: *Policy Rate Changes and the Response of the Term Spread*

$\Delta\zeta_{4q}$	US	UK	EMU
Δi_{4q}	-0.581***	-0.723***	-0.657***
Standard Error	(0.058)	(0.046)	(0.069)
Constant	-0.165*	-0.176**	0.099
Observations	123	110	60
R^2	0.450	0.690	0.610

Note: ***, ** and * denote significance on the 1 percent, 5 percent and 10 percent level.

Table 8.1: *Term Spread Regression Results*

For each region, the term-spread response to a cumulative one percentage point increase of the policy rate is significantly negative. The effect is most pronounced for the Euro Area and the UK, and slightly weaker for the US.[21] Even though the term spread responses are smaller than expected, they are nevertheless clearly negative. This lends support to the notion of a channel running from policy rate variations to banking profitability via the term spread.[22]

21 Adrian and Shin (2010b) find an almost perfect negative one-to-one relationship for the US. However, they calculate the term spread as the difference between ten year government bonds and three-month treasuries and use a sample with a different timeframe. The differing magnitude of coefficients notwithstanding, the result are qualitatively similar. To be sure, the term spread is also influenced by other factors, such as the term structure of inflation expectations and the relative supply of long-term government bonds. Moreover, the current policy stance is likely to affect expected future short rates, which may give rise to a level shift of the yield curve. The latter effect might weaken the relation between the current short rate and the term spread.

22 Another argument enhancing the importance of the short-term policy rate relates to the changing structure of financial intermediation. As argued by Adrian and Shin (2010a), market-based financial

More direct evidence of ABSM can be obtained by analyzing the evolution of intermediary balance-sheet aggregates. For that purpose, it is helpful first to consider a numerical example such as in Adrian and Shin (2010c): The initial balance sheet on the left-hand side of Table 8.2 consists of an asset position with an initial value of 100 which is financed by a combination of debt and equity. Leverage l is given by the ratio of total assets to equity and equals 10. The asset price now increases by 10 percent and leads to the balance sheet on the right-hand side of Table 8.2, where valuation gains on the asset position led to a one-to-one increase of the equity base. Importantly, leverage has decreased to $l = 110/20 = 5.5$. Taking this development as given without further adjustment establishes a negative relationship between asset growth and leverage.

Assets	Liabilities	Assets	Liabilities
Assets 100	Debt 90	Assets 110	Debt 90
	Equity 10		Equity 20

Table 8.2: *Passive Balance Sheet Management*

Consider now the balance sheet adjustment depicted in Table 8.3, which shall resemble the behavior of the leveraged intermediary sector. Active investors do not accept the decline in leverage. It enhances balance sheet capacity and allows to take on additional debt until the initial leverage ratio is restored.[23] Active investors therefore raise additional debt of 90 and buy additional assets in equal amount. In the end, the desired leverage ratio is restored. The strength of this amplification mechanism is impressive: The initial ten percent increase of assets caused the active investor's balance sheet to double in size.

It is easily conceivable that this strong additional demand impulse causes further increases of the asset price, giving rise to a powerful feedback loop of rising asset prices, a

systems are characterized by lengthened intermediation chains. Funds flowing from ultimate savers to ultimate borrowers undergo several intermediation steps. The intermediation margin is thus split between various participants. Given this structural decline in profitability, business models likely have become increasingly sensitive towards policy-induced changes in funding costs.

23 Targeting a constant leverage ratio may result from the fact that the VaR constraint starts to bind at $l = 10$ for a given asset risk. In reality, regulatory capital constraints may be the more relevant ones. Anyway, the nature of the capital constraint is of minor relevance for the workings of this mechanism.

Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Assets 100	Debt 90	Assets 110	Debt 90	Assets 200	Debt 180
	Equity 10		Equity 20		Equity 20

Table 8.3: *Active Balance Sheet Management*

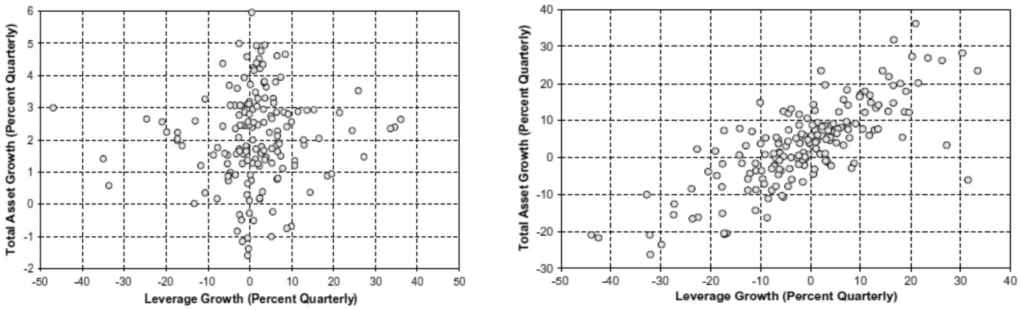
relaxation of balance sheet constraints and additional asset demand. This already holds when leverage is kept constant, but would be enhanced even further when leverage is procyclical.

Adrian and Shin (2010c) provide evidence for the relevance of this mechanism by comparing quarterly growth rates of total assets and leverage for various sectors in the US. The household sector is found to be the only one conducting passive balance management, in line with the pattern described in Table 8.2. Changes in households' total assets are associated with declines in leverage. By contrast, non-financial firms and commercial banks appear to manage their balance sheets actively, which is derived from the fact that, on average, leverage is kept constant while total assets vary, which corresponds to the balance sheet adjustments depicted in Table 8.3.

It is useful to make a further distinction *within* the intermediation sector between commercial banks and market-based financial intermediaries.[24] As shown by Adrian and Shin (2009), among others, the funding of the latter is almost entirely market based and mostly of very short-term nature. On the asset side, market-based intermediaries do not hold credit claims emerging from relationship lending as commercial banks do, but rather hold marketable assets such as bonds and asset-backed securities which are valued at market prices. Hence, ABSM can be expected to be more prevalent in the market-based intermediation sector. Adrian and Shin (2010b) show that this sector has grown at an extremely fast pace within the last 30 years, almost reaching the size of the commercial banking sector prior to the crisis. Hence, it is plausible to assume that the macroeconomic relevance of ABSM has increased considerably.

Figure 8.10, taken from Adrian and Shin (2010c, p. 422), plots growth rates of total assets against growth rates in leverage for the commercial banking sector and the broker dealer sector in the US. It can be seen that commercial banks tend to keep leverage

[24] Market-based intermediaries are for instance broker dealers (investment banks) and issuers of asset-backed securities. Put differently, market-based intermediaries are "shadow banks," i.e. entities which conduct intermediation business without relationship-based lending and the issuance of retail deposits. Moreover, market-based intermediaries are less regulated than commercial banks and do not have access to lender of last resort facilities. See Adrian and Ashcraft (2012) or Poschmann (2012) for detailed overviews on the structure of the shadow banking sector.



Commercial Banks

Broker Dealer

Figure 8.10: *ABSM in the US Intermediation Sector*

constant, even when total assets vary. The broker dealer sector (representing an important part of market-based intermediation) tends to increase leverage with the growth of total assets. Leverage thus exhibits a procyclical pattern. Nuño and Thomas (2013) and Jakab and Kumhof (2014) present similar evidence of ABSM for the US.

With respect to the Euro Area, ABSM seems to be equally prevalent. Figure 8.11 plots changes in total assets and changes in leverage for Monetary Financial Institutions (MFI) in the Euro Area.[25] Apparently, asset and leverage growth are related positively, pointing to procyclical leverage.

Somewhat surprisingly, commercial banks in the Euro Area seem to manage their balance sheets more actively than their US counterparts.[26] Baglioni et al. (2010) reach the same conclusion from their investigation of disaggregated balance sheet data for 13 large European banking groups.[27] They explain their findings with the different structure of the European banking market. In Europe, banking tends to be organized

25 Data was obtained from the ECB Statistical Data Warehouse. The Sample starts in Q1 1998 and ends in Q4 2014. Leverage was calculated as the ratio of total assets and capital. The definition of MFI includes credit institutions (basically commercial banks) and money market funds. Commercial banks constitute the overwhelming majority of the MFI sector. For instance, in 2013 total assets of the banking sector were about 97% of the MFI sector. See ECB (2012) for further details on collection procedures, precise definitions of balance sheet items and institutional classifications.

26 Interestingly, Panetta et al. (2009) find a slightly negative relation between total assets and leverage growth rates on the national level for Germany, Italy and France.

27 It should be noted, however, that their results are not perfectly comparable due to the inclusion of banks from Switzerland and the UK.

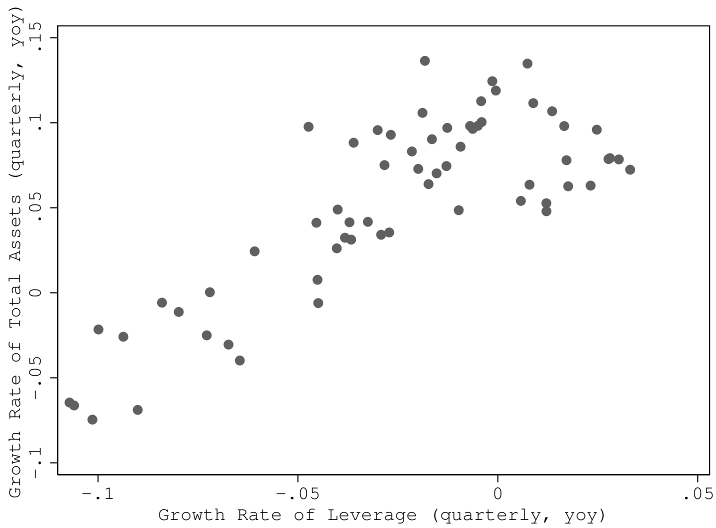
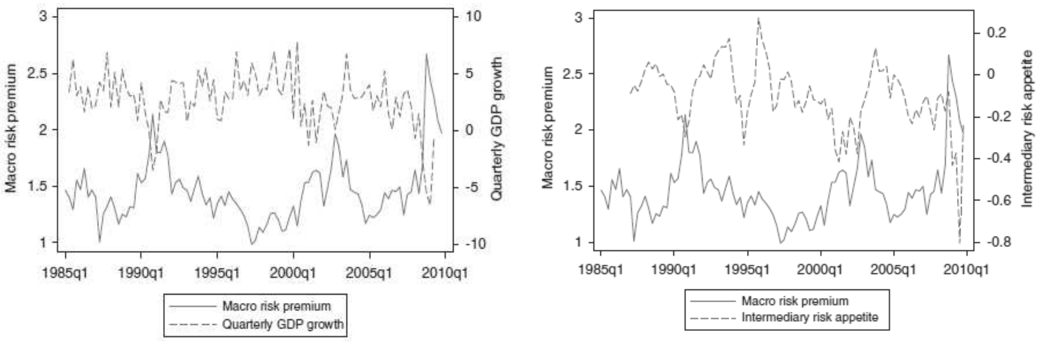


Figure 8.11: *ABSM in the EMU Intermediation Sector*

in universal banks which merge commercial and investment banking activities. Since these universal banks are typically very large, their activities figure prominently in the MFI statistics. Consequently, so do their (significant) investment banking operations, which may help to explain the procyclical pattern of leverage in the aggregate. Another potential reason are differences in regulation. Goodhart (2011) points out that the regulation of US commercial banks prior to the crisis involved an upper limit to leverage, while such a limit was absent for European banks.

The presence of ABSM as such says little about its macroeconomic relevance. However, the ABSM model predicts that strong intermediary balance sheet growth should go hand in hand with declining risk premia. In a further paper, Adrian et al. (2010) provide supportive evidence for this mechanism. To do so, they construct a Macro Risk Premium (MRP) which can be interpreted as the required average excess return on risky assets. The MRP is a weighted average of various yield and credit spreads, weights for which are obtained from a linear regression of GDP growth on these spreads. This implies that the MRP can be viewed as the required risk premium of a portfolio which is tracking real GDP growth and therefore represents a claim on macroeconomic performance. Their key finding is that the size of the MRP is inversely related to GDP Growth. This holds not only for the US, but also for Japan, the UK and Germany. It is further shown that the size of the MRP in turn depends on a so-called intermediary risk appetite factor, which in itself is driven by balance sheet growth of the financial sector.[28] These results, depicted in Figure 8.12 for the US, support the hypothesis of a transmission channel running from an increase in intermediary balance sheet growth - potentially caused by monetary expansion - to a decline in risk premia and a rise in real activity.



Source: Adrian et al. (2010, pp. 190, 195)

Figure 8.12: *Macro Risk Premium, Risk Appetite and Real Activity in the US*

8.4.3 Financing of Balance Sheet Expansions

Being of a partial-equilibrium nature, the ABSM model is silent on how the expansion of balance sheets is financed. It implicitly assumes that additional financing is supplied elastically and at fixed cost. Yet it is an open and arguably important question which market participants are willing to hold additional claims against an expanding intermediation sector.

Shin and Shin (2011) argue that balance sheet expansion can be financed via an increase in net capital imports. They document such a pattern for the economy of South Korea. Moreover, Bruno and Shin (2015) show that unexpected decreases in the US policy rate and the ABSM-driven response of US broker dealers trigger cross-border

[28] The risk appetite factor is constructed from growth rates of lagged financial sector balance sheet aggregates with particular predictive power for a change in the macro risk premium. Relative weights are determined in a similar fashion as for the MRP. See Adrian et al. (2010, pp. 191-96) for details.

banking flows, indicating that balance sheet expansion partly takes places in foreign assets. Hence, an easing of monetary conditions in the US spills over to financial systems throughout the world, which points towards an international dimension of the ABSM mechanism or the risk-taking channel in general. However, such arguments are less convincing on a global level, where net capital flows should cancel out by definition.

As an alternative, Shin and Shin (2011) point out that financing may occur via an increase in interbank claims and interbank liabilities, respectively. Put bluntly, the intermediation sector is self-financing its balance sheet expansion. Shin and Shin (2011, pp. 9-10) state that

> "banks draw on retail deposits to lend to ultimate borrowers. They can also hold claims against each other, if they so choose. Imagine a boom where the assets of [...] banks double in size, but the pool of retail deposits stays fixed. Then, the proportion of banking sector liabilities in the form of retail deposits must fall. In other words, rapidly expanding bank assets is mirrored by the increased cross-claims across banks."

In what follows, I will examine this mechanism with the help of a simple accounting exercise. Essentially, the banking sector issues additional deposits to attract additional assets from the non-leveraged sector. Note that this is in line with the Adrian-Shin ABSM model which predicted that relative holdings of assets by the intermediation sector increase in the wake of a balance sheet expansion after a favorable shock (see Section 8.4.1). Table 8.4 depicts the initial balance sheets of banks A and B.

Bank A		Bank B	
Assets	Liabilities	Assets	Liabilities
Assets 100	Deposits 90	Assets 100	Deposits 90
	Equity 10		Equity 10

Table 8.4: *Initial Balance Sheets*

Now suppose that Bank A borrows an amount of 100 from Bank B in the interbank market. Bank A consequently has an interbank liability (IL) to bank B, but also a corresponding balance of interbank deposits (IBD), representing a claim against Bank B. Conversely, Bank A has an interbank claim (IC) whereas the creation of an interbank

Bank A		Bank B	
Assets	Liabilities	Assets	Liabilities
Assets 100	Deposits 90	Assets 100	Deposits 90
IBD 100	Equity 10	IC 100	Equity 10
	IL 100		IBD 100

Table 8.5: *Balance Sheets after Interbank Lending*

deposits implies that its liabilities increase by an corresponding amount. The modified balance sheets are depicted in Table 8.5.

In a final step, Bank A uses its interbank deposit balance to buy additional assets, for instance from some passive outside investor. Final balance sheets are given in Table 8.6. Note that the balance sheet of Bank B is omitted since it does not change any more compared to Table 8.5.

Outside Investor		Bank A	
Assets	Liabilities	Assets	Liabilities
IBD 100	Equity 100	Assets 200	Deposits 90
			Equity 10
			IL 100

Table 8.6: *Balance Sheets after Asset Purchase*

The consolidated balance sheet of the banking sector after all of the aforementioned transactions is given in Table 8.7. The interbank claim and the interbank liability net out. In the end, balance sheet expansion is facilitated by the issuance of additional interbank deposits.

Banking Sector	
Assets	Liabilities
Assets 300	Equity 20
	Deposits 180
	IBD 100

Table 8.7: *Consolidated Balance Sheet of the Banking Sector*

Hence, balance sheet expansion for the sake of purchasing existing assets is conducted in a similar fashion as in the process of private credit creation, where banks extend loans and credit the corresponding amount as a deposit to the borrowers. However, the latter case involves the creation of *retail* deposits. In the case here, balance sheet expansion goes along with the creation of *interbank* deposits, which is a subtle yet important difference. The outsider, who receives a payment for selling his asset to the bank, does not discriminate between different forms of deposits. To him, deposits represent an ultimate claim on currency in any case.

However, the rise in interbank deposits increases the fragility of the system. While retail deposits are a relatively stable funding source which does not decline in aggregate under most circumstances, interbank funding can turn out to be very volatile and may disappear quickly. Suppose that Bank B starts to doubt the solvency of Bank A. It will then refuse to roll over its interbank claim on the latter. Bank A now faces a funding shortage and has to react by selling assets, which, at short notice, may involve a discount. Thus, Bank A may partly default on its interbank obligation and Bank B consequently realizes losses as well. As a result, the increase in balance sheet capacity may reverse quickly and is inherently unstable.

This is yet another manifestation of the argument that a financial system with pronounced and inherently fragile interconnections and strong reliance on short-term debt is prone to systemic risk. Put differently, loose monetary policy triggering ABSM-driven balance sheet expansion potentially aggravates systemic externalities associated with interconnectedness and fire sales (see Sections 4.1 and 4.3). In that respect, Shin and Shin (2011) have introduced the concept of *Non-Core-Liabilities*, which comprises various forms of interbank liabilities.[29] If the share of Non-Core Liabilities increases - as it arguably happens in a boom in which retail deposits grow slower than bank balance sheets - systemic risk is enhanced. Indeed, Hahm et al. (2013) and Shin (2013) show that the evolution of Non-Core Liabilities is a reliable predictor for future financial stress. Thus, a looser monetary policy stance induces not only a decline in desired risk compensation for assets, it *additionally* leads to an increasingly fragile refinancing structure within an expanding banking sector.

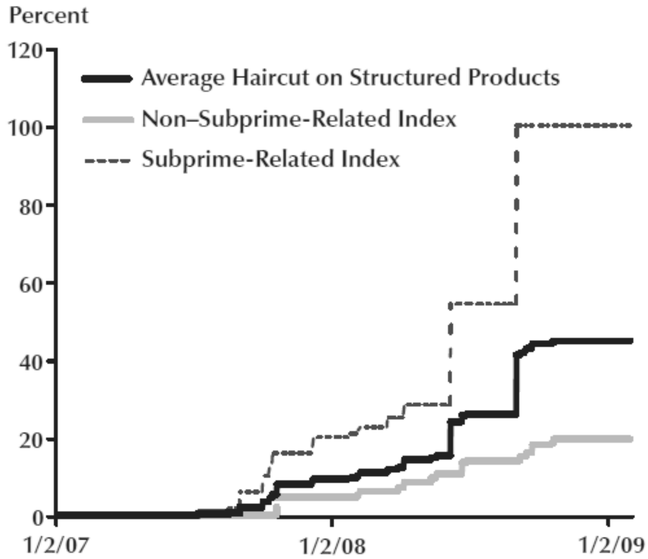
Figure 8.13 depicts Non-Core Liability Growth (defined in Appendix B) for US commercial banks. It is apparent that Non-Core Liabilities exhibit strong cyclical fluctuations. They consistently grew at double-digit rates prior to the crisis, and started to collapse drastically after the demise of Lehman Brothers in September 2008. Note also that their average growth rate is at about 6%, which indicates that the reliance on non-core funding is increasing in trend.

[29] See Shin and Shin (2011, p. 15) for a precise definition.

Figure 8.13: *Non-Core Liability Growth for US Commercial Banks*

Probably due to the recognition of the risks of large interbank exposures, financing via Non-Core Liabilities is often secured by collateral. However, this does little to mitigate the underlying procyclicality. For example, Shin and Adrian (2008, p. 299-300) neatly describe the peculiarities of collateralized finance via repurchase agreements:

> "[R]epurchase agreements (repos) [...] are the primary source of funding for market-based banking institutions. In a repurchase agreement, the borrower sells a security today for a price below the current market price on the understanding that it will buy it back in the future at a pre-agreed price. The difference between the current market price of the security and the price at which it is sold is called the "haircut" in the repo and fluctuates together with funding conditions in the market. The fluctuations in the haircut largely determine the degree of funding available to a leveraged institution. The reason is that the haircut determines the maximum permissible leverage achieved by the borrower. If the haircut is 2%, the borrower can borrow $98 for $100 worth of securities pledged. Then, to hold $100 worth of securities, the borrower must come up with $2 of equity."



Source: Gorton and Metrick (2010, p. 513)

Figure 8.14: *Haircuts on Asset-Backed Securities During the Crisis*

While collateral may be useful in mitigating counterparty risk, it is no remedy for the fragility of refinancing structures mainly relying on Non-Core Liabilities. The key point is that haircuts can vary. In a crisis, the value of assets become uncertain. Haircuts will consequently rise or, even worse, some securities will no longer be accepted as collateral at all. Hence, funding will dry up even in the presence of collateralization which gives rise to an adverse feedback loop between declining market liquidity and declining funding liquidity (see Section 4.4.2). Figure 8.14 shows the development of haircuts for asset-backed securities. They were considered safe prior to the crisis, and hence haircuts were close to zero. Especially haircuts for subprime-related products skyrocketed, reaching a level of 100% in late 2008. A haircut of 100% implies that this type of securities is no longer accepted as collateral. Thus, Figure 8.14 gives an impression on the funding strains which were present in the financial system during the crisis. These problems triggered massive fire sales leading to an adverse feedback loop between asset price declines and a gradual collapse of important funding markets.[30]

[30] For a detailed account of the behavior of collateralized funding markets during the financial crises, the reader is referred to Gorton (2010) and Gorton and Metrick (2010).

8.5 Monetary Policy and Risk-Taking via Asset Substitution

The model of Adrian and Shin (2010b) with its focus on ABSM has shown that a looser policy stance is likely to decrease the required risk compensation and to increase funding fragility. Yet it is subject to an important simplification. By assumption, banks only invest into one generic risky asset. In reality, however, portfolios consist of a variety of assets with different risk and return characteristics. It is therefore necessary to examine a potential response of banks' portfolio *composition* to variations in monetary policy.

Rajan (2005) stresses the importance of a so-called *search-for-yield effect* which creates a strong incentive for additional risk-taking if interest rates decline. If the duration of liabilities exceeds the duration of assets, a decline in the policy rate will gradually decrease returns on assets while liabilities still have to be served at the higher interest rates levels which prevailed in the past. In that situation, intermediaries cannot honor their commitments unless they increase the return on assets. This is only possible if the portfolio composition is modified such that it includes a greater share of risky assets. Intermediaries hence perform *asset substitution*, increasing their holdings of relatively risky assets at the expense of relatively safe assets.[31]

8.5.1 A Simple Example of Search-For-Yield Behavior

I formalize search-for-yield behavior with a simplified example of portfolio theory along the lines of Markowitz (1952). Suppose that an agent faces the problem of investing in a portfolio which consists of a risky and a risk-free asset. The risk-free asset has a certain net return of r_f, and its payoff is uncorrelated with the risky asset's payoff. The risky asset has an expected return $E(r) = r > r_f$ with a variance of σ_R^2. The share of the risky asset in the portfolio is given by α, and the share of the risk-free asset is given by $(1 - \alpha)$, respectively. The expected net portfolio payoff per unit is denoted by $E(R) = R = \alpha r + (1 - \alpha) r_f$. Akin to the passive investor in Adrian and Shin (2010b), the agent maximizes a mean-variance utility function of

[31] Empirical evidence for search-for-yield behavior in the presence of low policy rates has been provided by Becker and Ivashina (2013) for US insurance companies. Gungor and Sierra (2014) detect search-for-yield patterns for Canadian fixed-income funds. The behavior of funds, however, is unlikely to be driven by funding cost pressures. Instead, additional risk-taking in low-rate environments may be governed by concerns about the relative performance with respect to competing funds. In fact, Morris and Shin (2014) show that such coordination elements may give rise to increasing risk-taking within the fund industry if policy rates decline. Hence, the policy stance is likely to affect risk-taking behavior of *both* leveraged and non-leveraged investors.

$$U = E(R) - c\sigma_P^2 = \alpha r + (1-\alpha)r_f - c\alpha^2\sigma_R^2, \tag{8.39}$$

where c denotes the risk-tolerance coefficient and $\sigma_P^2 = \alpha^2\sigma_R^2$ is the portfolio variance.[32] The investor seeks to maximize utility via the optimal choice of α. Taking the FOC of (8.39) yields

$$\frac{\partial U}{\partial \alpha} = r - r_f - 2\alpha c\sigma_R^2 = 0 \quad \Leftrightarrow \quad \alpha^* = \frac{r - r_f}{2c\sigma_R^2}. \tag{8.40}$$

Interpretation is straightforward: The optimal weight of the risky asset α positively depends on the risky asset's expected excess return $r - r_f$ and is negatively related to its variance and also negatively related to an increasing c (which implies decreasing risk tolerance).[33] The expected return of the optimal portfolio is

$$R^* = \alpha^* r + (1-\alpha^*)r_f. \tag{8.41}$$

Suppose further that the liability structure of the agent imposes the additional constraint of a target return: $E(R) = R^*$ has to be achieved at the very minimum. This requirement does not pose a problem in the initial situation. However, consider a policy innovation which uniformly decreases the returns on risk-free and risky assets by $-\epsilon$. The return of the initially optimal portfolio becomes

$$R_\epsilon = \alpha^*(r-\epsilon) + (1-\alpha^*)(r_f - \epsilon) = R^* - \epsilon. \tag{8.42}$$

One needs to bear in mind that the optimal portfolio weight α^* remains unchanged due to the constant yield spread. Quite trivially, the portfolio return declines precisely by the amount ϵ. Since $R_\epsilon < R^*$, the target-return constraint now becomes binding. The

32 The general expression for the variance of a weighted portfolio of two assets x and y is $\sigma_{xy}^2 = \alpha^2\sigma_x^2 + (1-\alpha)^2\sigma_y^2 + 2\alpha(1-\alpha)\sigma_{xy}^2$. The variance of the risk-free asset's payoff is zero. So is the payoff covariance σ_{xy}^2. The expression therefore simplifies accordingly.

33 It is immediately apparent from (8.40) that (ceteris paribus) a decrease in r_f increases α^*. Formally, it holds that $\frac{\partial \alpha^*}{\partial r_f} = -\frac{1}{2c\sigma_R^2} < 0$. An increase in the excess return $r - r_f$ makes risk taking more attractive and hence increases the optimal share of the risky asset. However, I assume that the yield spread $r - r_f$ is constant, which renders this channel ineffective. Put differently, a change in r_f should be understood as a *level shift* of yields across the entire spectrum of assets.

investor has to readjust the portfolio by choosing a new portfolio weight α_ϵ in order to satisfy

$$\alpha_\epsilon(r-\epsilon)+(1-\alpha_\epsilon)(r_f-\epsilon)=R^* \tag{8.43}$$

Inserting (8.41) and collecting terms yields

$$\begin{aligned}\alpha_\epsilon(r-\epsilon)+(1-\alpha_\epsilon)(r_f-\epsilon)&=\alpha^* r+(1-\alpha^*)r_f\\ \alpha_\epsilon(r-r_f)&=\alpha^*(r-r_f)+\epsilon\\ \alpha_\epsilon&=\alpha^*+\frac{\epsilon}{r-r_f}\end{aligned} \tag{8.44}$$

which formally establishes the result that the share of the risky asset increases after a cut of the policy rate, i.e., $\alpha_\epsilon > \alpha^*$. The investor has no choice but to increase his holdings of the risky assets in order to meet the return requirement. The strength of the effect increases in the magnitude of the rate cut ϵ and decreases in the (constant) yield spread $r-r_f$. If the latter is large, less risky assets need to be added to boost expected returns. As Rajan (2005) stresses, such a mechanism may be of particular importance for insurance companies because they tend to make very long-term commitments with the promise of a constant interest rate. If average asset returns fall below that rate, searching for yield almost becomes a necessity.

However, it is hard to generalize this argument for the entire intermediation sector. Banks' balance sheets, for instance, exhibit a different structure: The duration of assets is typically exceeding the duration of liabilities. Under these circumstances, policy-rate cuts are beneficial for profitability which should decrease the incentive to take additional risks. The impact of policy variations on the riskiness of intermediary portfolios may therefore be heterogeneous. Furthermore, the decision on optimal portfolio risk is likely to interact with the choice of balance sheet size and leverage as well as with the choice on the optimal structure of funding.

As a preliminary result, the response of portfolio composition to policy variations should not be regarded in isolation. Interest rate changes may exhibit countervailing incentives on portfolio risk-taking, which has been neglected in the simple formalization of the search-for-yield problem. In what follows, I present the model of Dell'Ariccia and Marquez (2013), who recognize that the policy rate and portfolio risk-taking are interrelated through various channels which oppose each other. They nevertheless find that the net effect of a policy expansion on portfolio risk-taking is positive.[34]

8.5.2 The Dell'Ariccia-Marquez Model

Banks invest in a portfolio of risky loans with a certain repayment probability and obtain financing from a mix of equity and deposits. They are subject to limited liability and deposits are thus only repaid if the portfolio investment succeeds. Policy variations affect banks' risk-taking incentives via two countervailing mechanisms.

First, monetary policy affects banks' funding costs and thus banking profitability via its influence on the intermediation margin (see Section 8.4.2). This gives rise to a *risk-shifting effect*. In general, limited liability creates a powerful risk-taking incentive. Shareholders are willing to take enormous risks since the downside is mostly borne by depositors. However, if the profitability of successful banking operations is high per se, this risk-taking incentive is reduced. If the intermediation margin is high, shareholders are less willing to put the possibility of future profits at stake by taking unnecessary default risks. If profitability is low, optimal risk-taking increases since preserving the chance for (lower) future profits is considered less important. In isolation, a policy-rate increase fosters risk-taking due to a compression of the intermediation margin.

Second, monetary policy induces a *leverage effect* which indirectly affects risk-taking incentives via its impact on the optimal capital structure. A policy tightening increases funding costs. Since these are partly risk-sensitive, banks choose a safer capital structure to compensate their rise: They increase the reliance on equity and decrease their leverage. Importantly, the optimal amount of risk-taking decreases in the share of equity. If shareholders have to bear relatively more losses, they take less risks. Hence, an increase in the policy rate reduces risk-taking incentives.

Monetary policy has countervailing effects on bank risk by affecting both profitability and funding costs. The question about the net effect of the risk-shifting and the leverage effect on bank risk-taking after a policy variation can only be answered when inspecting the model in detail: Banks set the loan rate r_L and are confronted with a highly simplified loan demand schedule of

[34] For the subsequent discussion of the model, I also relied on the previous working paper version of Dell'Ariccia et al. (2010) which covers the technical details more extensively.

$$L^D = \begin{cases} L & \text{if} \quad r_L \leq R \\ 0 & \text{if} \quad r_L \geq R \end{cases} \tag{8.45}$$

implying that borrowers demand a fixed loan amount of L, as long as the loan rate r_L does not exceed their reservation rate R. Loans are risky and banks rely on a monitoring technology with scalable effort q, where q also represents the probability of loan repayment.[35] Monitoring produces quadratic costs of $\frac{1}{2}cq^2$ for each loan unit. Banks thus trade off ensuring an acceptable repayment probability and economizing on monitoring costs. The actual monitoring effort should be interpreted as a measure for banks' portfolio risk.

Bank owners finance a share k of loans with equity. The remaining share $1-k$ is financed with uninsured deposits. Despite the intensity of monitoring (and thus the repayment probability) is private information, depositors can calculate the optimal monitoring effort $\hat{q}$, since it is governed by the capital structure, which is observable. The rate r^* is the risk-free rate which should be regarded as the policy rate. Depositors consequently demand a rate

$$r_D = \frac{r^*}{E(q|k)} \tag{8.46}$$

where $E(q|k)$ is the repayment probability of the bank, conditional on its choice of the capital structure k. The opportunity costs of equity are given by

$$r_E = \frac{r^* + \varepsilon}{q} > r_D, \tag{8.47}$$

implying that ε can be regarded as a stylized equity risk premium. The model is decomposed in three stages. In stage 1, banks choose the capital structure k and depositors choose r_D accordingly. In stage 2, banks set the loan rate r_L. In the last stage, banks decide on their optimal monitoring effort $\hat{q}$. The model is solved via backward induction. That is, the first problem is to derive $\hat{q}$ while taking all other variables as given. Expected profits Π are given by

35 This model features only one generic asset. However, Dell'Ariccia et al. (2010, p. 8) argue that "[a]n alternative interpretation of this assumption is that banks have access to a continuum of portfolios characterized by a parameter $q \in [0,1]$, with returns $r_L - \frac{1}{2}cq^2$ and probability of success q."

$$\Pi = \left(q(r_L - r_D(1-k) - r_E k) - \frac{1}{2} c q^2 \right) L \tag{8.48}$$

where the bank receives a return of r_L (per loan unit) net of its weighted average capital costs with probability q. Monitoring costs accrue in any case. The profit function can be rearranged to

$$\Pi = \left(q(r_L - r_D(1-k)) - (r^* + \varepsilon)k - \frac{1}{2} c q^2 \right) L. \tag{8.49}$$

Taking the FOC yields

$$\frac{\partial \Pi}{\partial q} = \left(r_L - r_D(1-k) - cq \right) L = 0. \tag{8.50}$$

Since loan demand is assumed to be non-zero for meaningful parameter constellations, the FOC is satisfied if

$$\hat{q} = \frac{r_L - r_D(1-k)}{c}. \tag{8.51}$$

After the derivation of optimal monitoring effort $\hat{q}$, banks have to choose the optimal loan rate. This is trivial, since under entirely inelastic loan demand it is optimal to choose $\hat{r}_L = R$. Optimal monitoring is then given by

$$\hat{q} = \frac{R - r_D(1-k)}{c}. \tag{8.52}$$

Since rational depositors form model-consistent expectations $E(q|k) = \hat{q}$, the deposit rate can be substituted out of (8.52) by using $r_D = r^*/\hat{q}$. Solving (8.52) for the equilibrium level of monitoring yields

$$\hat{q} = \frac{1}{2c} \left(R + \sqrt{R^2 - 4cr^*(1-k)} \right). \tag{8.53}$$

The detailed derivation is devoted to Appendix A.4.[36] Other things equal, (8.53) reveals that monitoring effort decreases in r^*. This is the risk-shifting effect. Since

[36] Basically two possible solutions for $\hat{q}$ emerge. The selection procedure is simply to take the larger value (Dell'Ariccia et al., 2010, p. 22). This can be justified with the argument that a value considerably below unity for $\hat{q}$ is at odds with historical default rates of bank loan portfolios.

R is constant, an increase in r^* compresses the intermediation margin and decreases banking profitability. With lower profitability, banks have the incentive to take more risk since limited liability assigns downside risks primarily to depositors. The strength of this effect increases for a lower amount of k, which corresponds to a higher share of deposit financing.

So far, the idea of the risk-taking channel is contradicted since the model so far predicts that a relaxation if the policy stance, i.e., a decrease in r^*, would reduce risk-taking. However, the model is still incomplete as the endogenous choice of the capital structure - the first-stage problem - is not yet taken into account. Bank profits conditional on the capital structure are given by

$$\begin{aligned} \Pi &= \left(\hat{q}(R - r_D(1-k)) - (r^* + \varepsilon)k - \frac{1}{2}c\hat{q}^2 \right) L \\ &= \left(\hat{q}R - r^* - k\varepsilon - -\frac{1}{2}c\hat{q}^2 \right) L. \end{aligned} \tag{8.54}$$

Plugging (8.53) into (8.54) and taking the FOC with respect to k yields

$$\frac{r^* R}{2\sqrt{R^2 - 4cr^*(1-k)}} - \varepsilon - \frac{1}{2}r^* = 0. \tag{8.55}$$

After solving for k, it is possible to express the optimal capital ratio as

$$\hat{k} = 1 - R^2 \frac{\varepsilon(r^* + \varepsilon)}{cr^*(r^* + 2\varepsilon)^2}, \tag{8.56}$$

where it holds that the optimal capital ratio increases with rising policy rates, i.e., $\partial\hat{k}/\partial r^* > 0$. Substituting the optimal capital ratio $\hat{k}$ back into (8.53) yields

$$\hat{q} = R\frac{r^* + \varepsilon}{c(r^* + 2\varepsilon)} \tag{8.57}$$

which is the final expression for optimal monitoring effort. Incorporating the decision on the optimal capital structure now indicates that the optimal monitoring effort increases in r^*.[37]

[37] See Appendix A.4 for the detailed derivation of $\hat{k}$ and $\hat{q}$. Note also that for $\frac{\partial\hat{q}}{\partial r^*} > 0$, it is necessary that c < 2, which holds for reasonable parameter constellations.

Thus, tightening the policy stance increases the capital ratio and reduces credit risk-taking. Vice versa, it can be stated that a decline in the policy rate causes banks to (i) reduce monitoring efforts and to take more credit risk as well as (ii) to increase their leverage. The net effect of a policy expansion on bank risk-taking is therefore positive, which ultimately supports the notion of a risk-taking channel. While the risk-shifting incentive is attenuated, the decrease in funding costs calls for higher leverage and hence less monitoring. The leverage effect dominates the risk-shifting effect.[38]

8.6 The Policy Stance and its Impact on Funding Risk

8.6.1 The Term Spread as an Incentive for Maturity Transformation

If short-term interest rates decrease after a monetary expansion, banks have the incentive to rely more strongly on short-term debt since the increased term spread makes short-term funding relatively cheaper (Stein, 2012). As a consequence, the maturity mismatch of balance sheets increases. Funding long-term assets with short-term debt makes banks vulnerable against a sudden withdrawal of short-term funding (see Sections 4.3 and 4.4). Thus, if a looser policy stance indeed increases the incentive for more aggressive maturity transformation, there is a direct link from monetary policy to banking fragility via its effect on funding risk. This mechanism has been briefly discussed within the context of the ABSM model in Section 8.4.3. Angeloni and Faia (2013a) carry out a detailed model-based examination of this channel; they confirm that a policy expansion triggers (i) an increasing reliance on short-term funding and (ii) a net increase in funding risk. I will sketch out the key mechanism in the remainder.

8.6.2 The Angeloni-Faia Model

The model is of the New-Keynesian DSGE type and is augmented with a banking sector.[39] Banks invest in a large number of uncorrelated investment projects L_t (each of

[38] This result is robust against various modifications such as a change in the structure of loan demand or the introduction of deposit insurance. See Dell'Ariccia and Marquez (2013, pp. 133-135) and Dell'Ariccia et al. (2010) for detailed discussions and proofs.

[39] The following discussion will be limited to the banking sector. In general, the model features four sectors: Banks, households, final good producers and capital good producers. The latter sectors are modeled as is common in the DSGE literature. See Angeloni and Faia (2013a,b) for details.

unit size) in the capital-goods production sector whose price is given by Q_t. Loans in the aggregated bank balance sheet are thus $Q_t L_t$. Banks receive funding from households who operate partly as equity investors (bank capitalists, at amount BK_t) and partly as depositors (amount D_t). The non-contingent deposit rate is denoted by R_t and equals the policy rate. The ratio of deposits to total assets is $d_t = D_t / Q_t L_t$. Importantly, the deposit ratio is a proxy for both the amount of leverage and the fragility of the funding structure. The balance sheet identity reads

$$Q_t L_t = BK_t + D_t \tag{8.58}$$

Banks are run by managers who operate on the behalf of both bank capitalists and depositors. Their task is to find the optimal capital structure which maximizes the combined expected payoff of both investor groups. Deposits can be withdrawn on a first-come-first-serve basis. This gives rise to a bank run as in Diamond and Dybvig (1983), as soon as depositors realize that payoffs from loans are insufficient to repay the entire outstanding amount of deposits. If a bank run occurs, investment projects have to be liquidated at a loss. Liquidation receipts are distributed pro rata amongst depositors while bank capitalists receive a zero payoff.

Investment projects are risky. Their expected return is given by R_t^A plus a random shock x_t, which is assumed to follow a uniform distribution across the interval $[-h; h]$. Furthermore, it assumed that the bank manager acquires special knowledge about the investment project which is supposed to mirror the idea of relationship-based lending. The manager is able to extract a higher payoff from the project, compared to the case where it is liquidated by outside investors on their own. Outside liquidation lowers the payoff by some parameter $0 < \lambda < 1$. Given his special capability, the manager is able to demand a fee for his help in the process of payoff extraction. In any case, a bank run causes a general decrease of the project's payoff due to its disordered liquidation. It is measured by the coefficient $0 \leq c < 1$. As an overview, Table 8.8 shows the three possible return constellations.

If the project payoff $R_t^A + x_t$ is below the promised return on deposits, i.e., if $R_t^A + x_t < d_t R_t$, a bank run occurs with certainty and the project is liquidated. Liquidation receipts are transferred to depositors. The bank manager engages in project liquidation in exchange for a share of the additional payoff $(1 - \lambda)(1 - c)(R_t^A + x_t)$ he helps to generate (see Table 8.8 for a comparison). It is assumed that additional payoffs are split evenly. Depositor payoffs are then given by

Constellation	Project Payoff
No Bank Run	$R_t^A + x_t$
Bank Run, Liquidation with Bank Manager	$(1-c)(R_t^A + x_t)$
Bank Run, Liquidation without Bank Manager	$\lambda(1-c)(R_t^A + x_t)$

Table 8.8: *Conditional ex-post Project Return*

$$\begin{aligned} &\lambda(1-c)(R_t^A + x_t) + \frac{1}{2}(1-\lambda)(1-c)(R_t^A + x_t) \\ &= \frac{1}{2}(1+\lambda)(1-c)(R_t^A + x_t) \end{aligned} \tag{8.59}$$

An intermediate case emerges if $\lambda(R_t^A + x_t) < d_t R_t \leq R_t^A + x_t$. In this scenario, a bank run can only be prevented if the investment project is liquidated by the bank manager (which will happen in equilibrium). Additional payoffs are again split evenly, but now between the manager and bank capitalists. Depositors receive the full amount $R_t d_t$.

If $R_t d_t < \lambda(R_t^A + x_t)$, a bank run will never happen. Depositors receive $R_t d_t$ and the bank capitalist ends up with $\lambda(R_t^A + x_t) - R_t d_t$ in the worst case. Again, the bank manager is able to boost payoffs and they are split evenly between him and the shareholders. Table 8.9 summarizes the payoff structures in each scenario. The case of a certain bank run is shown in the upper row, the intermediate case in the middle row, and the no-run case in the bottom row. Summing up payoffs yields $R_t^A + x_t$ if the run is avoided and $(1-c)(R_t^A + x_t)$ if the run occurs. The distribution of project payoffs between stakeholders differs between scenarios.

Scenario	Depositor Payoff	Shareholder Payoff	Manager Fee
Certain Bank Run	$\frac{1}{2}(1+\lambda)(1-c)(R_t^A + x_t)$	0	$\frac{1}{2}(1-\lambda)(1-c)(R_t^A + x_t)$
Intermediate Case	$R_t d_t$	$\frac{1}{2}(R_t^A + x_t - R_t d_t)$	$\frac{1}{2}(R_t^A + x_t - R_t d_t)$
No Bank Run	$R_t d_t$	$\frac{1}{2}(1+\lambda)(R_t^A + x_t) - R_t d_t$	$\frac{1}{2}(1-\lambda)(R_t^A + x_t)$

Table 8.9: *Ex-post Payoffs for Bank Stakeholders*

The ex-ante optimization problem for the bank manager is to choose d_t so as to maximize the combined expected payoffs $E_t \Pi_{t+1}(d_t)$ for shareholders and depositors. They are given by

$$\begin{aligned} E_t \Pi_{t+1}(d_t) = & \frac{1}{2h} \int_{-h}^{R_t d_t - R_t^A} \frac{(1+\lambda)(1-c)(R_t^A + x_t)}{2} dx_t \\ & + \frac{1}{2h} \int_{R_t d_t - R_t^A}^{\frac{R_t d_t}{\lambda} - R_t^A} \frac{(R_t^A + x_t) + R_t d_t}{2} dx_t \\ & + \frac{1}{2h} \int_{\frac{R_t d_t}{\lambda} - R_t^A}^{h} \frac{(1+\lambda)(R_t^A + x_t)}{2} dx_t. \end{aligned} \tag{8.60}$$

The first integrand denotes outsider payoffs in the bank-run case. Integration occurs over x_t since the shock realization determines which constellation emerges. Hence, the upper limit of the first integral has to be $x_t = R_t d_t - R_t^A$. If $x_t \leq R_t d_t - R_t^A$, it holds that $R_t^A + x_t \leq R_t d_t$ which is the condition for the bank-run scenario. The integral limits belonging to the remaining scenarios are constructed accordingly (Angeloni and Faia, 2013a, p. 314). The integrands denote cumulated outsider payoffs in the respective scenario, as depicted in Table 8.9.

A lengthy proof shows that the value of d_t which maximizes expected payoffs for outsiders has to be in the interval $\lambda(R_t^A + h) < R_t d_t < R_t^A + h$.[40] In this interval, the no-run case is ruled out. Even in the best case with a positive shock realization of h, liquidation receipts without involving the bank manager are insufficient to cover deposits. It is therefore always optimal to allow a non-zero amount of funding fragility. Expected payoffs within this interval are then given by

$$\begin{aligned} E_t \Pi_{t+1} = & \frac{1}{2h} \int_{-h}^{R_t d_t - R_t^A} \frac{(1+\lambda)(1-c)(R_t^A + x_t)}{2} dx_t \\ & + \frac{1}{2h} \int_{R_t d_t - R_t^A}^{h} \frac{(R_t^A + x_t) + R_t d_t}{2} dx_t \end{aligned} \tag{8.61}$$

As shown in Appendix A.5, tedious expansion of the integral and taking the FOC with respect to d_t yields

$$(1-c)(1+\lambda) R_t d_t + h - 3 R_t d_t + R_t^A = 0 \tag{8.62}$$

Solving the FOC for d_t produces the optimal deposit ratio

40 The proof is included in an online appendix (Angeloni and Faia, 2013b). The expected payoff function is split into various intervals. If $R_t d_t < \lambda(R_t^A + h)$, it can be verified that $E_t \Pi_{t+1}$ strictly increases in d_t. For $\lambda(R_t^A + h) < R_t d_t < R_t^A + h$, payoffs become inversely U-shaped in d_t. For $R_t d_t > R_t^A + h$, payoffs strictly decrease in d_t. Hence, the optimal value of d_t can be determined by finding the local payoff maximum in the interval $\lambda(R_t^A + h) < R_t d_t < R_t^A + h$.

$$\hat{d}_t = \frac{1}{R_t}\frac{h + R_t^A}{2 - \lambda + c(1+\lambda)}, \tag{8.63}$$

from which it is apparent that $\hat{d}_t$ increases if the policy rate R_t declines. Other things equal, a run becomes less likely due to lower obligations to depositors, which raises the optimal deposit ratio. Banks thus increase their reliance on short-term funding in response to a policy expansion. Moreover, the optimal deposit ratio increases in R_t^A since a rise in expected asset payoffs allows to increase leverage (for similar reasons). Likewise, $\hat{d}_t$ increases in λ which measures the relative efficiency of outsider liquidation and is thus positively linked to outsider payoffs in adverse states. Hence, $\hat{d}_t$ also decreases in c which measures the inevitable decline of project payoffs in a bank-run scenario. Somewhat surprisingly, $\hat{d}_t$ also increases in the dispersion of payoffs: An increase in h raises expected shareholder returns in the no-run case, whereas depositor payoffs are independent of d_t in the run scenario as they receive the entire project payoff anyway (Angeloni and Faia, 2013a, p. 315).

Unfortunately, the net effect on funding fragility cannot be judged by inspecting the banking sector in isolation since there are two countervailing effects. A decrease in R_t increases $\hat{d}_t$, but also contributes to a decrease in the probability of a bank run as a lower policy rate effectively decreases banks' repayment obligations to depositors. However, the simulation of the model reveals that the first effect is stronger. In sum, lowering the policy rate causes both an increase in $\hat{d}_t$ and a rise in the bank-run probability. A decrease in the policy rate therefore enhances funding risk.

8.7 Overview on Empirical Evidence

Since the concept of the risk-taking channel is relatively new, its empirical analysis is still in its infancy compared to other transmission channels. However, the empirical literature is growing at a fast pace and generally verifies the existence of a quantitatively significant risk-taking channel. The literature can be best categorized with respect to the characteristics of the underlying data sets. Some studies use panels comprising data on large amounts of individual banks or individual loans, respectively, while other focus on aggregated macro time series.

In any case, the empirical identification of the risk-taking channel is complicated by various problems. First, it is questionable to treat monetary policy as an exogenous factor for the banking sector. Causality may also work in reverse with central banks responding to financial conditions. This gives rise to potential endogeneity problems which have to be addressed appropriately within the estimation procedure.

Second, when analyzing bank loans and their response to policy variations, it is also inherently difficult to distinguish between supply and demand-driven adjustment processes. One identification strategy is the analysis of loan rate adjustments after a policy rate cut. If loan rates decrease, this rather points to supply shifts. Vice versa, raising rates indicate that demand shifts dominate.

Third, the impact of the risk-taking channel needs to be separated from the influence of other bank-based transmission channels. This problem is tackled with appropriate control variables such as property and stock prices to account for changing collateral values of potential borrowers. With respect to the bank-lending channel, several studies control for banks' refinancing structure in order to account for the sensitivity of their funding costs to policy variations. Controlling for economic activity and inflation is equally important.

Fourth, bank-specific characteristics also matter. Studies employing bank-level and loan-level data therefore control for factors such as bank size, liquidity, capitalization and cost efficiency. These measures may provide risk-taking incentives independent of the policy stance. Some studies use additional proxies for the degree of bank competition and the intensity of supervision.

8.7.1 Studies with Micro-Level Data

Studies using panels with bank-level or loan-level data constitute the majority of available empirical research on the risk-taking channel. For example, Jiménez et al. (2014) analyze the Spanish market for bank loans from 2002 until 2008. They use a data set which covers bank loans to Spanish non-financial corporations with detailed information on the loan application process, the final loan volume and information on collateral requirements and the borrower's credit history. ECB policy is treated as exogenous since its policy stance is assumed to remain unaffected from Spanish loan market dynamics. As a key result, a decline in the policy rate causes banks to grant riskier loans at greater volume and with lower collateral requirements.[41] Banks hence engage in asset

[41] Loans are considered risky if the firm has a history of non-performing loans over the last four years. Moreover, the sample is restricted to "unknown" borrowers who do not have an existing business relation with the bank under consideration. The data set does not contain information on loan pricing, implying that potential effects on credit risk premia are omitted from the analysis.

substitution as predicted by the model of Dell'Ariccia and Marquez (2013). The effect is stronger for weakly capitalized banks, which points to the existence of risk-shifting effects. It is further shown that loans are not only more risky from an ex-ante perspective, but that they indeed have a higher probability of default in the future.

Altunbas et al. (2014) study a cross-country panel of banks from Europe and the US ranging between 1999 and 2008. They proxy individual bank risk with their Expected Default Frequency (EDF).[42] The stance of monetary policy is measured by country-specific gaps between the actual real short-term rate and a measure of the natural real short-term rate.[43] They find a negative relation between the interest-rate gap and the EDF. Accommodative policy thus increases the default probability of banks. Interestingly, a decline in the level of the policy rate per se leads to further increases of bank risk. Furthermore, the risk-taking channel is reinforced when monetary conditions are expansive for a prolonged period of time.

Ioannidou et al. (2009) study the behavior of Bolivian banks from 1999 to 2003. They use a data set covering every bank loan that was originated within this period, including detailed information on price and non-price terms as well as future performance. They use the US federal funds rate as an exogenous indicator of the policy stance, since the Bolivian Peso was pegged to the Dollar at that time. Moreover, an overwhelming part of the banking system was dollarized. They find that a decrease in the US policy rate increases the riskiness of newly granted bank loans. Loan riskiness is measured by estimates of ex-post default probabilities and ex-ante measures such as borrower default history. Interestingly, default probabilities of outstanding loans are reduced.[44] With respect to loan pricing, it is shown that required loan spreads decrease after a policy expansion, supporting the idea that desired credit risk premia decline when monetary conditions are relaxed.

There are various additional studies using bank-level or loan-level data, all of which are broadly in favor of the risk-taking channel. Ozsuca and Akbostanci (2012) find that Turkish banks increase risk-taking when short-term rates are relatively low. Gaggl and

[42] EDF is an expected probability of default estimated for various time horizons with information from balance sheet items, stock-market data and a database on historical defaults. It is provided by Moody's.

[43] As an alternative measure, they use the difference between the actual policy rate and the rate prescribed by some version of the Taylor Rule (Taylor Residual). Results remain unchanged.

[44] Thus, it would be highly interesting to analyze the net effect on the riskiness of the entire loan portfolio. This is not done in their paper, probably since the bank-specific aggregation of loan-level data is prohibitively time-consuming.

Valderrama (2010) detect a similar pattern for Austrian banks while Bonfim and Soares (2014) provide supportive results for Portugal. Delis and Kouretas (2011) and Delis et al. (2011) provide evidence for the risk-taking channel by inspecting separated panels of banks within the Euro area and the US, respectively. Further evidence for the US is delivered by de Nicolò et al. (2010) and Dell'Ariccia et al. (2013).

8.7.2 Studies with Macro-Level Data

Studies using macro-level data are clearly in the minority, yet their results tend to be equally in favor of the risk-taking channel. For instance, Maddaloni and Peydró (2011) analyze the relation between the policy stance and bank lending standards for a cross-country macro-panel including Euro Area countries and the US from 2002 to 2008. Measures for lending standards are obtained from survey data, in which banks report whether lending standards have been tightened or softened in the current period. The policy stance is measured by Taylor Residuals and accommodative policy is found to soften lending standards. The effect is amplified if banking supervision is less restrictive and if banks engage more heavily in securitization. Moreover, the relaxation of lending standards is especially pronounced if policy rates remain accommodative over an extended period.

Angeloni et al. (2015) estimate a vector autoregression model for the US economy from 1980 to 2008 which includes various measures of aggregate bank risk-taking. Lending risk is proxied by the levels of outstanding debt of non-financial firms and households, assuming that they are inversely related to their aggregate creditworthiness.[45] Funding risk is measured by a proxy for the outstanding level of potentially unstable Non-Core Liabilities, which comprises, for instance, liabilities from repurchase agreements. In addition, stock price volatility of the banking sector is included as an indicator for total bank risk. As a result, expansive policy shocks are found to increase each proxy of bank risk, the effect on funding risk being quantitatively most significant.

Adrian and Shin (2008) deliver a similar result by showing that, for the US intermediation sector from 1991 until 2007, the growth rate of outstanding repurchase agreements accelerates when monetary policy is expansive. And as mentioned in Section 8.4.2, Adrian et al. (2010) demonstrate that intermediary risk appetite increases after an

45 While (more granular) market-based risk measures are principally available, it is argued that they fail to reflect the build-up of financial fragility (Angeloni et al., 2015, p. 288).

expansive policy shock. Moreover, de Nicolò et al. (2010) find that aggregate lending standards for US banks decline in the policy rate. Finally, Peersman and Wagner (2014) show that securitization activities of US banks increase after an expansive policy shock. This possibly points to search-for-yield behavior by non-bank market participants who seek to substitute lower-yieldings assets with risky tranches of asset-backed securities, which are in turn supplied by banks via additional issuance.

To the contrary, Buch et al. (2014) find only limited support for a risk-taking channel in the US over the period from 1997 to 2008.[46] They employ a factor-augmented vector autoregression (FAVAR), which augments an otherwise standard macroeconomic VAR model with factors summarizing information from the Survey of Terms of Business Lending (STBL).[47] With respect to results, it is found that large commercial banks do not change the riskiness of their lending behavior after an easing of monetary conditions. Only smaller banks behave as suggested by the risk-taking channel and increasingly extend loans to riskier borrowers. Consistent with other studies, it is found that prolonged periods of low policy rates enhance the potency of risk-taking channel. If rates are low for a longer time, foreign commercial banks operating on US markets tend to increase their risk-taking as well.

[46] It should be noted that their sample is confined to business lending of commercial banks, while the lion's share of risk-taking prior to the crisis arguably took place in mortgage markets. They argue that the focus on business lending is advantageous since mortgage market dynamics have been highly distorted by political intervention. On the other hand, the exclusion of the mortgage sector possibly underestimates the strength of the risk-taking channel.

[47] In the STBL, about 400 commercial banks report extensively on price and non-price terms of newly originated business loans.

Chapter 9

Empirical Examination of the Risk-Taking Channel with a VAR Analysis

In what follows, I estimate a Vector Autoregression Model (henceforth VAR) for the US macroeconomy which is augmented with additional proxy variables for risk-taking behavior within the financial sector. The main result is that risk-taking responds procyclically to a monetary policy shock, which corroborates existing findings on the risk-taking channel. Risk-taking is measured by various proxies which aim to reflect the evolution of credit risk and the evolution of funding risk, respectively. It is found that the US banking sector tends to loosen lending standards and to increase its reliance on short-term non-core-funding in the wake of an expansionary monetary policy shock.

The technique of Vector Autoregressions has been popularized by Sims (1980). VAR models extend the framework of a univariate AR-process to a multivariate setting. Thus, VARs are essentially systems of simultaneous difference equations. Every included variable is treated as fully endogenous without any restrictions imposed a priori. Clearly, these feature make VARs a natural candidate for the empirical analysis of monetary policy transmission with its time lags and the likely feedback effects between macroeconomic aggregates.[1]

[1] Discussions of VAR-based monetary policy analysis are given in Christiano et al. (1999) and Stock and Watson (2001) among others.

9.1 Methodology

A *reduced-form* VAR model in matrix notation is given by

$$Y_t = \mu + A_1 Y_{t-1} + A_2 Y_{t-2} \ldots + A_p Y_{t-p} + \varepsilon_t, \tag{9.1}$$

where $Y_t, \ldots, Y_{t-p}$ are $n \times 1$ vectors of endogenous variables and their respective lagged realizations, μ is an $n \times 1$ vector of constants and $A(1), \ldots, A(p)$ are $n \times n$ coefficient matrices.[2] Thus, any endogenous variable depends on its own lags as well as the lagged realizations of all other variables. Estimation can be conducted separately for each equation by using ordinary least squares (OLS).

Each element in the $n \times 1$ vector of disturbances ε_t has a zero mean and follows a white noise process with finite variance. Importantly, the single disturbances are typically correlated with each other. It holds that

$$E(\varepsilon_t) = 0, \tag{9.2}$$

and the variance-covariance matrix (VCM) is characterized by

$$E(\varepsilon_t \varepsilon_s^{'}) = \begin{cases} \Sigma & \text{if} \quad t = s \\ 0 & \text{if} \quad t \neq s \end{cases} \tag{9.3}$$

which implies that residuals may be correlated in the same period according to the contemporaneous VCM Σ but not across time. Thus, there is a serious limitation to the reduced-form representation of a VAR since residuals do not represent structural shocks. Instead, they merely represent forecast errors. While impulse-response analysis in the reduced-form framework is still useful for forecasting, it is rather pointless for the analysis of genuine shocks to the endogenous variables.

As an example, consider a reduced-form VAR comprising unemployment, inflation and the policy rate. The residuals of the policy rate equation are not policy shocks. Given contemporaneous correlation, these residuals may likewise be influenced by

[2] The methodological discussion heavily relies on Becketti (2013, chap. 9) and Hamilton (1994, chap. 10-11).

shocks to inflation and unemployment. However, in order to analyze monetary policy transmission, it is necessary to uncover a distinct shock to the policy rate *per se* which needs to be unrelated to the shocks to other endogenous variables.

Fortunately, VAR analysis offers various possibilities to uncover these structural shocks. As shown in Hamilton (1994, pp. 259), a dynamically stable VAR model can be rewritten in its moving-average (MA) form

$$Y_t = \nu + \sum_{i=0}^{\infty} \Psi_i \varepsilon_{t-i}, \tag{9.4}$$

where ν is a vector of constants and Ψ_i is an $n \times n$ matrix measuring the impact of non-structural shocks on the vector of endogenous variables.[3] It is now possible to obtain the structural shocks from the MA representation of the reduced-form VAR: By using the Choleski Decomposition, the variance-covariance-matrix Σ of the reduced-form residuals can be decomposed in the product of a lower-triangular matrix P and its transpose, implying that

$$\Sigma = PP' \quad \Leftrightarrow \quad P^{-1}\Sigma P'^{-1} = I. \tag{9.5}$$

The reduced-form VAR is subsequently rearranged as follows:

$$Y_t = \nu + \sum_{i=0}^{\infty} \Psi_i P P^{-1} \varepsilon_{t-i} = \nu + \sum_{i=0}^{\infty} \Xi_i v_{t-i}, \tag{9.6}$$

where $\Xi_i = \Psi_i P$ and $v_t = P^{-1}\varepsilon_t$. This modified representation is called a *recursive VAR*. The VCM of v_t is

$$\begin{aligned} E(v_t v_t') &= P^{-1}\varepsilon_t P'^{-1}\varepsilon_t' = P^{-1}\varepsilon_t\varepsilon_t' P'^{-1} \\ &= P^{-1}\Sigma P'^{-1} = P^{-1}PP'P'^{-1} = I, \end{aligned} \tag{9.7}$$

which verifies that v_t is a vector of uncorrelated random disturbances, since the non-diagonal elements of its VCM are zero. Hence, v_t is the vector of structural shocks and Ξ_i measures their impact on Y_t, further implying that Ξ_t determines the shape

3 Technically, it holds that $\frac{\partial Y_{t+i}}{\partial \varepsilon_t} = \Psi_i$ (Hamilton, 1994, p. 318). The sequence of $\sum_{i=0}^{n} \Psi_i$ thus pins down the reduced-form impulse-response functions for a time horizon of n periods, i.e., the response of endogenous variables to a one-time transitory shock to an element of ε_t.

of the *orthogonalized impulse-response functions* (OIRFs) of the system after a one-time structural shock to some element of v_t.

Multiplying $v_t = P^{-1}\varepsilon_t$ with P yields $Pv_t = \varepsilon_t$. In a three-variable case it holds that

$$\begin{bmatrix} p_{11} & 0 & 0 \\ p_{21} & p_{22} & 0 \\ p_{31} & p_{32} & p_{33} \end{bmatrix} \begin{bmatrix} v_{1t} \\ v_{2t} \\ v_{3t} \end{bmatrix} = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \tag{9.8}$$

It is now possible to see how structural shocks affect Y_t via their influence on ε_t. Apparently, the structural shock v_{1t} to the variable in the upper row has an instantaneous effect on any variable within the system. Conversely, the structural shock v_{3t} to the variable in the bottom row has no immediate effect on ε_{1t} and ε_{2t}. Put generally, a structural shock v_{jt} has an instantaneous effect on the variables ordered in and below the j-th row. Hence, the order of variables is anything but innocuous. Choosing a specific order is inextricably linked to making an assumption about the direction of causality in the model. Thus, the ordering of variables should ultimately be guided by theory.

Consider again the VAR model comprising unemployment, inflation and the policy rate. Theory decidedly suggests that monetary policy reacts contemporaneously to movements in inflation and employment, for instance by following a reaction function such as the Taylor Rule. Therefore the policy rate should be ordered last, which implies the assumption that shocks to inflation and unemployment have an immediate impact on the policy rate. On the other hand, given nominal rigidities, it is unlikely that inflation displays an immediate response to unemployment and policy shocks. Therefore, inflation should be ordered first. As a rule of thumb, a variable which is responding quickly to changes in macroeconomic conditions should be ordered rather at the bottom whereas a variable which tends to show delayed responses should be ordered at the top.

Applying a VAR setup for monetary policy analysis goes hand in hand with making an implicit assumption about the structure of the central bank's reaction function. In a VAR, the policy rate depends on its own lags and lags of any other endogenous variable. Monetary policy is thus regarded to be backward-looking and to pursue some kind of interest rate smoothing. Some possible interpretations of the structural policy shock are offered by Christiano et al. (1999, pp. 71-73). According to them, a policy shock may inter alia reflect shocks to central bank preferences with respect to the relative importance of output stabilization or measurement errors in preliminary data available at the time of the policy decision.

9.2 Data and Model Specification

The VAR is estimated with quarterly data from Q1 1983 until Q2 2007. The reason for truncating the sample in Q2 2007 is the beginning of the financial crisis, when monetary policy began to increasingly rely on unconventional instruments, implying that the Federal Funds Rate is no longer a reliable proxy for the policy stance. The exclusion of observations prior to Q1 1983 is due to a likely regime switch of monetary policy in the beginning of the 1980s. It is widely argued that the experience of double-digit inflation rates in the 1970s eventually caused the Fed to switch towards a rigid anti-inflation strategy in 1979, which led to a painful disinflation process in the subsequent years.[4] Following Stock and Watson (2001), inflation is measured by the annualized rate of change of the GDP deflator and economic activity is tracked by the civilian unemployment rate. Monetary policy is captured via the quarterly average of the Effective Federal Funds Rate.

Risk-taking of financial market participants is gauged by the Credit Subindex of the Chicago Fed National Financial Condition Index (CCI) as proposed by Brave and Butters (2011, 2012). The index is constructed to have a zero mean and a unit variance. Negative values of the index correspond to credit conditions being looser than the historical average and positive values indicate relatively tight credit conditions.[5] The merit of the CCI lies in its generality: It captures credit conditions for the entire financial system and is not confined to a certain segment. Moreover, Brave and Butters (2012) demonstrate its predictive power for financial market stress. For a descriptive

[4] This regime switch is often attributed to the appointment of Paul Volcker as Fed Chairman in August 1979. Goodfriend and King (2005) argue that the so-called "Volcker Disinflation" was painful in real terms due to its initial lack of credibility. Therefore, I consider it advisable not to start the sample before 1983, i.e., until the credibility of the new regime has arguably become more or less established.

[5] The index is constructed by employing a dynamic factor model with various input variables such as survey-based measures of lending standards, an extensive amount of different credit spreads and credit aggregates as well as several non-performing loans ratios. See Brave and Butters (2011, 2012) for further details.

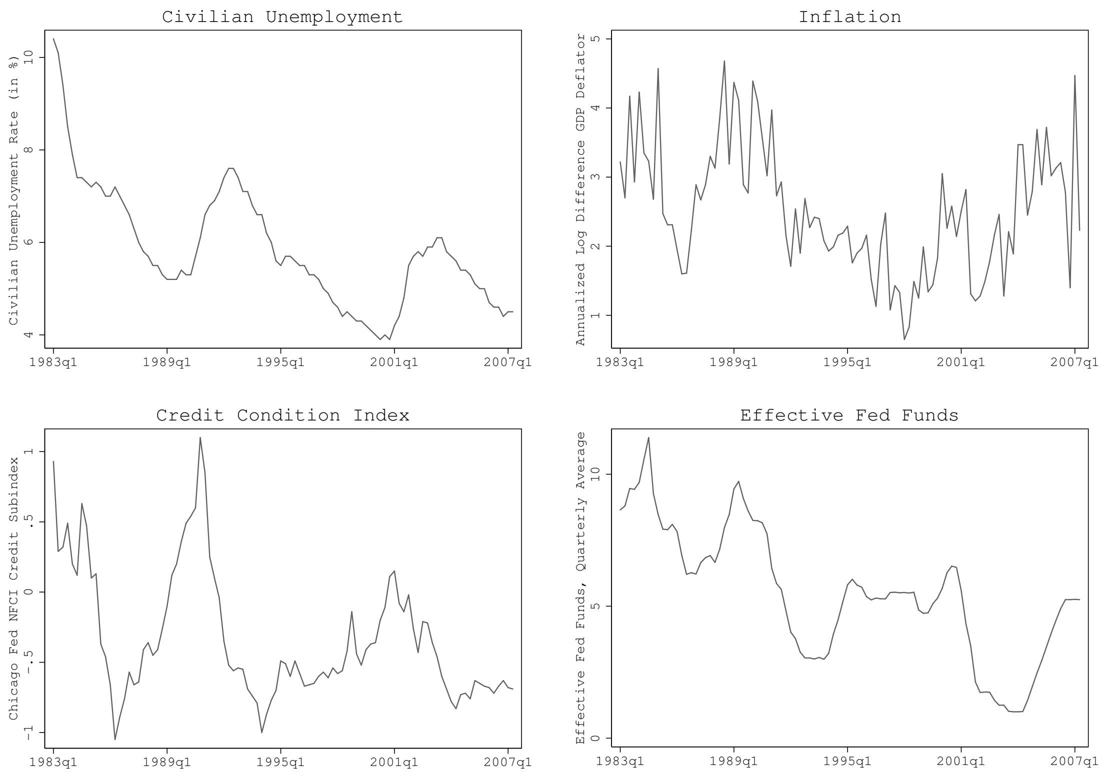


Figure 9.1: *Time Series Plots*

overview, time series plots of the data are displayed in Figure 9.1 and summary statistics are reported in Table 9.1.[6] All series are obtained from the Economic Data Service provided by the Federal Reserve Bank of St. Louis (FRED).

Clearly, there are a lot of additional variables which are likely to be relevant for macroeconomic dynamics such as the exchange rate, wages and measures for the fiscal policy stance. However, the inclusion of several further variables would reduce the remaining degrees of freedom to a prohibitive extent. This is because a VAR model with n variables and a lag length of p requires that $(n \times p) + n$ parameters have to be

6 The mean of the Credit Condition Index is non-zero since I use a subsample of the index which goes back to 1973. This is an interesting observation in its own right: Credit conditions seem to have been relatively loose on average over the entire period under consideration.

	Inflation	Unemployment	Credit Condition Index	Fed Funds
Mean	2.52	5.87	-.327	5.48
σ	.92	1.29	.45	2.46
Min	.65	3.9	-1.05	1
Max	4.68	10.4	1.1	11.39

Table 9.1: *Summary Statistics*

estimated. Given the naturally small sample size in macroeconometric applications, VAR models should thus be kept as parsimonious as possible.

The choice of the optimal lag length is usually made with the help of various model selection criteria which trade off the need for parsimony and the desire to enhance the goodness-of-fit.[7] The VAR is estimated for various lag lengths and the emerging model selection criteria are then compared in value. The Akaike Information Criterion (AIC) suggests an optimal lag length of $p = 4$, while the Hannan and Quinn information criterion (HQIC) and the Bayesian Information Criterion of Schwartz (SBIC) suggest $p = 2$. I choose the higher lag length, since only with $p = 4$ the residuals of the estimated reduced-form equations become white noise, which is verified with a Lagrange multiplier test for residual autocorrelation as described in Johansen (1995).

While textbook treatments require all underlying time series of the endogenous variables to be stationary, the applied VAR literature tends to refrain from differencing or de-trending data even when their stationarity is questionable. I therefore equally abstain from any transformation of the data, in line with Stock and Watson (2001).[8] Moreover, a post-estimation stability test of the VAR system as explained in Becketti (2013, pp. 309) fails to detect dynamic instability for any of the model specifications under consideration, implying that using the data in its original form is unproblematic.

The variables in the baseline case are ordered as follows: Inflation, Unemployment, CCI, Fed Funds. Thus, I assume that Fed Funds react instantaneously to shocks in

7 An extensive discussion of lag selection criteria is provided in Luetkepohl (2005, ch. 4).

8 Unit root testing indeed produces ambiguous results. The augmented Dickey-Fuller test rejects unit roots for every variable. Conversely, the modified Dickey-Fuller test of Elliott et al. (1996) cannot reject a unit root for all series except for inflation. Details are provided in Appendix B. A thorough discussion of the properties of VAR models including non-stationary time series is provided in Hamilton (1994, pp. 549-557), where it is argued that the integrity of the estimation results is not materially affected. In that respect, see also Enders (1995, p. 301) and the references therein for a defense of VARs employing non-stationary series.

any other variable. Credit Conditions respond immediately to shocks to inflation and unemployment but not to policy shocks. This ordering is generally consistent with other VAR studies such as Angeloni et al. (2015) and is also suggested by theory, as it was discussed in the methodological introduction. The only ambiguity arises with respect to the ordering of Fed Funds and Credit Conditions. It is equally conceivable to order credit conditions last, implying that they show an immediate reaction to policy shocks. This is done as a robustness check, but results remain basically unaffected.

9.3 Results

The main interest lies in the shape of the orthogonalized impulse response functions (OIRFs), which depict the system's response to structural shocks to the included variables. OIRFs are displayed for a time horizon of 20 quarters and the grey-shaded area depicts the 68% confidence interval as in Stock and Watson (2001).[9]

As the key result, Figure 9.2 depicts the response of the Credit Condition Indicator to a contractionary shock to the policy rate with a magnitude of about 33 basis points.[10] An unexpected policy contraction causes a tightening of credit conditions which remains elevated for several quarters and fades out after about three years. Conversely, an expansive policy shock would cause a relaxation of credit conditions which I view as further empirical support for the existence of a risk-taking channel.

The question whether the CCI response can really be attributed to the risk-taking channel deserves further comments. The indicators which receive the most prominent weights in the CCI are survey-based measures tracking the evolution of loans' price and non-price terms across various sectors. In line with the focus of the risk-taking channel, the CCI is thus primarily tracking *supply*-side conditions of the US loan market and its response indicates that lending standards decline after an expansive policy shock. This fits neatly with the asset substitution argument which was laid out in Section 8.5. However, the CCI also includes various credit spreads which may, at least in principle, react to policy-induced changes in loan demand as stressed in the credit channel literature.

[9] The main OIRFs for the risk-taking response of the financial sector also remain significant at a confidence level of 90%. They are depicted at the end of Appendix B for the sake of completeness.

[10] Unfortunately, the STATA software package I use does not allow to switch the sign of the structural shock. An expansive policy shock would produce the axisymmetrical mirror image of the OIRF corresponding to the contractionary shock.

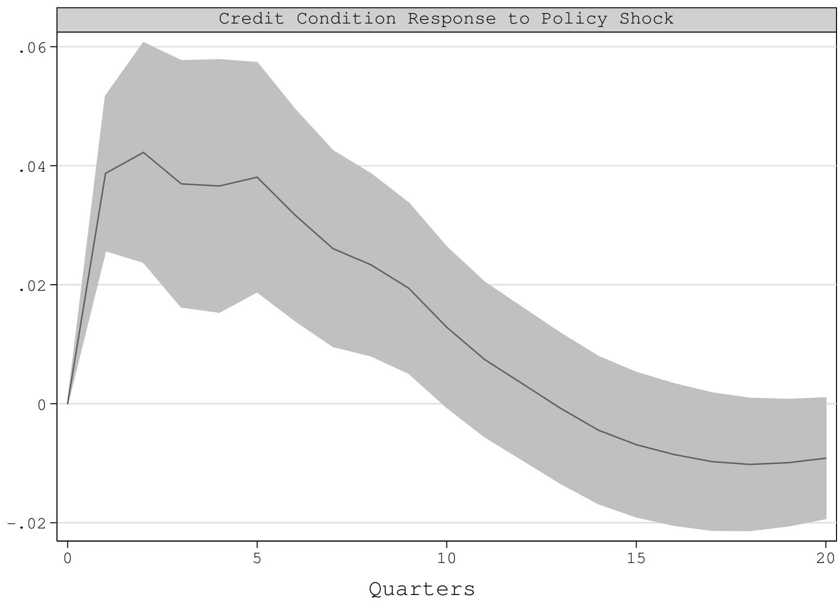


Figure 9.2: *Policy Shock and Credit Conditions*

To address this concern, I re-estimated the model and additionally included a property price variable to control for changing collateral values as proposed by Angeloni et al. (2015).[11] The response of the CCI to policy shocks remains unaffected. All in all, I consider the CCI to be a meaningful proxy which is well-suited to gauge financial market adjustments related to the risk-taking channel.

Figure 9.3 displays the response of unemployment and inflation to a policy shock. Unemployment starts to increase after about one year, peaks after three years and converges back to its initial level afterwards. The short-term response of inflation is somewhat ambiguous, yet after about six quarters inflation modestly decreases and remains persistently below its initial level before eventually converging.

11 Property price developments are measured with the Real Residential Property Price Index constructed by the Bank for International Settlements. Specifically, I use the cyclical component of the log of the Hodrick-Prescott filtered index ($\lambda = 1600$) as a measure of the percentage deviation of property prices from their long-run trend. The chosen lag order is $p = 4$ as indicated by AIC, HQIC and the Johansen test for residual autocorrelation.

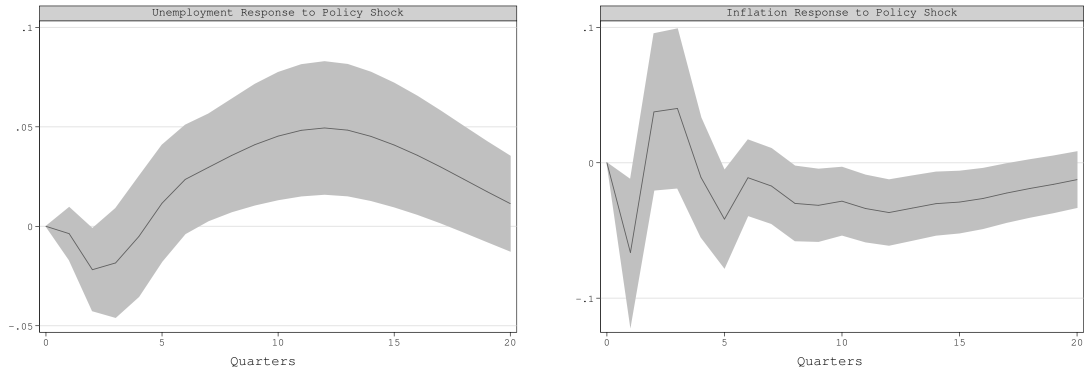


Figure 9.3: *Macro Response to Policy Shock*

It should be noted that small-scale VAR models tend to produce counterintuitive responses of inflation to a policy shock at short time-horizons almost by construction. It is a common finding that inflation first tends to increase after a contractionary policy shock, which is clearly at odds with theoretical predictions. There are various suggestions how to explain and eventually overcome this "price puzzle." A serious problem of the VAR setup is its negligence of the forward-looking nature of monetary policy, since interest rate setting is modeled to be driven by lagged variables only. It is however very likely that monetary policy is tightened when *expected* inflation increases. If future actual inflation does not become fully stabilized by this behavior, the correlation of today's policy rate and future inflation becomes positive, which is then mistakenly regarded as a policy shock outcome.[12]

In that respect, Castelnuovo and Surico (2010) demonstrate that the additional inclusion of expected inflation measures reduces the price puzzle considerably. So does Sims (1992) by using commodity price inflation as a control variable for supply shocks. In general, the inclusion of omitted variables which (i) are currently observable for policymakers and (ii) carry potential information on future inflation should bring the inflation response closer to theoretical predictions. Since the precise modeling of inflation dynamics is of minor interest here, I accept the moderate price puzzle in my VAR specification and do not explore this issue any further.

Figures 9.4 and 9.5 depict the impact of an unexpected tightening of credit condi-

12 This is in fact akin to the story of a supply shock in the New-Keynesian model, where we see a positive correlation of inflation and the policy rate, yet this certainly does not imply causality running from contractionary policy innovations to an increase in inflation.

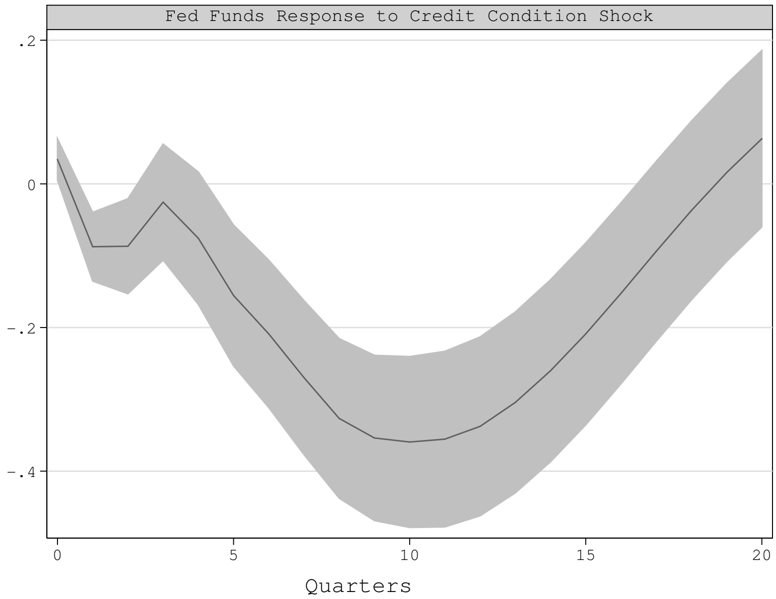


Figure 9.4: *Credit Condition Shock and Fed Funds*

tions. The policy rate shows a considerable and persistent decline, which can be interpreted such that the Fed reacts to headwinds on financial markets by relaxing its policy stance, probably since a shock to credit conditions also leads to an increase in unemployment as depicted in Figure 9.5. The pattern of inflation is hard to interpret. While there seems to be a short-term spike, the medium-term response of inflation is barely distinguishable from zero.

The graphs showing the OIRFs for inflation and unemployment shocks are deferred to Appendix B. They are basically in line with theoretical predictions: A positive inflation shock triggers an immediate and persistent increase in the Federal Funds Rate and a mild increase in unemployment in the medium term. Credit conditions also become moderately tighter. In the case of an unemployment shock, the Federal Funds Rate is reduced, which can be interpreted as an implication of the Fed's dual mandate. Inflation only declines in the first three quarters. Credit conditions are loosened a bit, probably as a by-product of the policy easing.

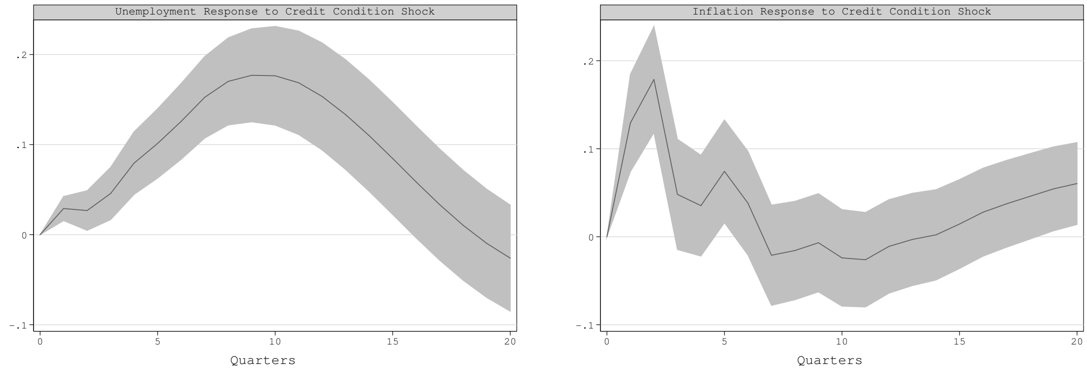


Figure 9.5: *Macro Response to Credit Condition Shock*

9.4 Extensions and Robustness Checks

I carried out various robustness checks to explore whether the results are sensitive to changes in the model specification, the sample length or the underlying data. I extended the sample back to Q1 1973, which represents the CCI base period. Moreover, I included the period until Q3 2008, after which Fed Funds hit their lower bound. Furthermore, I replaced the unemployment rate with the growth rate of real GDP as an alternative proxy for economic activity and measured inflation with the consumer price index (CPI) instead. Results do not differ materially in any case. The respective OIRFs are depicted in Appendix B.

With respect to model specification, I varied the lag length and re-estimated the model for both $p = 2$ and $p = 3$. I also swapped the ordering of CCI and Fed Funds, since theory does not stipulate a clear causal direction between these two variables. Moreover, to address concerns about unit root implications, I also estimated the model with de-trended series for Fed Funds and unemployment.[13] None of these modifications had a significant effect on the main result, which allows to conclude that my finding of a risk-taking channel for the US economy is robust against re-specification of the model.

As a last exercise, I used different risk-taking proxies. Angeloni et al. (2015) use the level of outstanding debt of households and non-financial firms as a measure for

[13] I used the cyclical component of the Hodrick-Prescott filter for that purpose. The smoothing parameter is set to $\lambda = 1600$ in any case, as it is proposed for quarterly data by Ravn and Uhlig (2002) among others.

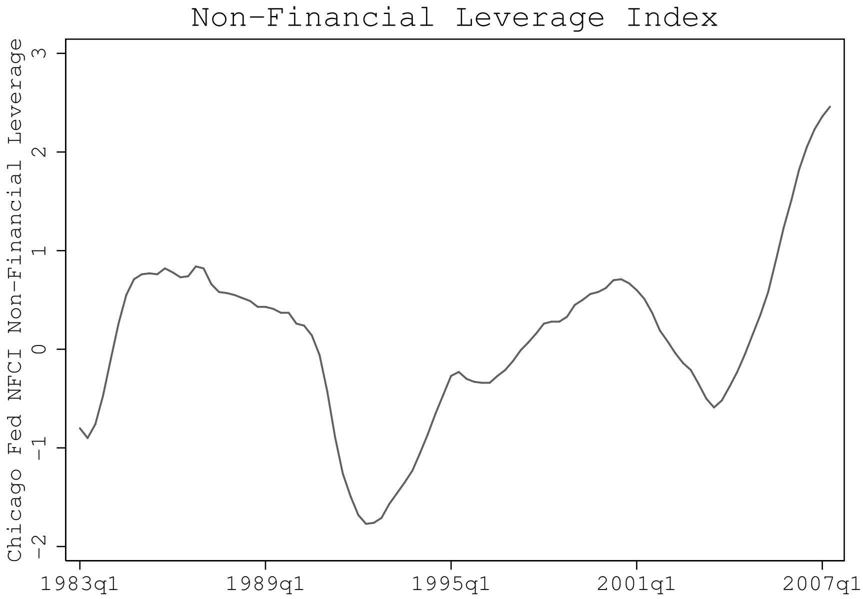


Figure 9.6: *Time Series Non-Financial Leverage*

credit risk, implicitly arguing that increasing private sector debt burdens after a policy shock are the outcome of a relaxation of loan supply conditions. I adopt this approach, however, I use the Chicago Fed Non-Financial Leverage Index (NFLI) by Brave and Butters (2012) instead of debt levels. Like the CCI, it is designed to have zero mean and unit variance. Various measures of household and firm leverage enter with a positive weight, implying that positive values of the index correspond to historically higher levels of non-financial leverage and vice versa. The index is plotted in Figure 9.6. Note its unprecedented increase in the years prior to the financial crisis.

Replacing the CCI with the NFLI does not change the responses of unemployment and inflation to the policy shock to a meaningful extent. Figure 9.7 depicts the response of the NFLI to a contractionary policy shock. Non-financial leverage shows a considerable decline and remains persistently below its initial value.[14] Vice versa, an expansive policy shock is found to cause a persistent surge in the NFLI. This result is likewise in favor

[14] Compared to the baseline case, I reduced the lag length to $p = 3$, since both model selection criteria and the residual autocorrelation test suggest doing so. The strong persistence and the slow convergence in the NFLI response should be interpreted with caution, as they could be driven by the high persistence of the original NFLI series itself. However, applying the Eigenvalue-based test verifies that the VAR as such is stable.

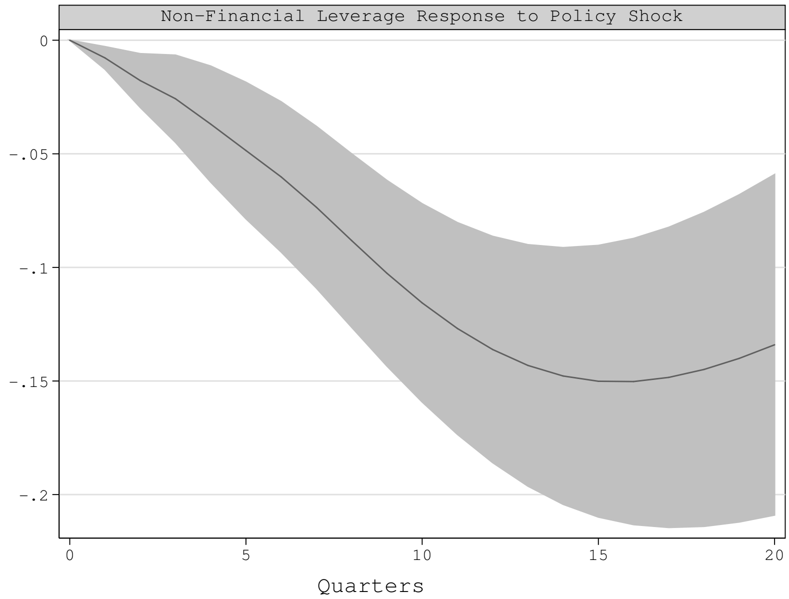


Figure 9.7: *Policy Shock and Non-Financial Leverage*

of risk-taking channel effects. Moreover, Brave and Butters (2012) stress the strong predictive power of the NFLI for financial stress over longer time horizons.[15] Therefore, one can draw the conclusion that an expansive policy shock enhances the risk of future financial instability. Put differently, an unexpected policy expansion is likely to cause an increase in systemic risk. This result continues to hold when controlling for house price growth. This is of particular importance since house price changes directly affect private sector balance sheets and thus their leverage.

As a further alternative, I rely on the credit spread indicator for US corporate bonds developed by Gilchrist and Zakrajsek (2012). This indicator can be further decomposed into a component reflecting firm-specific variations in financial health and another component reflecting time-varying attitudes of investors towards default risk. The latter component is called the excess bond premium (EBP) and represents a measure for general credit risk appetite. Figure 9.8 depicts the EBP response to a contractionary policy

[15] This corroborates the much-noticed work of Mian and Sufi (2010, 2014), who emphasize the key role of rising household debt prior to the financial crisis.

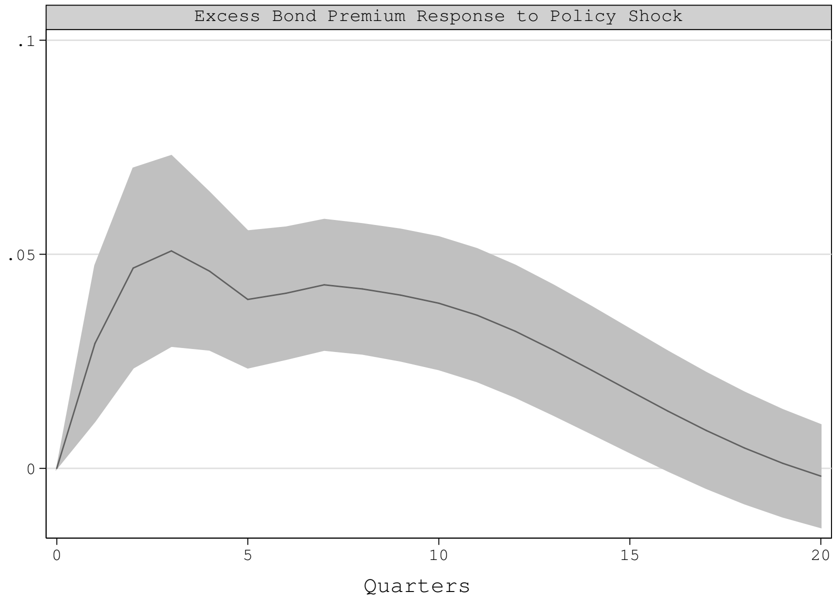


Figure 9.8: *Policy Shock and Excess Bond Premium*

shock.[16] Apparently, an unexpected policy tightening leads to an increase in the EBP. Conversely, a policy expansion increases investor appetite for credit risk. This result is likewise robust to the inclusion of house price growth. In addition, I augmented the baseline model with two proxies that seek to capture funding risk in the intermediary sector. Once again I draw on Brave and Butters (2012) and use their "risk index" for that purpose, which is designed to capture funding conditions in US financial markets.[17] I find that funding conditions tighten for about one year after a contractionary policy shock, yet there seems to be no significant response over longer time horizons (see Figure 9.9). Conversely, a policy expansion leads to a short-term increase in funding risk.

I also use a measure tracking the evolution of refinancing via run-prone Non-Core Liabilities. Following Angeloni et al. (2015), I use the year-on-year growth rate of a Non-

[16] Selection criteria suggested a lag length of $p = 3$. Medium-term macro responses remain in line with theoretical predictions, whereas short-term responses show some ambiguity.

[17] Its construction is akin to the other indicators. Negative values indicate loose funding conditions and vice versa. For instance, growth rates of outstanding repos and commercial paper enter with negative weights whereas various spreads on short-term refinancing instrument carry a positive weight. With respect to model specification, I ordered the funding risk index last since I assume that funding conditions show an immediate reaction to policy innovations.

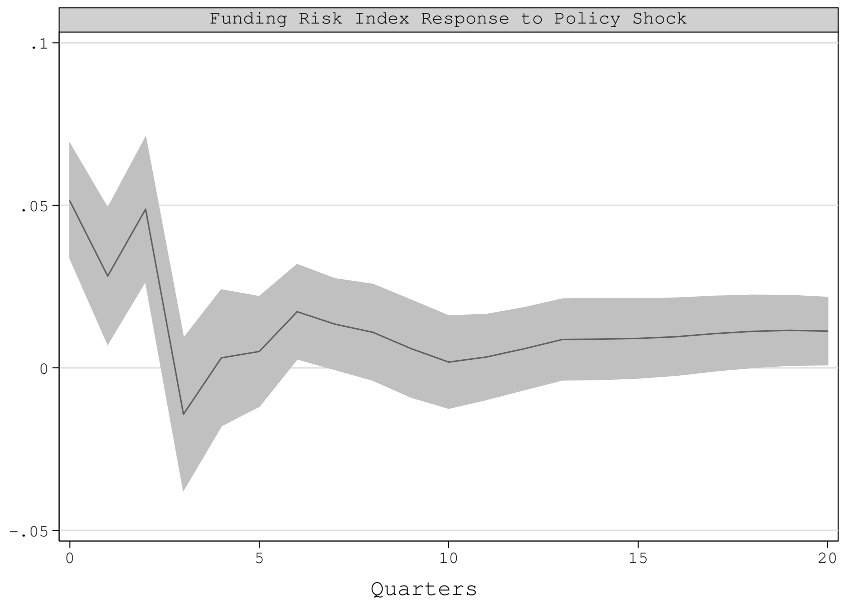


Figure 9.9: *Policy Shock and Funding Risk*

Core Liability aggregate as originally proposed by Hahm et al. (2013).[18] In line with Angeloni et al. (2015), I find that an unexpected contractionary policy shock decreases the growth rate of non-core liabilities (see Figure 9.10). Argued the other way around, an expansive policy shock increases the reliance on potentially unstable non-core funding.

To sum up, the VAR analysis provides robust evidence for the existence of the risk-taking channel in the US. Policy shocks are found to have significant procyclical effects on various proxies for credit and funding risks of the intermediation sector. Several of these proxies have strong predictive power for future financial market stress. Therefore, an unexpected policy expansion is likely to increase systemic risk and to enhance the probability of a financial crisis at longer time horizons. The conduct of monetary policy thus carries direct implications for financial stability.

[18] The aggregate comprises large time deposits and repo liabilities of commercial banks as well as money market assets. The reason for including the latter is that money market funds typically invest in short-term bank debt such as commercial paper. Data is taken from the US Flow of Funds statistic. I use year-on-year growth rates to mitigate seasonality effects. Importantly, Hahm et al. (2013) find that Non-Core Liability growth is a good indicator for the build-up of financial vulnerabilities.

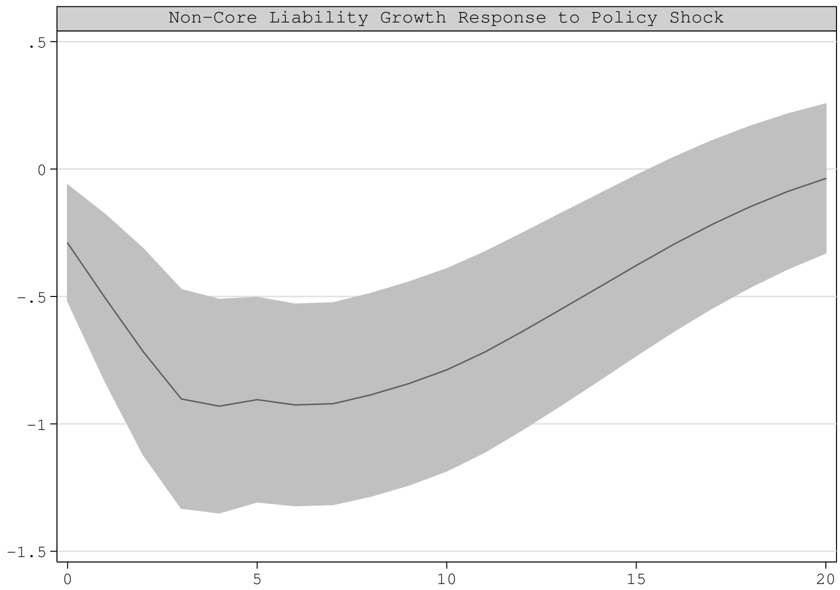


Figure 9.10: *Policy Shock and Non-Core Liabilities*

Chapter 10

A Reduced-Form Macro Model with a Risk-Taking Channel

This Chapter presents a macroeconomic model which is augmented with a stylized intermediation sector where banks pursue active balance sheet management (ABSM) in the spirit of Adrian and Shin (2010b). The model's macro block closely resembles the log-linearized version of the New-Keynesian benchmark model, as for instance discussed in Gertler et al. (1999) and Gali (2008). The inclusion of ABSM behavior allows for a stylized representation of an important element of the risk-taking channel (see Section 8.4). Furthermore, the model features a simplified version of banking regulation, represented by an exogenous equity constraint for financial intermediaries.

Simulation exercises and simple welfare analysis deliver a variety of important results. First, the intermediation sector tends to amplify macroeconomic shocks. Second, the procyclical behavior of the intermediation sector considerably worsens the trade-off between inflation and output variability. Third, optimal monetary policy responds countercyclically to intermediary balance sheet growth. Fourth, tighter financial regulation is able to mitigate the impact of intermediary behavior on macroeconomic volatility.

The model is of a reduced-form type in the sense that it abstracts from an explicit microfoundation of macro relations. This approach is less common these days.[1] However, it should be noted that appropriately specified reduced-form models are very

[1] The question whether this development is a blessing or a curse is lively debated. See for instance Spahn (2009) and Wren-Lewis (2009) for detailed and forceful criticism on the microfoundation of the New-Keynesian workhorse model.

similar to the log-linearized versions of micro-founded models. Hence, omitting microfoundations seems tolerable in my view, since the fundamental compatibility between both modeling approaches is essentially preserved. While providing microfoundations would be nevertheless desirable, it is beyond the scope of this work.[2]

In the literature, there are only few contributions studying the properties of reduced-form macro models with a financial sector. For instance, Friedman (2013) models aggregate demand as being dependent on a risky long-term rate instead of the policy rate. The risk premium of the long-term rate in turn depends on the relative supply of risky assets and a catch-all disturbance term which is designed to capture financial shocks. The approaches of Spahn (2013, 2014) augment a macro model with a stylized aggregated banking sector, which allows for the analysis of various feedback mechanisms and policy instruments such as a Taylor Rule responding to financial conditions or various macroprudential instruments. A different approach is pursued by De Grauwe and Macchiarelli (2013), Lengnick and Wohltmann (2013) and Scheffknecht and Geiger (2011), who study the interplay between monetary policy, financial markets and the real economy in reduced-form models where expectation formation is subject to bounded rationality.

10.1 Model Setup

The model can be split into a macro block and an intermediary block. The intermediation sector pursues ABSM in the sense of a constant leverage target, which gives rise to procyclical fluctuations of balance sheet aggregates and risk premia. The macro block is set up in a standard fashion, except for the fact that aggregate demand is dependent on a risky interest rate as in Friedman (2013). Hence, the model establishes a link running from balance sheet dynamics and their impact on risk premia to economic activity, similar to Adrian et al. (2010). Vice versa, balance sheet dynamics are critically affected by changes in the policy rate, as they carry a decisive influence on intermediaries' net worth and thus on their leverage. Since changes in the policy rate are mostly motivated by macroeconomic shocks, the intermediation sector equally responds to changes in economic conditions.

2 A micro-founded model with a resemblant representation of the intermediation sector reaching similar conclusions is provided by Gambacorta and Signoretti (2014). Aside from that, see Cúrdia and Woodford (2009, 2010) and Gertler and Kiyotaki (2010) among others for examples of fully-fledged New-Keynesian DSGE models augmented with a financial sector.

10.1.1 Intermediary Block

The intermediation sector is modeled in the form of an aggregated balance sheet. It is highly stylized and consists of only four types of balance sheet items. Financing occurs either via equity E_t or deposits D_t. On the asset side, banks hold marketable risk-free securities A_t and risky loans L_t. The balance sheet in period t then reads

$$A_t + L_t = D_t + E_t, \tag{10.1}$$

While loans are valued at historical costs, assets are valued at market prices given by

$$A_t = \frac{1}{1+i_t} + \varepsilon_t^a, \tag{10.2}$$

where i_t denotes the monetary policy rate and ε_t^a is a disturbance term. A_t can be interpreted as a position in risk-free, liquid assets such as government bonds or other assets with equivalent risk characteristics, whose payoff has been normalized to unity. Their market price is determined by the policy rate which equals the relevant risk-free discount rate. Note that Equation (10.2) should not be viewed as a formal asset pricing equation. It rather seeks to capture the negative relation between the policy rate and asset prices in a qualitative fashion.[3] Following Adrian and Shin (2010b), I assume that valuation effects immediately affect the equity position. Its law of motion is then

$$E_t = E_{t-1} + A_t - A_{t-1}. \tag{10.3}$$

I further assume that the banking sector is targeting a constant equity ratio which can be regarded as an exogenously imposed capital requirement by banking supervision authorities, implying that

$$\frac{E_t}{A_t + L_t} = \tau, \tag{10.4}$$

[3] Providing a formally consistent asset pricing formula would require to account for term structure dynamics and arbitrage relations between loans and marketable securities. This would complicate the structure of the model considerably, yet without changing the qualitative relation between asset prices and the policy rate. Hence, I consider this simplification as an acceptable shortcut.

where τ denotes the capital requirement in relation to total assets. Importantly, a change in the value of A_t inevitably leads to a deviation from the leverage target. Banks respond to an observed deviation by adjusting the volume of loans L_t, such that the desired equity ratio is restored.[4] This necessary adjustment yields the law of motion for loans:

$$L_t = L_{t-1} + \frac{1-\tau}{\tau}(E_t - E_{t-1}) = L_{t-1} + \frac{1-\tau}{\tau}(A_t - A_{t-1}). \tag{10.5}$$

An increase (decrease) in A_t triggers a sizable balance sheet expansion (contraction) via the adjustment of loan supply. Following the argument of Jakab and Kumhof (2014), balance sheet expansion is effectively self-financing, since additional loans imply the creation of additional deposits. Furthermore, I assume that adjustment of the actual towards the desired balance sheet size takes place in a gradual fashion. Jakab and Kumhof (2014, pp. 26) offer "institutional lags" as an explanation. Finding new borrowers or terminating existing borrowing relationships is likely to take time and probably carries adjustment costs. The final law of motion for loans is then

$$L_t = \sigma\left(L_{t-1} + \frac{1-\tau}{\tau}(E_t - E_{t-1})\right) + (1-\sigma)L_{t-1}, \tag{10.6}$$

where σ serves as a smoothing parameter. From a microeconomic perspective, σ can be regarded as the optimal speed of balance sheet adjustment which minimizes total costs from (i) balance sheet adjustment and (ii) the temporary violation of the supervision requirement.[5]

This setup of the intermediation sector is capturing the ABSM channel highlighted in Section 8.4 in a very stylized fashion. As discussed in Adrian and Shin (2010b), changes in the policy rate affect intermediary net worth and trigger subsequent balance sheet adjustments, which ultimately carry implications for the desired risk compensation. To be sure, I am aware that this setup lacks important details. There is no rigorous modeling of loan supply and loan demand. In fact, I assume that loan supply is primarily driven by ABSM considerations. Furthermore, I abstract from a detailed treatment

4 A numerical example for this mechanism is given in Section 8.4.2.

5 Insofar, this mechanism is akin to models on optimal investment, where the adjustment of the capital stock towards its optimal value likewise occurs incrementally in the presence of adjustment costs.

of the portfolio decision of the intermediation sector. Moreover, it would make sense to tie the evolution of balance sheet items directly to the level of macroeconomic activity.[6]

Notwithstanding the possibility of plausible extensions, the intermediation sector as described here captures a key element of the risk-taking channel: Market-based financial intermediaries pursuing ABSM show an inherently procyclical response to changes in the policy stance. The proposed setup is able to illustrate this feature in a parsimonious manner.

10.1.2 Macro Block

As in Friedman (2013), the macroeconomy is characterized by four key equations. First, there is a standard forward-looking Phillips Curve which reads

$$\pi_t = E_t \pi_{t+1} + \kappa y_t + \varepsilon_t^s, \tag{10.7}$$

where π_t denotes the current inflation rate, $E_t \pi_{t+1}$ is (rationally) expected inflation for the next period and y_t is the output gap, which is the difference between actual and potential output growth. Furthermore, there is an additive disturbance term ε_t^s which is usually referred to as a cost-push shock. The aggregate demand relation is given by

$$y_t = g + E_t y_{t+1} - \delta(r_t - E_t \pi_{t+1}) + \varepsilon_t^d, \tag{10.8}$$

where g denotes autonomous spending, r_t denotes a risky interest rate and ε_t^d represents an additive demand shock.[7] Thus, I assume that spending decisions are governed by a risky rate instead of the policy rate as in Friedman (2013). The policy rate is nevertheless critical for the level of the risky rate. Specifically, the risky rate follows

$$r_t = i_t + \theta - \alpha l_t + \varepsilon_t^r, \tag{10.9}$$

[6] See Spahn (2014) for a richer setup, where an upward-sloping loan supply schedule is derived from an optimization problem of the banking sector, while loan demand is tied to macroeconomic conditions and inversely depends on the loan rate.

[7] Macro relations of a very similar nature arise from the micro-founded New-Keynesian model (Gali, 2008, ch. 2-3). The Phillips Curve emerges from the profit maximization of a representative firm facing monopolistic competition and stochastic price rigidity. The aggregate demand relation is obtained as a log-linearized version of the representative household's Euler Equation, and therefore reflects the optimal allocation of consumption across time.

where θ is the risk premium prevalent in the steady-state equilibrium, i_t is the policy rate and l_t is the growth rate of loans compared to the previous period. Hence, the risky rate decreases in credit growth as in Adrian and Shin (2010b). The strength of this effect is determined by the parameter α. I likewise include a shock term ε_t^r to capture unexpected shifts in the risky rate, for instance due to varying market sentiment. This equation eventually relates balance sheet dynamics to economic activity as in Adrian et al. (2010). An increasing loan supply is associated with a decline in desired risk premia, which lowers funding costs for the private sector and boosts aggregate demand.

The model is closed with a rule for the interest-setting behavior of monetary policy, which takes the form of a standard Taylor Rule given by

$$i_t = R_t^* + \gamma\pi_t + \varphi y_t + \varepsilon_t^i, \tag{10.10}$$

where γ and φ determine the policy reaction to deviations of inflation and output gap from their steady state values. Moreover, there is the possibility of a policy shock ε_t^i. The risk-free "natural" rate R_t^* is given by

$$R_t^* = \frac{g}{\delta} - \theta \tag{10.11}$$

since it has to be corrected for the steady state risk-premium.[8] Each disturbance term in the model follows an AR(1) process of the form

$$\varepsilon_t = \rho\varepsilon_{t-1} + \zeta_t, \tag{10.12}$$

where ζ_t is a white noise process with finite variance. Hence, shocks exhibit persistence and its strength is governed by the value of ρ.

For computation I use Dynare, which is a plug-in for the Matlab software package and especially suited for the analysis of DSGE models. Dynare automatically log-linearizes the model around its steady state with the help of a Taylor Approximation, solves for the rational expectation equilibrium and computes the policy functions, i.e.,

[8] The steady state values of y_t and π_t are normalized to zero. From Equation (10.8), it follows that $r_t^* = g/\delta$. Plugging this result into Equation (10.9) yields $i_t^* = g/\delta - \theta$, since credit growth is zero in steady state. Eventually, Equation (10.10) stipulates that $i_t^* = R_t^*$ for zero inflation and a closed output gap.

the law of motion for each endogenous variable dependent on past realizations and exogenous disturbances. Moreover, Dynare calculates theoretical moments for each variable such as unconditional mean and variance. It is also possible to generate impulse-response functions in order to analyze model dynamics in the wake of a specific shock.

10.2 Simulations

The simulation exercise analyzes the model response to a transitory cost-push shock, a demand shock, a shock to the risky rate, a policy shock and a shock to asset valuations. Specifically, there is a one-time disturbance ζ in the initial period whose impact persists for several periods according to Equation (10.12).

Before that the model needs to be parameterized. Table 10.1 depicts the parameter choices for the macro block. The parameters κ, δ, γ and φ are taken from Gali (2008). The steady-state risk premium θ is set to 0.0221 such that it matches the average spread of the US Moody's Baa corporate bonds index over treasuries, which historically has been 2.21%.[9] The reaction of the risky rate to credit growth is set to $\alpha = 0.25$. The parameter depicting autonomous expenditure g is set to 0.0421 such that Equation (10.11) delivers a risk-free natural rate of two percent as originally advocated by Taylor (1993). For the shock persistence, I choose $\rho = 0.8$, except for the policy shock which is modeled to be less persistent with $\rho_i = 0.33$.[10] The standard deviation of the white noise innovation ζ is 0.01 in any case, implying that the standard shock size amounts to one percentage point.

Table 10.2 shows the parameterization of the intermediation sector. Since the size of the balance sheet in the steady state is not explicitly determined within the model, I have to specify appropriate steady state values. As indicated by Equation (10.2), the steady state value of the asset position is its unit payoff discounted with the steady state policy rate i_t^*. For simplicity, I assume that the steady state loan position has the same value. The positions on the liability side follow directly from the specification of A_t^* and L_t^*, since the equity constraint is fulfilled in the steady state.

9 The spread is taken from FED FRED from Q1 1973 until Q4 2014 (series title: BAA10YM).

10 This is in line with Angeloni and Faia (2013a), who model the policy shock with comparably low persistence. Since a policy shock in the model represents a policy error, for example due to measurement problems, it is reasonable to assume that it will fade out rather quickly.

Symbol	Parameter Description	Parameter Value
κ	Output Gap Elasticity of Inflation	0.5
g	Autonomous Expenditures	0.0421
δ	Risky Rate Elasticity of Aggregate Demand	1
γ	Taylor Coefficient on Inflation	1.5
φ	Taylor Coefficient on Output Gap	0.5
θ	Steady-State Risk Premium	0.0221
α	Credit Growth Coefficient on Risky Rate	0.25
R_t^*	Steady State Natural Rate	0.02
i_t^*	Steady State Policy Rate	0.02

Table 10.1: *Parameterization and Steady State Values of the Macro Block*

Symbol	Parameter Description	Parameter Value
τ	Equity Ratio Target	0.2
σ	Balance Sheet Adjustment Smoothing Parameter	0.5
L_t^*	Steady State Loan Volume	$1/(1+\mathrm{i}_t^*)$
A_t^*	Steady State Marketable Asset Volume	$1/(1+\mathrm{i}_t^*)$
D_t^*	Steady State Deposit Volume	$(1-\tau)(L_t^* + A_t^*)$
E_t^*	Steady State Equity Base	$\tau(L_t^* + A_t^*)$

Table 10.2: *Parameterization and Steady State Values of the Intermediary Block*

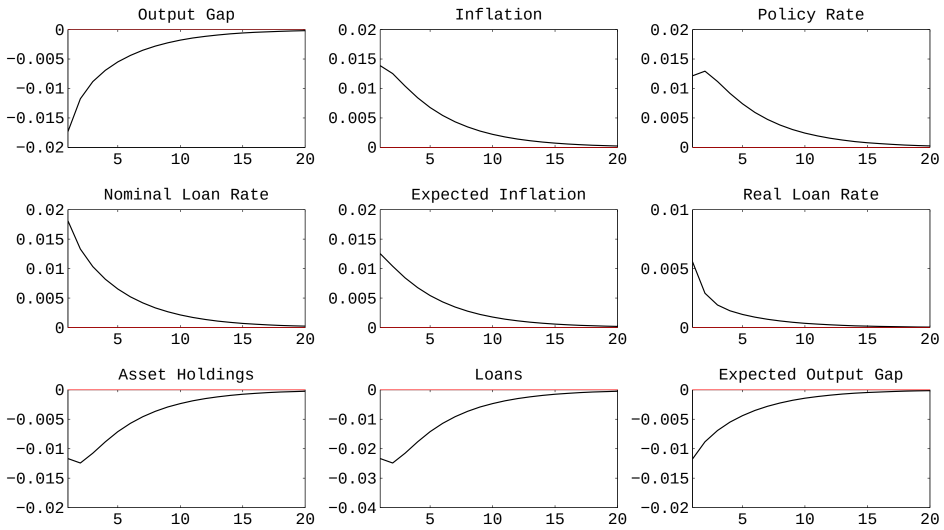


Figure 10.1: *Simulated Cost-Push Shock*

Figure 10.1 shows the model response to a transitory cost-push shock. The cost-push shock triggers an immediate spike in inflation and the central bank responds with an increase of the policy rate. This causes an adverse valuation effect for the asset position of intermediaries and a consequent cutback of loan supply. The loan rate rises sharply both due to the policy rate increase and the negative growth in loans. The impact on the real loan rate $r_t - E_t\pi_{t+1}$ is moderated by the increase in inflation expectations, but it nevertheless increases by about 0.6%. As a result, aggregate demand declines and both actual and expected output gap become negative. The supply shock subsequently fades out and every variable reverts back to steady state within about 15 periods.

The dynamics of an unexpected increase of the risky rate are depicted in Figure 10.2. Interestingly, the policy response is so strong that the risky rate declines as a net effect. The central bank responds with a decisive cut of the policy rate of about 1.5%, which is mostly motivated by the initial decline in both actual and expected inflation. This boosts asset valuations in the intermediation sector and thus loan growth, which puts additional downward pressure on the risky rate. In sum, the risky rate declines by about 1.2%. The response of the real loan rate is negative on impact, but turns to

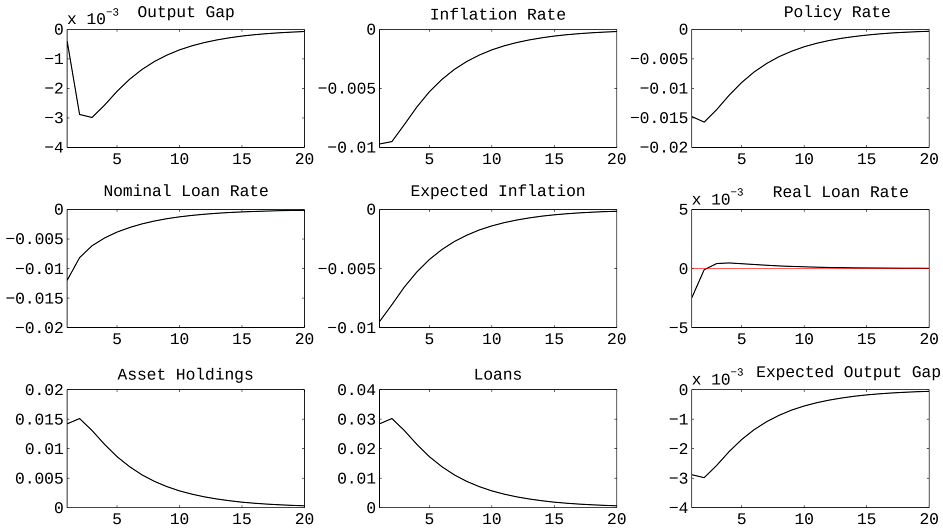


Figure 10.2: *Simulated Loan Rate Shock*

be mildly positive after two periods. The output gap initially turns negative, declines to about -0.3% and starts converging back to zero after about 3 periods. To sum up, monetary policy counteracts the risky rate shock with a policy rate cut and achieves a relative stabilization of the real loan rate and thus aggregate demand. Yet the central bank is less successful in stabilizing inflation.

Figure 10.3 depicts the model dynamics in the wake of a valuation shock to the asset position of the banking sector. Assets and loans increase on impact. While there is an immediate (yet moderate) reaction of the policy rate, the net effect on both nominal and real loan rate is nevertheless negative. The output gap initially increases by some modest 0.2%. This effect fades out rather quickly. Output gap and inflation show (very small) negative values in the subsequent periods, which motivates the central bank to cut the policy rate slightly. All in all, the impact of the valuation shock on output and inflation is comparably small.

A demand shock is shown in Figure 10.4. The policy rate strongly increases in response by about 1.5% and asset holdings as well as loan growth decline. Both the

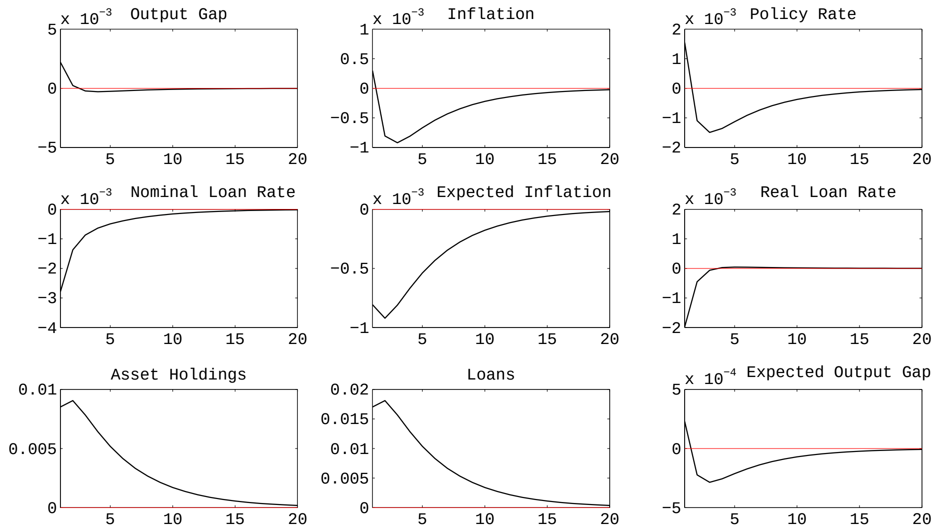


Figure 10.3: *Simulated Asset Valuation Shock*

nominal and the real loan rate increase as well, which attenuates the impact of the demand shock on the output gap. Conversely, actual and expected inflation rise by a full percentage point on impact. Again, monetary policy is successful in stabilizing output and less successful in stabilizing inflation.

Figure 10.5 shows the effect of a policy shock. The increase of the policy rate triggers a decline in asset values which translates into negative loan growth. Both effects lead to a rise in the loan rate and a simultaneous decrease in output and inflation. Given the modest persistence of the shock, these effects fade out rather quickly after roughly five periods. Note that the model response is qualitatively similar to the VAR results in the previous Chapter, where I found that a contractionary policy shock leads to tightened credit conditions, a contraction of economic activity and a small drop in inflation over the medium term.

10.3 Welfare Analysis

The simulation exercise has explored the dynamics of the model and it became clear that the intermediation sector tends to amplify macroeconomic shocks and is a gen-

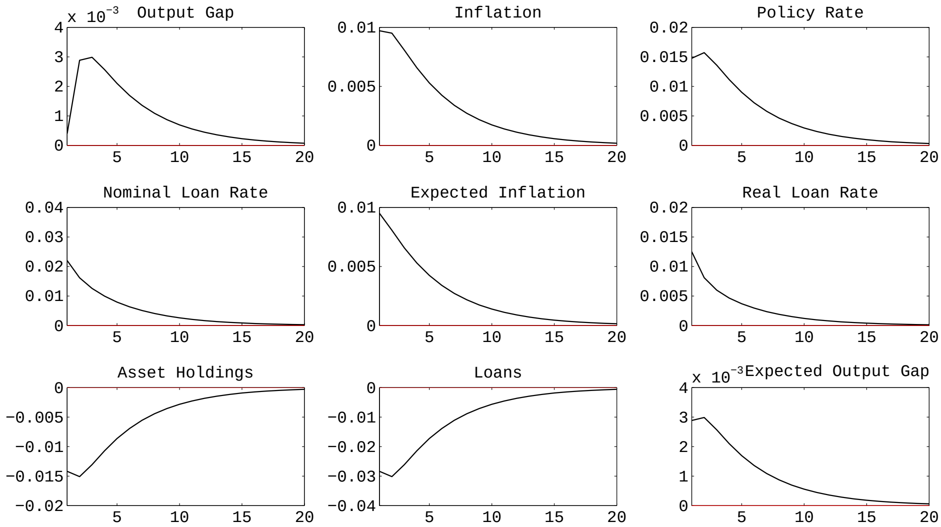


Figure 10.4: *Simulated Demand Shock*

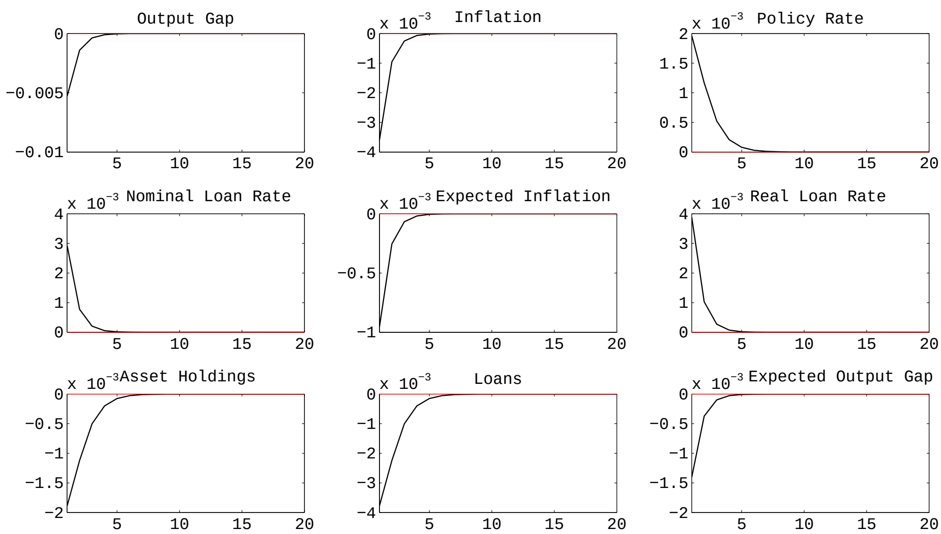


Figure 10.5: *Simulated Policy Shock*

uine source of shocks with a macroeconomic impact in its own right. Against this background, the welfare effects of financial sector procyclicality deserve a closer examination. For that purpose, I compare the baseline model with a model in which the feedback between financial and real sector is not present. Setting $\alpha = 0$ breaks the link between balance sheet dynamics, fluctuations of the risky rate and aggregate demand and effectively shuts down the risk-taking channel (henceforth RTC). Figure 10.6 now compares the response to a cost-push shock in both models with respect to the output gap and inflation. The baseline model with an active risk-taking channel shows larger deviations of inflation from the steady state. Regarding output, the gap in the baseline model is more negative on impact but converges marginally quicker back to the steady state. All in all, the inclusion of the intermediation sector magnifies the impact of the supply shock.

The analysis of Taylor Curves for both models in Figure 10.7 gives a more detailed impression of welfare implications. To obtain Taylor Curves, each model was simulated over a grid of policy coefficients. While keeping γ constant at 1.5, I varied the output gap parameter φ in the Taylor Rule between zero and unity with an interval of 0.05. Each variant of the policy rule delivers a specific combination of inflation and output gap volatility. With rising values of φ, output volatility declines at the expense of heightened inflation volatility. Insofar, the model replicates the well-known trade-off between output and inflation variability, as discussed in Section 8.3.1. It should be noted, however, that a weak response to the output gap is always suboptimal. For constellations with a low value for φ, which corresponds to the area in the upper left, the slope of the Taylor Curve is not strictly negative. In that case, an increase in φ is clearly beneficial as it allows to move closer to the origin, i.e., to achieve a simultaneous decline of both inflation and output volatility. The comparison of both Taylor Curves delivers a clear result. If the risk-taking channel is active, the Taylor Curve shifts to the right. The policy trade-off becomes less favorable, and policymakers have to accept a higher degree of macroeconomic volatility.

To support this conclusion, I simulated the model under optimal rule-based policy. Optimal rule-based policy means that the central bank sets the reaction coefficients γ and φ such that to minimize a loss function L given by

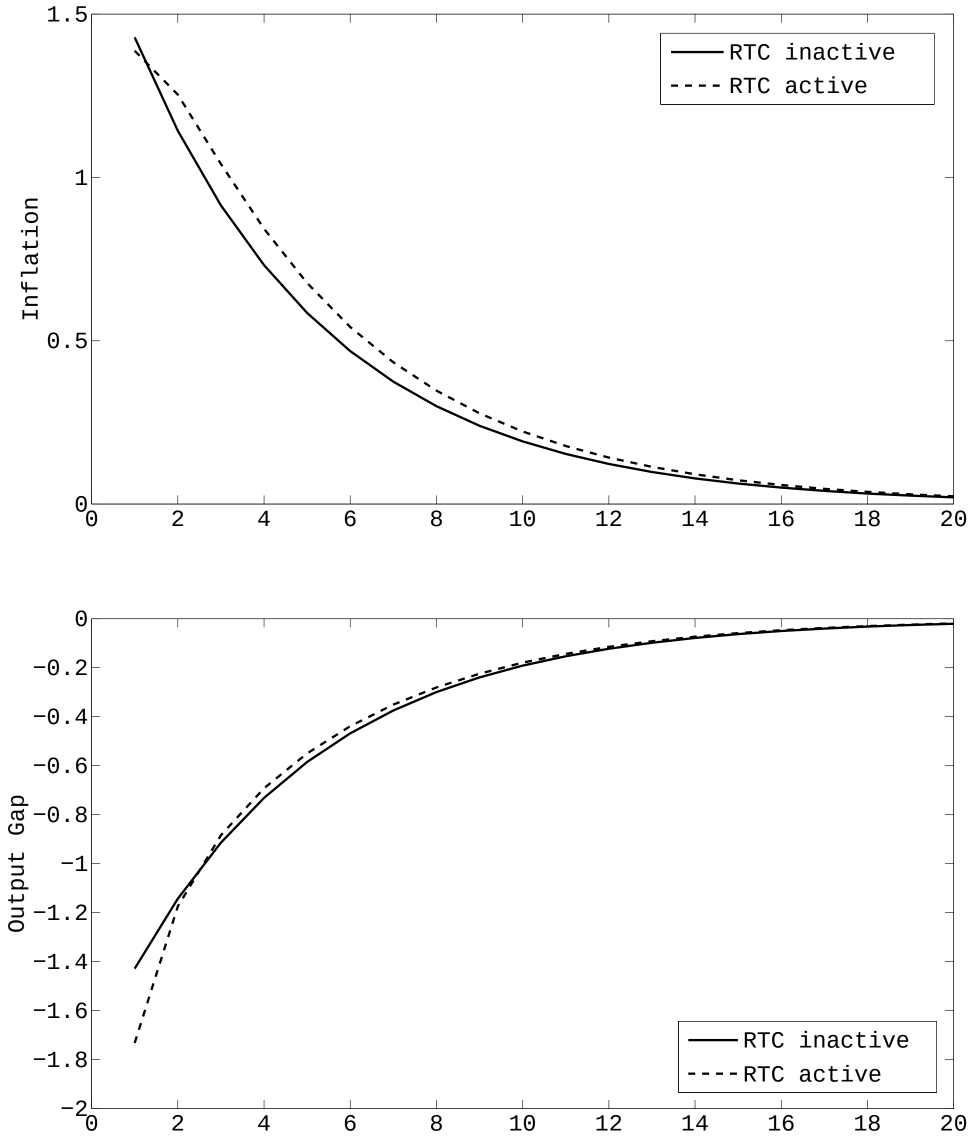


Figure 10.6: *Supply Shock with and without Risk-Taking Channel*

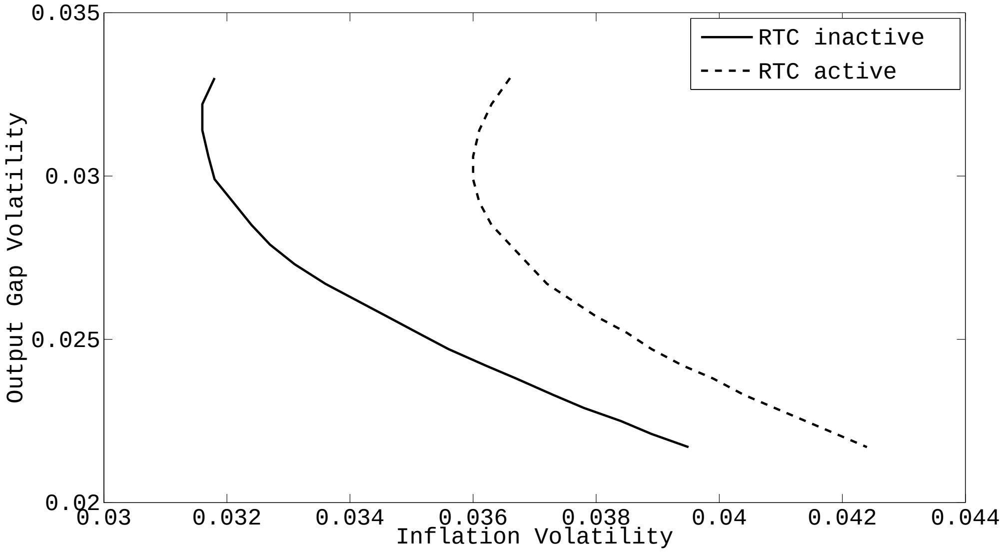


Figure 10.7: *Comparison of Taylor Curves*

$$\min_{\varphi,\gamma} L = \sigma_y^2 + \sigma_\pi^2, \tag{10.13}$$

where σ_y^2 and σ_π^2 denote the unconditional theoretical variances of inflation and the output gap, respectively. Minimizing these variances is equivalent to minimizing deviations of inflation and output gap from their steady-state values. Dynare computes the solution with a numerical optimization method initially proposed by Sims (1999).

In order to facilitate comparability between model variations, I have excluded the possibility of shocks to asset valuations and the risky rate since these shocks do not generate meaningful dynamics in the model if the risk-taking channel is inactive. The valuation shock simply has no impact due to the fact that $\alpha = 0$, while the shock to the risky rate is akin to a simple demand shock. Results for optimal rule-based policy are given in Table 10.3.

Optimal policy within the baseline model responds stronger to inflationary pressure than implied by the initial parametrization. The reaction coefficient roughly doubles to 3.139. The earlier analysis of the impulse-response functions with the baseline parametrization revealed that the central bank has difficulties in bringing inflation back

	γ	φ	σ_π	σ_y	Total Loss ($\times 10^{-3}$)
Baseline Model	3.139	0.185	0.0089	0.0322	1.117
RTC inactive ($\alpha = 0$)	2.616	0.199	0.0112	0.0311	1.093

Table 10.3: *Optimal Policy Rule Comparison*

to target quickly. Therefore, a more aggressive response to inflation under optimal policy is not surprising. Indeed, the unconditional standard deviation of inflation declines to 0.89%, whereas output volatility remains relatively elevated at 3.22%. A comparison with the model variant in which the risk-taking channel is inactive shows that losses are higher. In sum, the amplification mechanisms within the intermediation sector increase macroeconomic volatility and reduce welfare, even when monetary policy follows an optimal rule.

It is also interesting to analyze to role of banking regulation, which is represented in a stylized fashion by the equity ratio τ. For that purpose, I simulated the model over a grid of different values for τ and compared the respective results for inflation and output volatility. Specifically, I varied τ between 0.1 and 0.4 with an interval of 0.02. Figure 10.8 displays the results. A rise in τ implies moving along the curve towards the origin. Hence, a more restrictive capital requirement dampens macroeconomic volatility. Equation (10.6) shows that an increase in τ attenuates the strength of the balance sheet adjustment process. Therefore, amplification within the intermediation sector is weakened and the risk-taking channel become less potent. Tighter financial regulation is seemingly able to mitigate the impact of intermediary behavior on macroeconomic volatility.

Table 10.4 shows the outcome of two optimal policy simulations with varying values for τ. Inflation volatility increases with a rise in τ whereas output volatility decreases. As a net effect, an increase in τ slightly lowers the loss associated with macroeconomic volatility. This is broadly in line with the findings in Figure 10.8 under standard Taylor Policy.

In addition, I allow for the possibility that monetary policy responds directly to credit growth, which can be seen as a stylized version of a "leaning-against-the-wind-policy" under which the central bank actively reacts to financial market developments. The policy rule then changes to

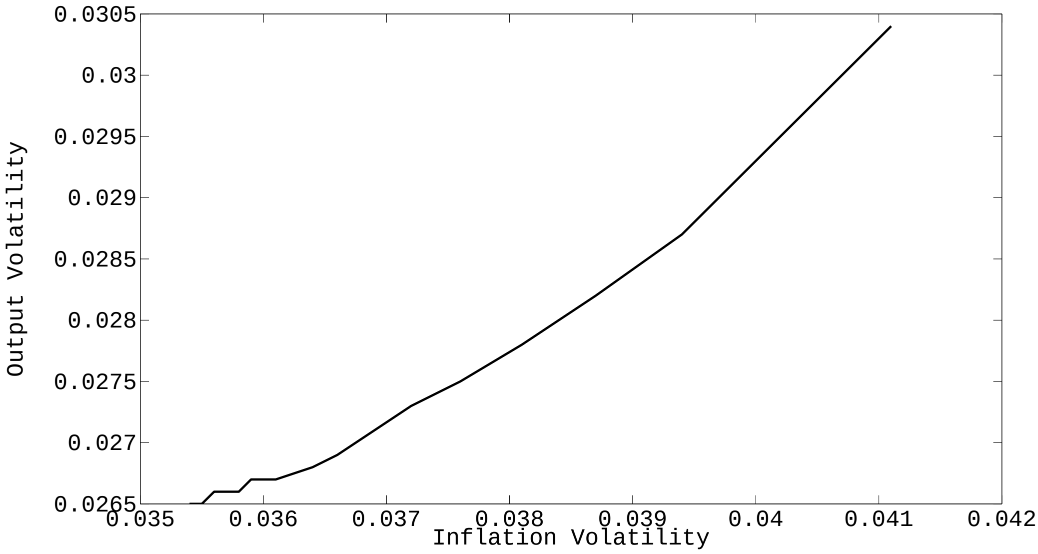


Figure 10.8: *Equity Constraint and Macro Volatility*

	γ	φ	σ_π	σ_y	Total Loss ($\times 10^{-3}$)
Baseline Model ($\tau = 0.2$)	3.139	0.185	0.0089	0.0322	1.117
Baseline Model ($\tau = 0.4$)	2.763	0.189	0.0105	0.0315	1.1105

Table 10.4: *Optimal Policy with Varying Equity Requirement*

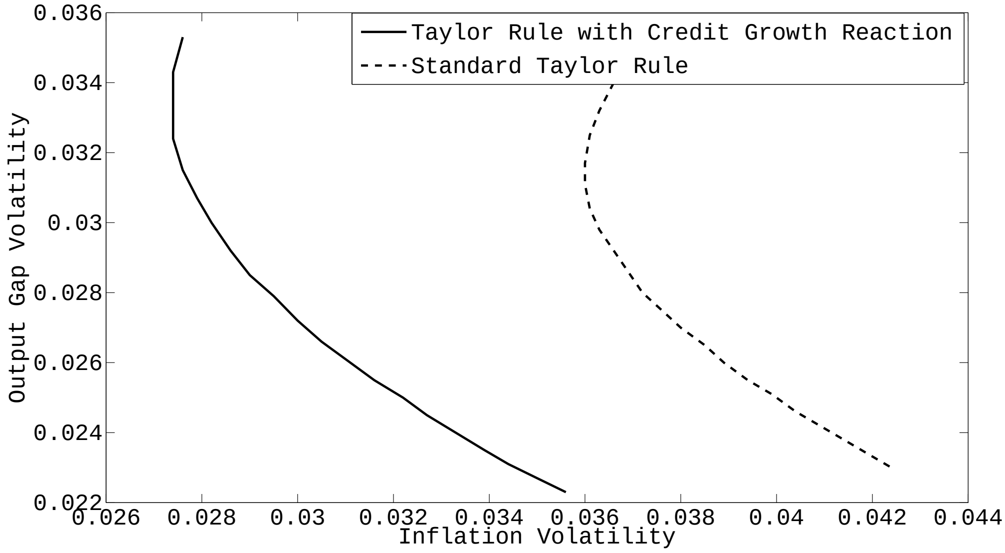


Figure 10.9: *Taylor Curve With and Without Credit Growth Reaction*

$$i_t = R_t^* + \gamma\pi_t + \varphi y_t + \eta l_t + \varepsilon_t^i, \tag{10.14}$$

implying that for $\eta > 0$, the central bank exerts additional tightening in the wake of positive credit growth (and vice versa). Figure 10.9 plots the Taylor Curve of the baseline model versus the Taylor Curve of a policy with $\eta = 0.5$. Again, the models were simulated over a grid of different values for φ. Clearly, the inclusion of an active response to credit market developments shifts the Taylor Curve to the left. Leaning-against-the-wind-policy (henceforth LATW policy) reduces macroeconomic volatility to a considerable extent.

The benefits of this policy can be further analyzed by deriving a modification of the optimal policy rule, this time with the difference that η becomes an additional choice variable for the policymaker. Table 10.5 shows the respective results. It is optimal to respond to credit dynamics, as indicated by the positive vale of $\eta = 0.800$. Losses decrease compared to the baseline case.[11]

[11] Losses are even lower than in the case where the risk-taking channel is inactive. However, these constellations are not really comparable due to the different policy rules and varying shock implications.

	γ	φ	η	σ_π	σ_y	Total Loss ($\times 10^{-3}$)
Baseline Model	3.139	0.185	-	0.0089	0.0322	1.117
LATW policy ($\eta > 0$)	2.4545	0.229	0.800	0.0125	0.0299	1.053

Table 10.5: *Optimal Policy With and Without Credit Growth Reaction*

As a last step, Table 10.6 compares losses under different policy mixes. In particular, I analyze optimal policy with a credit growth reaction for different values of the equity ratio. The credit reaction parameter η decreases as the capital requirement tightens. This points to some degree of complementarity between monetary policy and banking regulation with respect to the stabilization of the intermediation sector. Thus, tighter banking regulation may be genuinely beneficial in a sense that it relieves monetary policy (at least partly) from the necessity to react to financial market developments. This may be particularly important if the volatility of the policy rate as such represents a concern for policymakers, for example due to the risk of unintended short-term effects on aggregate demand. On the other hand, losses increase slightly with a rising capital ratio which could imply that monetary policy on its own is equipped best to contain financial procyclicality.

Another intriguing reason could be that the existence of an additional amplification mechanism turns out as beneficial if shocks push the output gap and inflation in the same direction, which is true for the demand shock and the policy shock. In such a case, monetary policy gains additional grip on the economy and is potentially able to engineer a quicker reversion to the steady state. A tighter capital constraint weakens this effect by reducing the strength of the amplification mechanism. Thus, the optimal way of policy coordination is likely to be critically dependent on the relative importance of the various shocks, an issue well-known in monetary policy analysis since the important contribution of Poole (1970).

Yet it would be exaggerated to claim that tighter capital constraints decrease welfare. The analysis under Taylor policy - which is arguably the empirically relevant benchmark - has clearly shown the benefits of an increasing equity ratio. Moreover, higher equity ratios have benefits in their own right which are not captured within the model (see Chapter 5). In any case, the analysis shows that monetary policy and banking regulation need to be carefully coordinated.

	γ	φ	η	σ_π	σ_y	Total Loss ($\times 10^{-3}$)
LATW policy ($\tau = 0.2$)	2.4545	0.229	0.800	0.0125	0.0299	1.053
LATW policy ($\tau = 0.3$)	2.5055	0.214	0.732	0.0119	0.0304	1.064
LATW policy ($\tau = 0.4$)	2.537	0.207	0.674	0.0116	0.0306	1.074

Table 10.6: *Losses with Different Policy Mixes*

To sum up, the welfare analysis has delivered several interesting results. I have found that the procyclical behavior of the intermediation sector worsens the trade-off between inflation and output variability. Hence, optimal monetary policy should respond countercyclically to intermediary balance sheet growth. Tighter financial regulation is able to mitigate the impact of intermediary behavior on macroeconomic volatility under a Taylor policy, but seems slightly counterproductive in an optimal-policy setting, where the central banks on its own performs best in stabilizing the financial sector and the macroeconomy.

Chapter 11

Implications for Monetary Policy

Should monetary policy mandates be extended to include a financial stability objective? In an ideal world, this question should be denied. If macroprudential regulation is successful in mitigating the build-up of systemic risk, there is no reason for central banks to incorporate financial stability considerations into their policy decisions. In this case, price stability and (to a lesser extent) sustainable growth and employment remain the central bank's only concerns. Put differently, effective macroprudential regulation acts as a shield in two directions: First, it ensures that systemic risk is not a concern for monetary policy. Second, it mitigates unintended consequences from the monetary policy stance on systemic risk. For example, if macroeconomic conditions call for an easy policy stance, macroprudential regulation can ensure that prolonged periods of monetary expansion - warranted by weak aggregate demand or subdued inflation - do not lead to an increase of systemic risk as a by-product. Such a setting would satisfy the well-known Tinbergen Principle, which states that each policy objective should be pursued with one specific instrument.

Figure 11.1 provides a graphical exposition. Macroprudential regulation which adequately contains systemic risk insulates monetary policy from the adverse real-economy spillovers of a financial crisis which impair the central bank's ability to fulfill its primary objectives. On the other hand, macroprudential regulation can mitigate the unintended consequences monetary policy has on systemic risk. Nevertheless, monetary policy and macroprudential regulation cannot be regarded as completely separate

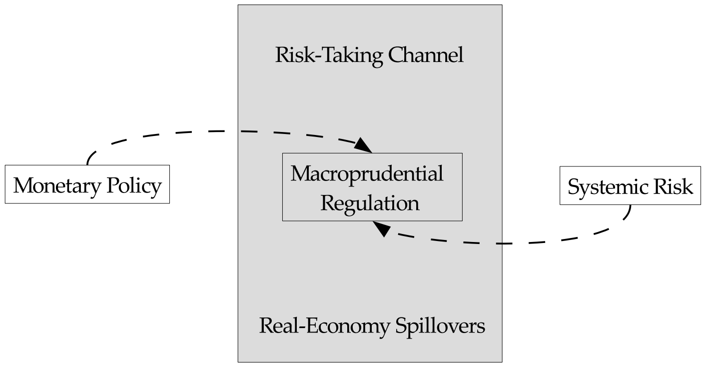


Figure 11.1: *First-Best Policy Arrangement*

policy areas. Monetary policy affects financial market dynamics just as well as macroprudential regulation affects economic activity via its impact on loan supply. Therefore, monetary policy and macroprudential regulation should be carefully coordinated. The discussion of this issue is postponed to Section 11.4.4.

However, as argued in Section 5.4, macroprudential regulation in its current form suffers from various shortcomings. It is therefore unlikely that it is capable to shield monetary policy and systemic risk from each other. Thus, systemic risk becomes a concern for monetary policymakers. First, real-economy spillovers of a potential crisis adversely affect the primary objectives of monetary policy (see Chapter 6). Second, as discussed in Chapter 8, monetary policy might influence the build-up of systemic risk via the risk-taking channel. Systemic risk is hence endogenous to monetary policy which indicates that central banks should respond to its build-up on an *ex-ante* basis. Figure 11.2 depicts the policy arrangement in the case of insufficient macroprudential regulation. In this case, monetary policy has to account for its influence on systemic risk and the associated risk of adverse real-economy spillovers arising from future crises.

Does this policy arrangement pose a problem? After all, it is argued that monetary policy pursuing a price stability objective automatically fosters financial stability (Bordo et al., 2002; Issing, 2003). However, if there are constellations in which the analysis of economic conditions and the monitoring of systemic risk deliver *diverging* recommendations for the policy stance, the policy trade-off becomes more complicated.

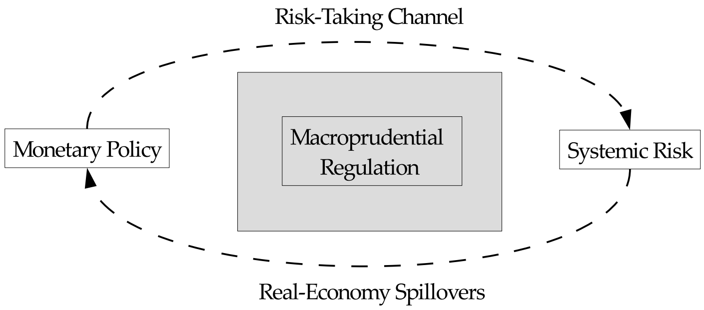


Figure 11.2: *Second-Best Policy Arrangement*

Balancing output and inflation variability (see Section 8.3.1) may become more challenging as systemic risk considerations may introduce an additional constraint. Hence, assigning financial stability objectives to monetary policy should not be regarded as a beneficial improvement of the institutional framework. Financial stability objectives are a *burden* for monetary policy, potentially distracting it from pursuing its macroeconomic goals. Such an arrangement is nothing but the unfortunate consequence of insufficient financial regulation.

In what follows, I discuss constellations in which monetary policy potentially faces a trade-off between achieving price stability and containing systemic risk. After that, I contrast several popular arguments in favor of and against monetary policy having an eye on financial stability. Especially, I sketch out how the recent crisis has changed views on that matter. I then review model-based representations of monetary policy that take financial stability considerations into account. Finally, I highlight possible adjustments of practical policy frameworks and discuss the issue of optimal coordination between monetary policy and macroprudential regulation.

11.1 Is there a Trade-Off between Price Stability and Financial Stability?

What are potential constellations under which the analysis of systemic risk and macroeconomic conditions deliver diverging recommendations for the policy stance? Table 11.1 depicts the responses of macroeconomic variables and systemic risk to various forms of shocks along the lines of the model presented in Chapter 10. It is henceforth assumed that systemic risk increases in positive values of the output gap and in negative deviations of the policy rate from its steady-state value. More specifically, balance sheet expansions of the financial sector can be regarded as a proxy for an increase in systemic risk.

Shock	Output Gap	Inflation	Systemic Risk	Policy Response
Demand Shock	+	+	+	$i_t \uparrow$
Negative Cost-Push Shock	-	+	=	$i_t \uparrow$
Positive Cost-Push Shock	+	-	+	**?**
Technology Shock	?	-	+	**?**
Financial Shock	+	=	+	**?**

Table 11.1: *Macroeconomic Shocks, Systemic Risk and Policy Trade-Offs*

Demand shocks do not give rise to a policy trade-off. Output and inflation rise simultaneously and, due to the positive output gap, so does systemic risk. Hence, tightening the policy stance is unambiguously beneficial. Negative cost-push shocks do not pose a trade-off between price and financial stability either. Given inflationary pressure, the central bank contracts output by raising interest rates, such that systemic risk remains unaffected or even decreases. Things change in the wake of a positive cost-push shock, i.e., an unexpected decline in inflation. The associated undershooting of the inflation target calls for a lower policy rate, however, this will come along with a positive output gap and a likely increase in systemic risk. Positive cost-push shocks thus give rise to a trade-off between monetary policy and financial stability, and the optimal policy response is not clear.

Figure 11.3 depicts the OIRFs for an unexpected increase in inflation from the VAR model estimated in Chapter 9. By construction, the response to an unexpected decline in inflation (positive cost-push shock) is depicted by the axisymmetrical mirror image of the impulse-response functions in Figure 11.3. A positive cost-push shock triggers a decline in the Federal Funds Rate as well as a modest decrease in unemployment. However, the credit condition indicator also declines, implying that credit is granted more freely which potentially increases systemic risk. The model simulations in Chapter 10 draw a similar picture: An unexpected decline in inflation leads to a decline in the policy rate in line with the Taylor Rule, while the output gap becomes positive. Moreover, the balance sheet of the financial sector expands, which might contribute to the build-up of systemic risk.[1] Hence, both the empirical results obtained in Chapter 9 as well as the model simulations conducted in Chapter 10 tend to support the view that benign cost-push shocks create a trade-off between price stability and the containment of systemic risk.

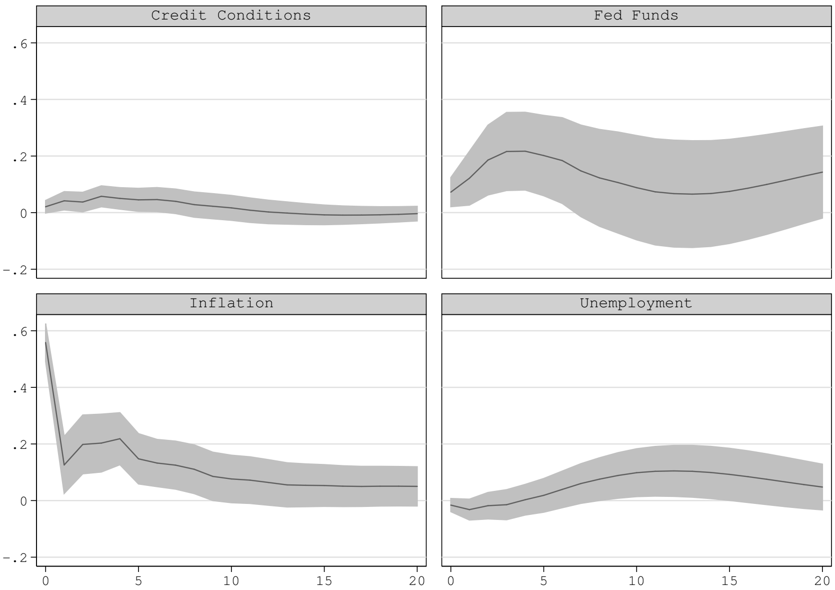


Figure 11.3: *VAR Impulse-Response Functions for an Inflation Shock*

Figure 11.4, adapted from De Grauwe and Gros (2009), depicts comparative statics in the case of a benign technology shock in a simple AS-AD model. The initial equilibrium is depicted by point A. Output is at its potential Y^* and the price level equals its target value P^*.[2] A benign technology shock is assumed to increase productivity and asset prices, with the latter decreasing firms' cost of capital. Thus, the supply curve shifts to the right (from AS to AS'). Moreover, the technology shock is supposed to trigger a shift of the aggregate demand curve from AD to AD'. It is argued that "[n]ew technologies create new products and thus lead consumers to spend more" (De Grauwe and Gros,

1 The response of the model economy to a negative cost-push shock is depicted in Figure 10.1. As in the VAR analysis, the impact of a positive cost-push shock corresponds to the axisymmetrical mirror image.

2 The argument remains valid if it is assumed that central banks target a specific inflation rate instead of a specific price level (De Grauwe and Gros, 2009, p. 3).

2009, p. 3). Furthermore, the supply shift is supposed to be stronger in magnitude than the demand shock. The new temporary equilibrium is in point B at a lower price level and at an increased potential output of Y^{**}. Since the price level in point B undershoots the central bank's price level target, monetary policy will relax the policy stance. This shifts the AD curve further to the right (AD”) and leads to the new temporary equilibrium C. However, point C is not sustainable. Even though the desired price level has been restored, monetary policy accommodation increases the risk that asset prices develop into an eventually unsustainable bubble. If it bursts, aggregate demand declines sharply and the economy finds itself in point D, which is below potential output Y^{**} and also below the price level target P^*. The key point is that the central bank either has to accept the decline in the price level associated with point B, or it can push the price level back to target at the expense of a potential asset price bubble which increases systemic risk. In this sense, a benign technology shock likewise creates a trade-off between price stability and financial stability.

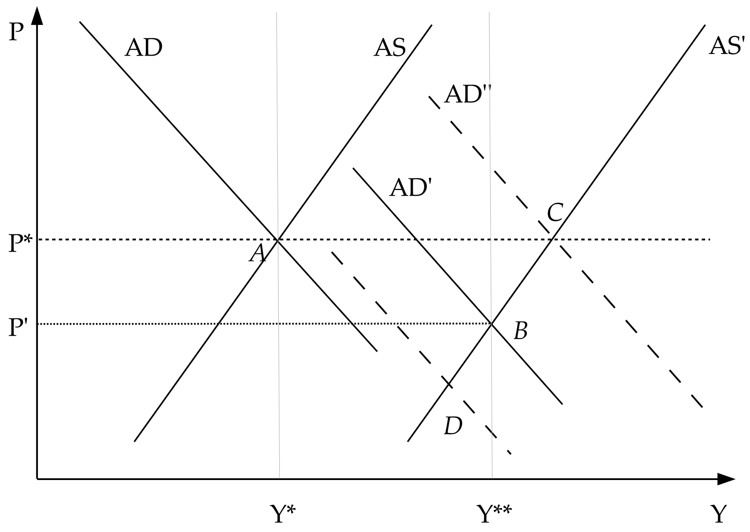


Figure 11.4: *Impact of a Technology Shock on Economic Conditions and Systemic Risk*

Figure 11.5, again adapted from De Grauwe and Gros (2009), represents comparative statics in the case of a positive financial shock, i.e., an increase in asset prices and/or a decline in external finance premia. Both effects lower firms' cost of capital which shifts the AS curve to the right. Moreover, the rise in asset prices (or the greater availability of credit) boosts aggregate demand. The AD curve consequently shifts to the right as well. As a result, the economy realizes an output level above potential at an unchanged price level, accompanied by an increase in systemic risk (point *F*). Monetary policy can counteract the build-up of systemic risk by tightening the policy stance which shifts the AD curve to the left. However, this comes along with a decline in the price level. Hence, financial shocks are another possible manifestation of the trade-off between price stability and financial stability. Interestingly, this constellation is partly mirrored in the responses to an asset valuation shock in the model of Chapter 10, in which an unexpected increase in asset valuations triggers balance-sheet expansions whereas inflation and output respond only moderately (see Figure 10.3).

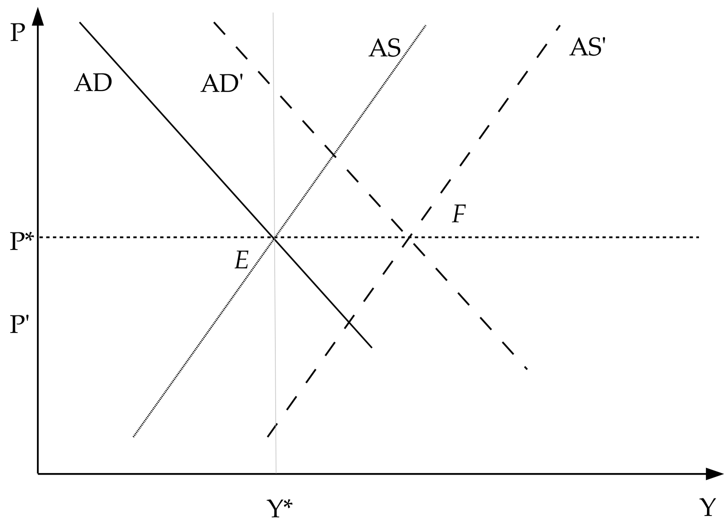


Figure 11.5: *Impact of a Financial Shock on Economic Conditions and Systemic Risk*

Hence, there are various constellations in which the analysis of economic activity and the surveillance of financial-sector developments can deliver contradicting recommendations for the policy stance. Adrian and Liang (2014) argue that such constellations imply that monetary policy faces a risk-return trade-off between easing financial conditions today (for the sake of short-term macro stability) and the risks which may arise due to an increase in future financial vulnerability. This trade-off complements the trade-off between inflation and output variability. Generally, declines in inflation appear to be particularly relevant in this respect. Moreover, credit or asset price booms which are not mirrored in the inflation rate can create trade-off situations as well. Borio and Lowe (2002) and Borio and White (2004) argue that positive supply-side developments can mask inflationary pressure on goods markets, whereas asset prices increase strongly (see also Section 8.3.2). Drehmann and Juselius (2012) show that the upswing of a financial boom-bust cycle is often preceded by positive supply shocks. Moreover, global economic integration may exert downward pressure on inflation in advanced countries, be it via cheap imports or the intensification of competition.[3] If monetary policy responds to these developments by easing the policy stance (instead of taking them for granted as a secular trend), systemic risk may increase as an unintended consequence.[4] In summary, it can be concluded that trade-offs between price stability and financial stability are likely to have considerable relevance for practical policymaking.

11.2 The Leaning-versus-Cleaning Debate Revisited

The question whether monetary policy should react to financial imbalances in a preemptive fashion was lively debated in the early 2000s. Those in favor advocated ex-ante policy responses which are usually dubbed as "leaning against the wind" (LATW). On the other hand, opponents of the LATW-approach preferred to not react to financial imbalances unless they signal near-term inflationary pressure. If a financial crisis materializes nevertheless, the central bank should mitigate real-economy spillovers with decisive accommodation. The latter strategy is often termed the "mopping-up approach" or "cleaning view," respectively. The Leaning-versus-Cleaning Debate appeared to be settled prior to the crisis: The majority of policymakers and academics agreed on the premise that financial market developments should enter the central bank's reaction

[3] See for instance Bernanke (2007) and Rogoff (2006) for extensive reflections on potential relations between globalization and subdued inflation in advanced countries. On the other hand, Ball (2006) argues that the inflation impact of globalization is transitory at most because declines in the relative price of imports should be offset by price increases in other sectors if central banks target the evolution of a general consumer price index.

[4] Borio et al. (2013, p. 6) state that "[i]t is no coincidence that the financial booms that preceded the recent financial crisis went hand in hand with the globalization of the real side of the world economy and the entry of China and other former communist countries into the global trading system. No doubt this represented a major string of positive supply side shocks."

function only to the extent that they carry some information for the inflation outlook. Bernanke and Gertler (2001, p. 253) summarize this proposition as follows:

> "The inflation-targeting approach gives a specific answer to the question of how central bankers should respond to asset prices: Changes in asset prices should affect monetary policy only to the extent that they affect the central bank's forecast of inflation. To a first approximation, once the predictive content of asset prices for inflation has been accounted for, there should be no additional response of monetary policy to asset-price fluctuations."

The cleaning view is justified by the argument that asset price bubbles or financial imbalances in general are difficult to identify in real time. Even if a bubble is detected, pricking it might require sharp increases in the policy rate which possibly imposes large collateral damage on the broader economy (Posen, 2006). Put differently, the policy rate is too blunt a tool to tackle financial imbalances. Hence, proactively leaning against bubbles should not become a task of the central bank. If at all, financial regulation is in charge to enhance the resilience of the financial system against large swings in asset prices (Bernanke, 2002). Moreover, Svensson (2013) argues that LATW policy is counterproductive as it in fact raises the indebtedness of the private sector. If monetary policy tightens the policy stance to mitigate the build-up of systemic risk, nominal GDP will fall. While tighter policy will discourage agents from accumulating new debt, the existing stock of outstanding debt is likely to respond very sluggishly. Hence, if the stock of outstanding debt remains approximately constant but nominal GDP declines, private sector debt ratios increase.[5] The cleaning view was supported analytically by Bernanke and Gertler (1999, 2001), whose model simulations showed that a policy of aggressive inflation targeting delivers the best outcomes, even in the presence of exogenous asset price bubbles.

The advocates of LATW policy stress that bursting asset price bubbles cause enormous macroeconomic costs so that monetary policy should have a vital interest in ex-ante prevention. While bubbles are indeed difficult to detect, there are nevertheless

5 The argument of Svensson (2013) explicitly refers to the economy of Sweden. By contrast, the VAR analysis in Chapter 9 shows for the US that an unexpected contraction of the policy stance leads to a decline in the measure of private sector leverage (see Figure 9.7). Moreover, it is conceivable that debt ratios rise even more in the absence of a contractionary policy stance. Nevertheless, it has to be admitted that the treatment of debt as an important nominal rigidity is often absent from the discussion of monetary policy transmission. A notable exception is Iacoviello (2005), who shows that inflation-driven redistribution effects between borrowers and lenders amplify demand disturbances but dampen cost-push shocks.

promising indicators that signal substantial asset price misalignments or financial market overheating in general (Borio and Lowe, 2002). Moreover, the argument of unreliable measurement is deemed inconsistent since virtually any relevant variable for practical policymaking is subject to measurement problems, most notably the output gap (Cecchetti et al., 2000). Disyatat (2010) argues that even if bubble identification is subject to uncertainty, monetary policy should still react to mispricing signals. However, this should occur in a gradual and careful fashion, in line with the Brainard Principle. Besides, an asymmetric cleaning approach which lets bubbles unfold but decisively tries to mitigate the consequences of their inevitable collapse may induce moral hazard within the financial sector (Roubini, 2006). Cecchetti et al. (2000) and Filardo (2001, 2004) conducted simulation exercises which demonstrate the optimality of preventive reactions to asset price booms. More recently, Gambacorta and Signoretti (2014) have shown that LATW is beneficial in case of supply shocks, even if the central bank does not have a distinct financial stability objective. My own simulation results obtained in Chapter 10 likewise point to the benefits of LATW policy. Furthermore, as outlined in Section 8.3.2, some authors claim that the very credibility of monetary policy which is necessary to successfully pursue an inflation-targeting approach might have unintended and adverse consequences for financial stability.[6]

As is apparent from the references so far, the leaning-versus-cleaning debate mainly took place in the early 2000s. It therefore stood under the impression of the dotcom-bubble on US stock markets. Indeed, it was mainly centered around the question whether monetary policy should respond to "asset price bubbles." In this respect, experience supported the cleaning view since the recession following the crash of US stock markets had been relatively mild. One possible reason for this is that stock market exposures at the time were debt-financed to a relatively low extent, which left the banking sector more or less unaffected. Of course, the bursting bubble destroyed an enormous amount of private sector wealth, however, it did not trigger widespread defaults on debt obligations. Moreover, the connection between household wealth and aggregate

[6] Another argument for the relevance of asset price inflation has been made by Alchian and Klein (1973). They highlight that a price index should be based on the price of both current and future consumption, given that individuals obtain utility from an intertemporal consumption path. Since prices of future consumption are typically unobservable, asset prices which represent prices of claims on future consumption should be taken into account when constructing a price index. If, other things equal, asset prices rise, future consumption becomes more expensive and the price index rises. If inflation would be measured by such a price index, central banks would respond mechanically to asset price inflation. However, while theoretically appealing, such a price index possibly including highly unstable asset prices would make interest-rate setting by the central bank prohibitively volatile (Goodhart, 2001).

demand is supposedly weak. For instance, Catte et al. (2004) estimate that the marginal propensity to consume out of housing wealth or financial wealth for OECD countries lies consistently below ten percent.

Of course, the experience of the current crisis has revived interest in the question whether monetary policy should lean against the wind. The boom-bust cycle on US housing markets has been fundamentally different from the dotcom-bubble as it was mainly financed with debt. House price collapses made households default on their mortgage payments causing distress in the financial sector, which has evolved into a state of fragility during the pre-crisis years. The subsequent global amplification of financial strains triggered a massive macroeconomic fallout. Hence, the developments during the recent crisis lend some support to the LATW position.

In my view, the focus on the (inevitably fuzzy) concept of asset price bubbles unnecessarily blurred the debate. Indeed, monetary policy should not be in the business of spotting bubbles. Instead, central banks should devote their attention to the emergence of potentially fragile financing schemes of whatever assets, be it stocks, real estate or anything else. Put differently, it is about preventing that assets are financed by excessive leverage. As shown in Section 8.4 and Chapter 10, the short-term interest rate is a powerful tool to affect balance sheet dynamics in the financial sector. Hence, even small changes in policy rates may have large consequences for leverage or, more generally, the total amount of outstanding debt, which renders sharp contractions in order to prick asset price bubbles unnecessary. Importantly, it is not the boom-bust cycle of asset prices per se which inflicts damage to the economy. Instead, it is the painful unwinding of financing schemes which turn out to be unsustainable ex post.[7] This point is illustrated by Brunnermeier and Schnabel (2014), who conduct an extensive historical analysis of asset price bubbles and find that the costs of a bubble do not depend on the particular asset class, but rather on whether it is financed with debt. Woodford (2012, p. 5) puts it as follows:

> "The real issue, I would argue, should not be one of controlling the possible mis-pricing of assets in the marketplace - where the central bank has good reason to doubt whether its judgments should be more reliable than those

7 Koo (2013) has coined the term "balance sheet recession" for a constellation in which the private sector is forced to deleverage after a financial crisis. Deleveraging can only be achieved by an increase in saving activity, which is, however, self-defeating on an aggregate level as it diminishes aggregate demand and hence income ("paradox of thrift").

> of market participants - but rather, one of seeking to deter extreme levels of leverage and of maturity transformation in the financial sector. Once the problem is recast in this way, the relevance of interest-rate policy decisions - whether to exacerbate the problem or to mitigate it - is more obvious."

It is also noteworthy that the claim that interest rate variations are a rather blunt way to influence financial market dynamics has undergone some reconsideration. It is exactly this bluntness of an interest-rate reaction to the build-up of financial imbalances that can be an advantage because it affects the costs of leverage for any entity relying on short-term debt. It is therefore immune against regulatory arbitrage, which constitutes a key improvement over macroprudential measures. In this respect, Stein (2013, p. 17) notes:

> "[W]hile monetary policy may not be quite the right tool for the job, it has one important advantage relative to supervision and regulation - namely that it gets in all of the cracks. The one thing that a commercial bank, a broker-dealer, an offshore hedge fund, and a special purpose ABCP [Asset-Backed Commercial Paper] vehicle have in common is that they all face the same set of market interest rates. To the extent that market rates exert an influence on risk appetite, or on the incentives to engage in maturity transformation, changes in rates may reach into corners of the market that supervision and regulation cannot."

What do these considerations imply for practical policymaking? If monetary policy takes the LATW approach seriously, the objective of preventing the build-up of systemic risk overrules the objective of short-term price stability under the circumstances discussed in Section 11.1. Eichengreen et al. (2011, p. 30) recommend to proceed as follows (emphasis added):

> "Instead of seeking to identify bubbles, the authorities should simply ask whether current financing conditions are raising the likelihood of sharp reversals in asset prices that are disruptive to economic activity. [...] Where the answer to the aforementioned question is yes, central bankers should then lean against the wind using a combination of the tools at their disposal, turning first to nonmonetary micro- and macroprudential tools, but also to

> monetary policy tools when necessary. If this results in periods when, in the interests of financial stability, the central bank sets policies that could result in deviations from its inflation target, *then so be it*."

This view seems to become increasingly embraced by policymakers, as exemplified by the subsequent quotation of FED chairwoman Janet Yellen (2014, pp. 1-2):

> "How should monetary and other policymakers balance macroprudential approaches and monetary policy in the pursuit of financial stability? [...] I believe a macroprudential approach to supervision and regulation needs to play the primary role. [...] I am also mindful of the potential for low interest rates to heighten the incentives of financial market participants to reach for yield and take on risk, and of the limits of macroprudential measures to address these and other financial stability concerns. Accordingly, there may be times when an adjustment in monetary policy may be appropriate to ameliorate emerging risks to financial stability."

It is important, however, to note that the central bank does not target systemic risk in its own right. Monetary policy responds to systemic risk as its build-up poses the threat of negative output gaps and weak inflation in the medium term. In this sense, LATW policy is by no means inconsistent with price-stability orientation. In fact, it extends the safeguarding of price stability to a longer time horizon. For example, Disyatat (2010) stresses that assigning a distinct financial stability objective to central banks is only necessary if macroeconomic implications of financial crises cannot be incorporated in conventional forecasts of inflation and output.

Figure 11.6 tries to illustrate this point by plotting hypothetical paths for inflation and the policy rate under both an LATW and a cleaning-up policy. Suppose that in $t = 2$, systemic risk warning indicators signal the build-up of potentially dangerous financial imbalances which possibly trigger a crisis starting in $t = 6$. LATW policy reacts by raising the policy rate such as to contain systemic risk even though inflation falls below the target value of two percent during that period. If LATW policy successfully contains systemic risk, it can prevent the crisis and inflation is back to target from $t = 6$.[8]

[8] The output gap is omitted from the graph for the sake of simplicity. It is however reasonable to assume that it co-moves with inflation.

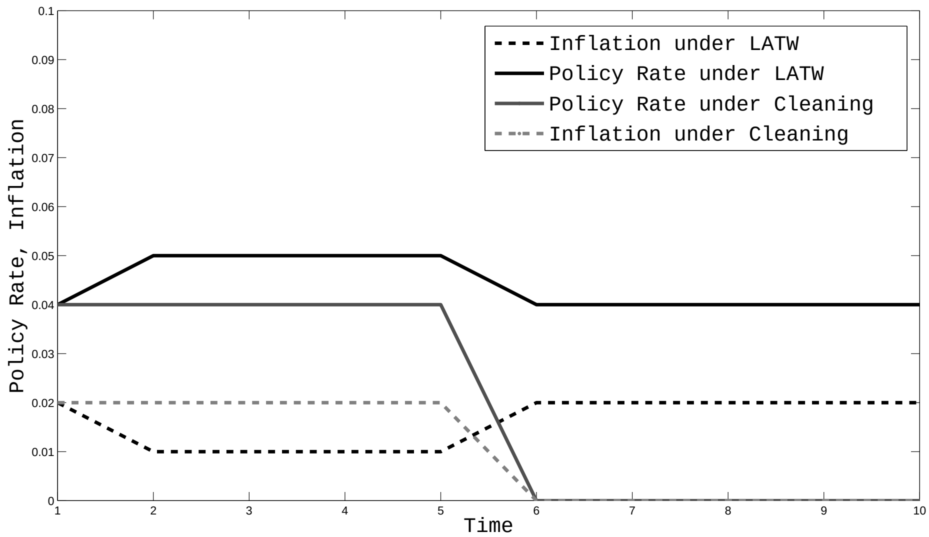


Figure 11.6: *Stylized Paths of Inflation and the Policy Rate*

To the contrary, cleaning-up policy does not react preemptively. If the crisis materializes ex-post, policy rates are cut until the zero-lower bound becomes binding, yet this does not prevent inflation from falling below target.[9] Hence, cleaning-up policy achieves short-term stability at the expense of a later crisis whereas LATW policy sacrifices short-term stability to prevent a future crisis. Giving up on short-term stability makes perfect sense if the medium-term forecast signals significant downside risks to inflation due to a likely materialization of systemic risk. However, incorporating downside risks in the distant future warrants LATW policy responses today, even though macroeconomic conditions appear in line with primary objectives.[10] In a nutshell, LATW policy trades off short-term and medium-term macro stability. Importantly, this trade-off vanishes if macroprudential regulation effectively mitigates medium-term downside risks stemming from systemic risk. In this case, deviating

[9] The risk of reaching the zero-lower bound is an additional argument in favor of LATW. If the real-economy spillovers from a financial crisis are severe, conventional interest rate policy can provide only limited stimulus since nominal rates cannot become negative. Some authors have alternatively proposed higher inflation targets to reduce the risk of such constellations (Ball, 2014; Blanchard et al., 2010).

[10] Note the importance of the forecast horizon in this respect: If the central bank did not account for likely macroeconomic developments after $t = 5$, LATW and cleaning-up policy would be in fact identical.

from the inflation target in the short term would be obsolete. Hence, this example illustrates how ineffective macroprudential regulation creates additional challenges for monetary policy. Technically, insufficient macroprudential regulation shifts the Taylor Curve away from the origin as it forces the central bank to either accept near-term inflation volatility or the build-up of systemic risk associated with future macro-volatility.

11.3 Modeling Leaning-Against-The-Wind Policy

11.3.1 Formal Challenges

Modeling LATW policy in a consistent manner is inherently difficult because it requires the development of a macroeconomic model augmented with a crisis-prone financial sector. Moreover, the vulnerability of the financial sector should be modeled as a (partly) endogenous outcome, ideally due to the presence of systemic externalities (see Chapter 4). Consider the following description of a financial boom-bust cycle given by Fisher (1933, p. 339):

> "[W]hen a debtor gets "broke," or when the breaking of many debtors constitute a "crash," [...] there is no coming back to the original equilibrium. [...] [S]uch a disaster is somewhat like the "capsizing" of a ship which, under ordinary conditions, is always near stable equilibrium but which, after being tipped beyond a certain angle, has no longer the tendency to return to equilibrium, but, instead, a tendency to depart further from it."

It is quite apparent that modeling such processes is hard to accomplish within DSGE models. Most of them are centered around a stationary steady-state with fluctuations only occurring in its neighborhood. Moreover, dynamics are introduced by fundamentally exogenous shocks. There may be frictions within the model which amplify shocks and affect their persistence, yet an endogenous build-up of systemic risk is usually not present. For example, Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) provide fully-fledged DSGE models augmented with a detailed financial sector, yet disruptions to financial intermediation are modeled as conventional exogenous shocks.

However, several authors have proposed methodological innovations which make DSGE models more flexible (albeit at the cost of decreasing tractability). For example, Krishnamurthy and He (2015) provide a model in which systemic risk is captured as an occasional state with the financial sector experiencing binding balance sheet constraints. Moreover, the model features multiple steady states with steady-state values of production and investment considerably lower in the systemic risk state. Brunnermeier and Sannikov (2013, 2014) propose models of a similar type which are capable of endogenously replicating non-linear crisis events and prolonged economic slumps. Importantly, these models are not linearized around the steady-state. Instead, they allow for an analysis of global dynamics. In what follows, I will briefly review the model of Woodford (2012), which captures systemic risk by an endogenous regime-switching mechanism and studies implications for optimal monetary policy.

11.3.2 The Regime-Switching Model of Woodford (2012)

The model of Woodford (2012) abstracts from explicit microfoundations and consists of reduced-form equations describing aggregate demand, aggregate supply and a regime-switching mechanism which allows for an endogenous transition from a "normal" state to a crisis state (and vice versa). The aggregate demand relation reads as follows:

$$y_t - g_t + \chi\Omega_t = E_t[y_{t+1} - g_{t+1} + \chi\Omega_{t+1}] - \sigma[i_t - E_t\pi_{t+1}]. \tag{11.1}$$

The output gap is denoted by y_t and the inflation rate by π_t. Moreover, there is an exogenous demand disturbance g_t, which for instance reflects shocks to government expenditures and i_t corresponds to the market interest rate which can be directly influenced by monetary policy. The variable of particular importance is the credit spread Ω_t which can take two values: If $\Omega_t = \underline{\Omega}$, the credit spread is relatively low which corresponds to the normal state in which financial intermediation operates smoothly. If $\Omega_t = \overline{\Omega}$, the credit spread is high which corresponds to a crisis state in which financial intermediation is severely impaired.[11] When isolating y_t on the left-hand-side of

[11] The model setup loosely relies on Cúrdia and Woodford (2009), which is a fully microfounded DSGE model with a financial sector. It is constructed under the assumption of heterogeneous time preferences within the household sector which implies that patient households lend to impatient ones. By assumption, lending and borrowing takes place via financial intermediaries. The cost of intermediation as well as the possible existence of a risk premium give rise to a credit spread Ω_t. A positive credit spread represents a deadweight loss, since it impedes the provision of consumption to those households who currently value it most. Technically, the credit spread is proportional to the difference in the marginal utility of consumption of impatient and patient households, respectively. With frictionless financial markets, credit would flow to impatient households until marginal utilities are equated (Cúrdia and Woodford, 2009, p. 18).

Equation (11.1), it is apparent that aggregate demand decreases in Ω_t, since a higher credit spread tightens financing constraints for potential borrowers. The same holds on expectation for future values of y_t and Ω_t.

The credit spread endogenously switches between its two possible realizations according to Table 11.2. If the model is in the normal state with $\Omega_t = \underline{\Omega}$, the credit spread switches to the crisis value with probability γ_t or remains on its normal level with probability $1 - \gamma_t$, respectively. In this sense, γ_t can be regarded as the probability of a crisis or, equivalently, as a proxy for systemic risk. If the model has reached the crisis state, the latter persists with probability $1 - \delta$. Transition back to the normal state occurs with probability δ.

	To $\underline{\Omega}$	To $\overline{\Omega}$
From $\underline{\Omega}$	1-γ_t	γ_t
From $\overline{\Omega}$	δ	1-δ

Table 11.2: *Transition Probabilities of the Credit Spread*

The key point is that the crisis probability γ_t is modeled as an endogenous variable. Specifically, γ_t satisfies the conditions $\gamma_t(L_t), \gamma_t^{'}(L_t), \gamma_t^{''}(L_t) > 0$, where L_t is a proxy for leverage within the financial sector. Hence, the crisis probability is strictly convex in L_t and therefore displays a non-linear increase in leverage. The evolution of leverage itself is coupled with economic activity and follows

$$L_t = \rho L_{t-1} + \xi y_t + v_t, \tag{11.2}$$

implying that a positive output gap leads to an increase in leverage, for instance due to the relaxation of balance sheet constraints (as discussed in Section 8.4). Moreover, leverage exhibits persistence and is subject to a stochastic disturbance term v_t.

The aggregate supply relation takes the form of a standard New-Keynesian Phillips Curve, except for the fact that the credit spread enters with a positive sign. This is due to the following mechanism: A rising credit spread hampers the efficient allocation of consumption and decreases the average marginal utility of income across households under reasonable parameter constellations (Woodford, 2012, pp. 10-11). The latter effect increases real wages and hence marginal costs of firms which translates into higher inflation.[12] Hence, the modified New-Keynesian Phillips Curve is given by

$$\pi_t = \kappa_y y_t + \kappa_\Omega \Omega_t + \beta E_t \pi_{t+1} + u_t \tag{11.3}$$

where u_t denotes a cost-push shock. The central bank minimizes the following loss function:

$$\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\pi_t^2 + \lambda_y y_t^2 + \lambda_\Omega \Omega_t^2 \right], \tag{11.4}$$

where steady-state values of (target) inflation and potential output growth have been normalized to zero. The central bank also tries to minimize fluctuations of the credit spread due to its distortionary effect on consumption.[13] Woodford (2012, pp. 31-33) shows that the FOC of optimal monetary policy under commitment is given by

$$\lambda_y y_t - \kappa_y \varphi_t = \beta \rho E_t \{ \lambda_y y_{t+1} - \kappa_y \varphi_{t+1} \} - \beta \xi X_t, \tag{11.5}$$

where φ_t denotes the Lagrange Multiplier associated with the constraint that the Phillips Curve (11.3) imposes on central bank optimization. The variable X_t denotes *marginal crisis risk* and is defined as

$$X_t \equiv \gamma_t'(L_t) \Delta V_{t+1|t} \tag{11.6}$$

where $\Delta V_{t+1|t}$ is the expected increase in future central bank loss conditional on a crisis outbreak. Formally, it holds that

$$\Delta V_{t+1|t} \equiv E\left[V_{t+1} | \Omega_{t+1} = \overline{\Omega} \right] - E\left[V_{t+1} | \Omega_{t+1} = \underline{\Omega} \right]. \tag{11.7}$$

Hence, X_t can be regarded as marginal systemic risk. It is the product of the marginal increase in the crisis probability γ_t for a marginal increase in leverage and the additional

12 The equilibrium real wage in the New-Keynesian model equals the ratio of marginal disutility from supplying labor and the marginal utility of income (see for instance Gali (2008, ch. 2)). If the latter decreases, the real wage consequently rises.

13 Cúrdia and Woodford (2009) show that minimizing (11.4) maximizes social utility in their setup with explicit microfoundations of the credit spread.

central bank loss a crisis produces on expectation.[14] Equation (11.5) indicates that the central bank should lower current output if the marginal crisis risk is high, since leverage as the key driver of the crisis probability varies with the output gap.

The first-order condition can be rearranged to obtain a generalized price-level target criterion (Woodford, 2012, pp. 18-19). It is given by

$$p_t + \phi_y y_t + \phi_X E_t \sum_{T=t}^{\infty} (\beta\rho)^{T-t} E_t X_T = p^* \tag{11.8}$$

with $\phi_X = \beta\xi/\kappa_y$ and $\phi_y = \lambda_y/\kappa_y$. The actual price level is denoted by p_t while p^* is defined as its respective target value. It is useful to rewrite Equation (11.8) in terms of the gap between actual and desired price level:

$$p_t - p^* = -\phi_y y_t - \phi_X E_t \sum_{T=t}^{\infty} (\beta\rho)^{T-t} E_t X_T. \tag{11.9}$$

The central bank tolerates deviations from the target price level for two reasons: First, if the output gap becomes negative (positive), the policy stance is relaxed (tightened) to smooth output fluctuations at the expense of deviating from p^*. By recalling that $\phi_y = \lambda_y/\kappa_y$, it becomes apparent that the willingness to accept price level deviations for the sake of output stabilization positively depends on λ_y, which is the weight placed on output stabilization in the loss function (11.4). Moreover, the central bank allows the price level to decline below target if the sum of current and discounted future marginal crisis risks $E_t \sum_{T=t}^{\infty} (\beta\rho)^{T-t} E_t X_T$ increases. A switch of the credit spread to its crisis value has two unfavorable implications: It depresses the output gap and raises inflation. In that sense, its effects on the economy are akin to a cost-push shock. However, the credit spread may remain elevated for a prolonged period of time, conditional on δ, which is the transition probability back to the normal state. It is therefore reasonable to assume that the adverse effects of a crisis are more persistent than a cost-push shock.

The expectation of persistently negative output gaps and inflationary pressure creates the case for LATW policy similar to the stylized example given in Figure 11.6. The central bank will tighten the policy stance with an increase in X_t, such that the price level temporarily undershoots p^* and the output gap declines. According to Equation

[14] Note that this definition of systemic risk corresponds closely to the definition of systemic risk as the expected cost of a financial crisis (see Section 2.1).

(11.2), the latter effect reduces leverage in the financial system and hence the crisis probability. Generally, the magnitude of the policy response depends on the expected loss of a crisis $\Delta V_{t+1|t}$ as well as on the degree of leverage in the financial system. Since γ_t is assumed to be a strictly convex function, $\gamma_t^{'}(L_t)$ increases in leverage, implying that monetary policy tightens the policy stance if leverage exceeds its "normal" level.

Hence, the model provides a relatively tractable and insightful formalization of LATW policy. However, this comes at the cost of considerable simplification. First, given the lack of a microfounded financial sector, the build-up of leverage is not modeled explicitly. Second, it would be interesting to incorporate other drivers of crisis probabilities, for instance measures of liquidity mismatches and, most importantly, the policy rate such as to capture the risk-taking channel.[15] Third, the transition probability from the crisis back to the normal state could be endogenized as well, for example as being related to the state of financial sector balance sheets. Fourth, the role of macroprudential regulation should be included. Nevertheless, I consider the model to be a useful starting point for further model-based investigations of the LATW approach.

11.4 Policy Adjustments in Practice

11.4.1 Systemic Risk as an Intermediate Target

How should practical policy frameworks be adjusted to incorporate the idea of LATW policy? If it were possible to precisely estimate the impact of systemic risk on future paths of inflation and output, a slight modification of the inflation targeting framework as in Woodford (2012) would be sufficient. If an increase in systemic risk signals risks for output and inflation in the medium-run, the central bank would lean against the wind to contain systemic risk in order to ensure that inflation and output forecasts are in line with their target values.

However, it is difficult (if not impossible) to precisely assess the macroeconomic impact and the timing of a financial crisis. Inflation and output forecasts conditioned on systemic risk are therefore likely to be unreliable. As an alternative, systemic risk could become an *intermediate target* for monetary policy. An intermediate target has to

[15] As an avenue for future research, Woodford (2012, p. 21) proposes to replace L_t with a vector of financial risk factors whose interrelation with crisis risk and macroeconomic variables could be estimated by (yet to be developed) structural econometric models.

satisfy two criteria: First, it needs to be controllable in a reliable manner by the policy instrument. Second, the intermediate target has to display a stable relationship with the ultimate objectives of price and output stability. Both conditions arguably hold true for systemic risk. It can be influenced by the policy rate via the risk-taking channel and empirical evidence shows that the materialization of systemic risk is associated with output losses and declining inflation.

A directly related question is how to define the intermediate target. Systemic risk is a multifaceted phenomenon which cannot be grasped by any single indicator. As described in Section 5.3, there are various systemic risk indicators which appear promising. Especially, credit-to-GDP gaps and Non-Core-Liability aggregates seem to be useful measures. Even slight variations in the policy rate affect the price of short-term debt for any leveraged entity which should profoundly affect balance sheet dynamics in the financial sector and hence these very indicators. By contrast, cross-sectional systemic risk measures are less useful as the policy rate does little to affect the distribution of systemic risk within the financial system. In any case, systemic risk analysis should be guided by a variety of indicators.

De Grauwe and Gros (2009) and Galí (2010) propose to implement LATW policy via a modification of the ECB's two-pillar strategy. In its original form, this strategy includes an economic pillar and a monetary pillar. The economic pillar uses variables on real activity and financial conditions such as wages, commodity prices, capacity utilization and bond yields to assess the short-term inflation outlook whereas the monetary pillar analyzes the development of monetary and credit aggregates to assess medium-term risks to price stability, exploiting the assumed long-run relationship between monetary aggregates and prices. The monetary pillar is regarded as a cross-checking device, verifying whether decisions made according to the economic pillar are in line with medium-term inflation risks. For instance, persistent trend deviations of money growth could signal misperceptions of potential output which may lead to an inflation bias (Beck and Wieland, 2007).[16]

According to De Grauwe and Gros (2009) and Galí (2010), the two-pillar strategy could be modified as follows: The purpose of the monetary pillar has to be changed

16 See ECB (2015) for a more detailed description of the two-pillar strategy. The ECB's reliance on the monetary pillar has been criticized for various reasons. On theoretical grounds, it has been shown that an appropriate interest rule is sufficient to provide a nominal anchor. Given stable money demand, the close correlation of money and prices is therefore a mere equilibrium phenomenon without any distinct informational value. Moreover, it is unclear how the ECB should respond if the two pillars deliver diverging recommendations for the policy stance. See Galí (2010) and the references therein for further elaborations on these points.

from a tool to assess medium-term inflation risks from monetary aggregates to a tool used for systemic risk diagnosis. This *systemic risk pillar* can likewise be used as a cross-checking device, which could signal the need for an upward adjustment of the interest-rate recommendation derived from the economic pillar in the wake of rising systemic risk. Figure 11.7 provides an illustration: Conditional on the available information set, policymakers assess inflation risks posed by economic conditions and systemic risk. Note that the analysis within the systemic risk pillar tends to be of a medium-term horizon, just as it was the case with the monetary pillar. An overall assessment eventually leads to the formulation of the desired policy stance.[17]

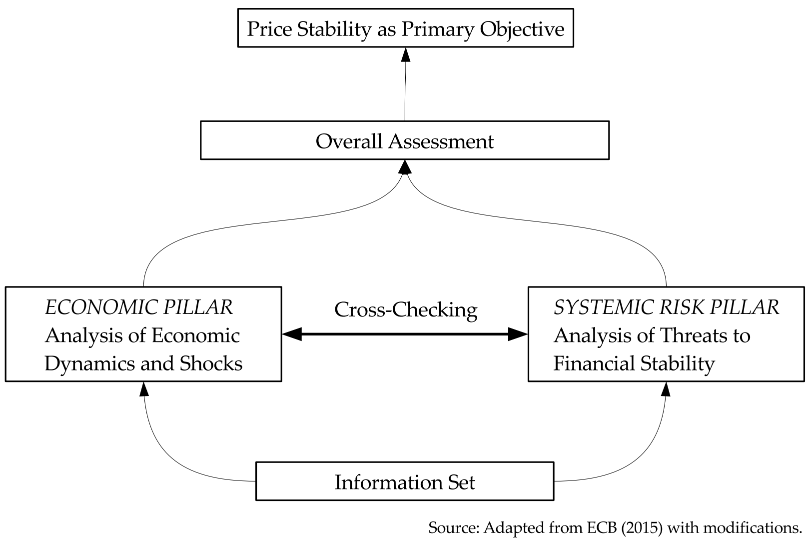


Figure 11.7: *Modified Two-Pillar Strategy*

Of course, some of the general objections held against the two-pillar strategy continue to be relevant. For example, it is questionable whether the two pillars are really

[17] The ECB tended to emphasize that the monetary pillar already acts as a device to track financial imbalances, since credit growth is mirrored in the growth rates of broad money (Issing, 2002). However, the course of events has shown that monitoring monetary aggregates is insufficient to capture the build-up of systemic risk, probably since conventionally defined monetary aggregates track credit expansion within the financial sector only to a limited extent. In that respect, Schularick and Taylor (2012) show that monetary aggregates have little predictive power for future crises, whereas credit aggregates display very promising forecasting abilities.

independent. After all, economic activity and financial market dynamics influence each other via several channels. Hence, it appears implausible to disregard information on economic conditions in systemic risk analysis (and vice versa). Moreover, the question how decisions are made in the case of diverging recommendations for the policy stance is still on the table. Besides that, it is not clear which indicators should be used for systemic risk analysis. This could impede the anticipation and the understanding of policy actions.[18]

11.4.2 Extension of the Instrument Toolkit

Under LATW policy, the short-term interest rate serves the dual purpose to deliver price stability and to contain systemic risk. Section 11.1 provided examples in which such a constellation gives rise to trade-offs between short-term and medium-term inflation variability. Hence, it is natural to ask whether monetary policy can be equipped with a second instrument to account for systemic risk concerns, such that the policy rate can be set in an unconstrained fashion. In fact, there are various proposals for additional policy instruments. Generally, these potential instruments seek to impose a binding quantitative constraint on balance sheet expansion of the financial sector, yet without affecting the use of the policy rate as an instrument for delivering price stability.

Spahn (2010) argues that the policy rate and the money supply can become independent policy tools if the money market is organized as a floor system. In such a setting, the central bank flexibly supplies reserves M at a given policy rate i. Importantly, deposits at the central bank are remunerated at the policy rate as well, such that the policy rate sets a lower bound for money-market rates. It is reasonable to assume that money demand of the banking system is downward-sloping in the policy rate for low levels of M and becomes horizontal afterwards. If money demand is horizontal, the central bank can vary M without any implication for i. Thus, variations in reserves M can be used to affect liquidity conditions in the banking system. For example, if balance sheet expansion leads to an increase in systemic risk, decreasing M tightens liquidity conditions and curbs lending dynamics by imposing a quantitative constraint. Hence, reserve variations can be an independent instrument, potentially usable for systemic risk management. However, this approach may not work if the desired reduction of M

[18] A practical issue is that bank-level data submitted to central banks and supervisory agencies is usually treated as confidential, which effectively rules out that market participants can analyze systemic risk as thoroughly as the central bank.

is large. In this case, reducing M to a great extent may imply that money supply and money demand intersect in the region where money demand is downward-sloping in the interest rate. As a result, the policy rate increases and M and i are no longer independent instruments.

Along similar lines, Stein (2013) points to the use of open-market operations as an additional policy tool. In general, central banks can buy (sell) government bonds or private sector assets, which comes along with an increasing (declining) money supply. More specifically, he discusses the possibility to adjust the *composition* of the central bank balance sheet in response to increasing systemic risk. If the central bank sells short-term assets and simultaneously buys longer-term securities, the yield curve should flatten and the term spread declines. Decreasing term spreads reduce the incentive for maturity transformation or balance sheet expansion in general (see Section 8.4.2). However, the associated price increases in longer-term assets may act as a countervailing effect since they potentially encourage balance sheet expansion due to favorable valuation effects. In my view, it appears more intuitive to sell long-term assets without sterilization, such as to reduce liquidity within the system in conjunction with asset price declines. Such measures could even be targeted at specific sectors. Yet again, the net effect on financial sector risk-taking is unclear, due to the likely rise in the term spread. Moreover, in order to be able to engineer contractionary open market operations, the central bank has to own the respective assets in the first place. That is, the central bank needs to hold a stock of public and possibly also private sector assets as "ammunition." While generally conceivable, this comes along with credit risk exposures and potentially adverse consequences for central bank independence. Moreover, permanent market interventions of the central bank could distort price discovery mechanisms, so that some asset prices no longer exclusively reflect market expectations.

Ashcraft et al. (2011) provide a model which highlights the use of haircuts as a potential policy instrument. As discussed in Section 4.4.2, haircuts represent an important financing constraint for leveraged intermediaries. If the economy is hit by a crisis, central-bank lending against low but prudent haircuts helps stabilizing aggregate demand. Importantly, lowering interest rates is less effective since it does little to ease financing constraints. While the model focuses on managing an actual crisis, its insights can also be applied to potential crisis prevention. Raising haircuts for collateralized central-bank refinancing operations during a boom tightens financing constraints and may therefore restrict balance sheet expansion without relying on policy-rate variations. With respect to the Eurozone, Brunnermeier (2012) advocates the use of country-specific haircuts to account for national differences in business cycles and systemic risk. Alternatively, De Grauwe and Gros (2009) suggest the countercyclical adjustment of minimum reserve requirements. As shown in Section 7.2.4, tightening minimum reserve requirements constrains loan supply which may help to reduce excessive credit growth in the boom phase.

To sum up: There are various additional instruments at the disposal of central banks. They are principally capable to affect quantitative constraints in the financial sector, possibly without influencing the policy rate. Hence, these instruments could be used for systemic risk management such that interest-rate setting can be focused on price stability in an unconstrained manner. However, some of these instruments come along with serious drawbacks. Moreover, their implementation would represent a step into unknown territory and their impact on market outcomes as well as possible unintended consequences are uncertain.

11.4.3 Financial Factors and Output Gap Measurement

An interesting way to systematically incorporate financial factors into monetary policy has been put forward by Borio et al. (2013). They propose to augment measurement procedures for the output gap with financial factors such as credit and property-price growth. Periods characterized by strong financial booms are then associated with higher output gaps than under conventional measurement. If monetary policy reacts to the output gap, for instance in line with a Taylor Rule, it automatically reacts to the build-up of financial imbalances. In this sense, an augmented measure of the output gap provides an elegant way for the implementation of LATW policy which potentially circumvents the problems associated with the modified two-pillar strategy or, more generally, a strategy which relies on systemic risk as an intermediate target.

The authors justify the inclusion of financial variables in output gap measurement as follows: Typically, a constellation in which actual equals potential output is associated with the absence of inflationary pressure. However, potential output should be regarded more broadly as a measure of *sustainable* output. If financial imbalances build up in a low-inflation environment, output may well be on an unsustainable path despite inflation seemingly being on track. The output gap is estimated on a quarterly basis as

$$y_t - y_t^* = \beta(y_{t-1} - y_{t-1}^*) + \gamma_2 \Delta cr_{t-k} + \gamma_3 \Delta ph_{t-k} + \varepsilon_{t,1}, \tag{11.10}$$

where $y_t - y_t^*$ denotes the log difference between actual and potential output, Δcr_{t-k} denotes the deviation of real credit growth from its time-varying mean and Δph_{t-k} denotes the respective mean deviation of house prices. Financial variables are included with a lag of up to $k = 4$ such that the model fit is maximized. Moreover, the lagged value of the output gap is included to account for its persistence. The sample ranges from Q1 1980 to Q4 2012.[19] Hence, unlike with the univariate HP-filter, the output gap is modeled to be driven by additional economic variables. The authors show that financial variables are capable to explain a substantial portion of the cyclical component in output. Importantly, their method produces lower estimates of potential output during booms and consequently higher estimates of the *finance-neutral output gap*, since unusually strong growth rates in credit or property prices signal a potentially unsustainable path for output.

Figure 11.8 compares the finance-neutral output gap with HP-filtered industrial production as a (crude) alternative measure for deviations between actual and potential output for the United States.[20] While both measures show close co-movement in the 1990s, the finance-neutral output gap remains clearly positive in the 2000s, reflecting strong credit and property-price growth. By contrast, HP-filtered industrial production indicated a negative output gap until 2005. After the crisis, the finance-neutral output gap remains persistently negative, which can be explained with subdued credit and house-price dynamics. This can be interpreted as indicating a prolonged slump due to a "balance sheet recession," characterized by deleveraging of the private sector and weak aggregate spending (Koo, 2013).

Relying on such an output-gap measure could have profound implications for monetary policy. Figure 11.9 depicts the actual Federal Funds Rate in comparison with Taylor Rates implied by the output-gap measure based on industrial production (IP) and

[19] Technically, this setup corresponds to a multivariate Hodrick-Prescott filter in state-space form. Potential output growth is modeled to follow a stochastic trend, i.e., $\Delta y_t^* = \Delta y_{t-1}^* + \varepsilon_{t,0}$. It has to hold that the ratio of the variance of the output gap estimate to the variance of the second difference in potential output growth equals 1600, which corresponds to the common smoothing parameter for quarterly data in the univariate HP-filter setup. The estimation is conducted with Bayesian methods. See Borio et al. (2013, pp. 9-11) for details.

[20] I am grateful to Piti Disyatat for sharing data and MATLAB routines to calculate finance-neutral output gaps. Data on industrial production was obtained from FED FRED.

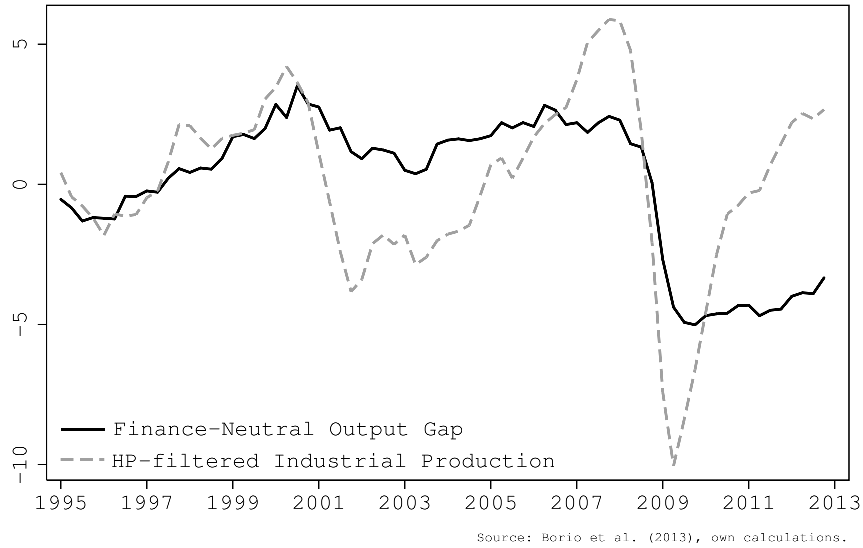


Figure 11.8: *Comparison of Output Gap Measures*

the finance-neutral output gap (FN).[21] While Taylor Rates and the actual Federal Funds Rate moved closely together until 2001, the actual policy rate subsequently declined whereas Taylor Rates remained relatively elevated. While both versions of the Taylor Rate generally indicate that monetary policy was too loose, the Taylor Rate computed with the finance-neutral output gap suggested an even tighter policy stance, being at least one percentage point higher than the IP-based Taylor Rate until 2007.

Hence, the finance-neutral output gap would have called for substantially higher policy rates prior to the crisis, thereby supporting the view of Taylor (2007) who claims that interest rates have been "too low for too long." Moreover, an additional benefit of this output-gap measure is given by its robustness against mis-measurement problems. As shown in Borio et al. (2013), finance-neutral output gap estimates do not differ much when either estimated with available real-time data or ex post for the entire sample.

11.4.4 Coordination of Monetary Policy and Macroprudential Regulation

Monetary policy and macroprudential regulation do not operate in isolation. Variations in the policy stance affect risk-taking within the financial sector. Vice versa, variations

[21] The Taylor Rate i_t^T is computed as: $i_t^T = r^* + \pi^* + 1.5(\pi - \pi^*) + 0.5(y_t - y^*)$ with $r^* = p^* = 2$. Data on CPI inflation was taken from FED FRED.

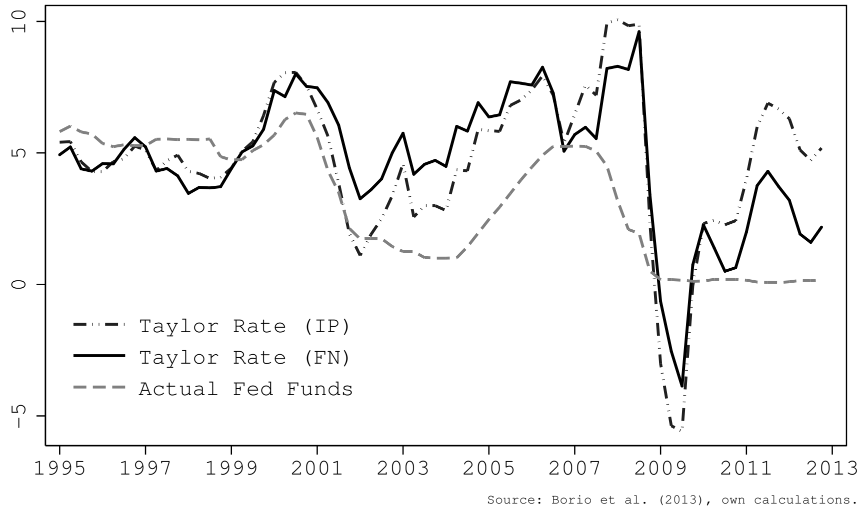


Figure 11.9: *Fed Funds and Counterfactual Taylor Rates*

in macroprudential regulation may influence macroeconomic dynamics via their influence on lending dynamics. In order to simultaneously achieve an optimal degree of macroeconomic and financial stability, both policies should be closely coordinated.

In recent years, several authors have conducted model-based examinations of various coordination schemes.[22] For example, Angelini et al. (2012a) simulate a DSGE-model augmented with banks that are subject to an exogenous capital constraint under different policy frameworks. Monetary policy follows a Taylor-type rule such as to minimize the unconditional variance of output, inflation and the policy rate itself. Its loss function is given by

$$L^{CB} = \sigma_\pi^2 + k_{y,CB}\sigma_y^2 + k_i\sigma_{\Delta i}^2, \tag{11.11}$$

where k_y and k_i denote the weights put on output stabilization and interest-rate smoothing. The macroprudential authority sets the capital constraint for the banking sector such as to minimize the variance of the loan-to-output ratio, the variance of output and the variance of the capital requirement as such. The loan-to-output ratio is regarded as a proxy for the financial cycle. Positive steady-state deviations indicate financial booms and vice versa. The corresponding loss function reads

22 For a detailed overview on the literature, the reader is referred to Angelini et al. (2012b) and the references therein.

$$L^{MP} = \sigma^2_{L/y} + k_{y,MP}\sigma^2_y + k_v\sigma^2_{\Delta v} \tag{11.12}$$

with $\sigma^2_{L/y}$ denoting the variance of the loan-to-output ratio L/y and $\sigma^2_{\Delta v}$ denoting the variance of the capital requirement v. The parameters $k_{y,MP}$ and k_v are the weights put on output stabilization and capital-requirement smoothing.

If policies are coordinated, this amounts to the central bank simultaneously choosing both instruments i and v to minimize the sum of both loss functions L^{CB} and L^{MP}. If policies are non-coordinated, each authority minimizes its own loss function while taking the policy of the other authority as given. The latter arrangement is clearly inefficient, especially if objective variables develop into different directions.

For example, in the wake of an adverse technology shock, output declines while inflation as well as the loan-to-output ratio increase. The central bank relaxes its policy stance to smooth output fluctuations. However, the macroprudential regulator tightens capital requirements due to the increase in the loan-to-output ratio. Hence, the attempt of monetary policy to stabilize aggregate demand is counteracted by the procyclical response of macroprudential regulation. As a result, welfare decreases. By contrast, under coordination the capital requirement is relaxed which enables the policy rate to remain effectively constant. In the case of an adverse shock to banks' capital, inflation, output and the loan-to-output ratio decrease simultaneously. Hence, there is no fundamental conflict between authorities. Coordination generally improves welfare. Specifically, it is shown that the central bank supports stabilization of the financial sector at the expense of slightly higher inflation volatility in the optimum.

Smets (2014) focuses on the game-theoretic interactions between authorities. He similarly shows that policy coordination by minimizing a joint loss function delivers superior results compared to a setup in which each authority pursues its own objective. Under coordination, the central bank reaches its inflation target and the macroprudential authority sets its instrument such as to balance output stability and the risks of debt accumulation within the financial sector. By contrast, if macroprudential policy is modeled to be the Stackelberg leader, welfare declines. Macroprudential policy is set to boost output at the expense of strong debt accumulation within the financial sector by taking into account the reaction function of the central bank. The central bank is then forced to allow inflation to reduce the real debt burden. As a result, an inflation bias emerges in equilibrium.

What do these findings imply for the desired institutional setup in practice? The theoretical results highlighting the benefits of close coordination suggest that the task of macroprudential regulation should be assigned to the central bank. However, such a solution has its drawbacks as well.[23] From an organizational perspective, the delegation of macroprudential supervision to central banks appears reasonable. By nature, central banks are experienced in assessing macroeconomic and macro-financial developments. Moreover, there would be no need for potentially time-consuming exchanges of data and expertise between two different institutional bodies. On the other hand, financial stability objectives are hard to define and therefore difficult to communicate, which could potentially impair central bank credibility. Moreover, a macroprudential mandate implies that central banks have to deal with solvency problems of banks (and potentially even governments). Hence, macroprudential policy has a quasi-fiscal dimension which may raise the issue of the central bank's democratic legitimation. Furthermore, it cannot be ruled out that interest-rate setting becomes influenced by macroprudential concerns. For example, interest rates could be kept too low for too long (from a price-stability perspective) after a financial bust. This problem can be tackled by the implementation of separate decision-making structures and distinct communication channels. All in all, I consider the idea of assigning macroprudential supervision to the central bank to be the most reasonable institutional setup, which, however, has to be implemented with an eye on the aforementioned drawbacks.

The institutional frameworks actually implemented differ between countries. In the United Kingdom, the macroprudential mandate has been assigned to the Bank of England. Hence, both monetary and macroprudential policies are carried out by the central bank. By contrast, the United States have implemented the Financial Stability Oversight Council for the implementation of macroprudential policies. Its voting council consists of the Secretary of the Treasury, the Chairman of the Federal Reserve and various chairpersons of different regulatory agencies. Thus, the central bank's influence on macroprudential regulation in the US is rather limited. An intermediate way is pursued in the Euro Area. Macroprudential regulation is basically carried out on the national level. Nevertheless, the Single Supervisory Mechanism as the newly implemented supranational banking-supervision department of the ECB can decide on macroprudential measures with which national authorities have to comply (see Section 5.2.1).

[23] The following collection of arguments heavily relies on IMF (2013a) and Bundesbank (2015).

Chapter 12

Conclusion and Outlook

In the introduction of my thesis, I have raised two key issues. First, I posed the question whether financial markets are inherently unstable and whether their regulation should be reconsidered. Second, it was asked whether monetary policy should play a more active role in stabilizing financial markets. Taking into consideration the acquired results, I conclude that the first question should be answered positively without qualification. With respect to the second question, I conclude that monetary policy should stabilize financial markets, yet this is mainly due to the deficiencies of financial regulation and should not be regarded as beneficial in its own right.

Systemic risk on financial markets is inefficiently high in the absence of adequate macroprudential regulation. This is strongly suggested by both the approaches stressing limited rationality as well as the ones highlighting the importance of systemic externalities. While I consider systemic externalities as the superior concept, it is nevertheless telling that both approaches reach similar conclusions. If anything, this strengthens the case for appropriate macroprudential regulation. It is also important to note that the endogenous build-up of systemic risk can be reconciled with the notion of rational agents. It is not necessary to depart from mainstream paradigms, except for the fact that the role of externalities needs to be recognized more prominently.

Systemic risk is a multifaceted phenomenon which can be explained by the presence of various forms of systemic externalities. Specifically, banks tend to not internalize the potentially adverse consequences of their interconnectedness. Moreover, choices of business models as well as lending standards may become strategic complements, leaving the financial system with poorly diversified intermediaries and procyclical dynamics of loan supply. Furthermore, individually prudent behavior such as selling assets or hoarding liquidity in crisis states exacerbates systemic stress via fire-sale externalities and the aggravation of aggregate liquidity shortages. Last, the presence of asymmetric information can give rise to the collapse of important market segments due to adverse selection.

In my view, the theoretical case for regulating systemic risk is very convincing. However, bridging the gap between the theoretical analysis of systemic risk and practical macroprudential policymaking remains challenging. Given the stylized nature of most of the theoretical models, policy conclusions are primarily of a qualitative nature. Hence, the conduct of macroprudential policy is guided by a mix of qualitative theoretical prescriptions, mostly non-structural techniques to measure systemic risk and a considerable amount of discretion based on supervisory judgment. Thus, the development of empirically applicable systemic risk models which incorporate systemic externalities in their various forms appears to be an important avenue for future research.

Especially, more sophisticated models could further substantiate the claim that macroprudential regulation in its current form is insufficient. The key concern is that financial intermediaries are still allowed to operate with excessive leverage. Moreover, it is highly doubtful if countercyclical macroprudential measures will be applied with sufficient rigor, especially when taking into account political constraints. It would be highly desirable to increase the structural resilience of the financial sector by imposing substantially higher capital requirements. They have the particular benefit of being capable to internalize several forms of systemic externalities at the same time. Liquidity requirements and restrictions on activities as well as on the composition of assets and liabilities of financial intermediaries can serve as important complements. Moreover, increasing structural resilience decreases the need for countercyclical measures, which are difficult to calibrate and probably politically infeasible. However, the current state of macroprudential regulation offers little reason for being optimistic. In its current form, it can hardly mitigate systemic risk in an effective manner.

This intermediate result carries direct implications for the second key question of whether monetary policy should play a more active role in financial market stabilization. Given insufficient macroprudential regulation, systemic risk becomes a concern for central banks due to its potential of causing adverse spillovers to the real economy in the crisis case. On the other hand, the policy stance affects the level of systemic risk via the risk-taking channel of monetary policy transmission. The theoretical and empirical examination of the latter reveals that a looser policy stance leads the financial sector to take more credit risk, to lower required risk compensation, to increase its reliance on unstable short-term funding and to increase its leverage. Yet the mere fact that monetary policy is capable to influence systemic risk does not imply that this is beneficial per se. There are various constellations under which short-term macroeconomic stability and medium-term financial stability considerations may call for a different policy stance. In such cases, monetary policy either needs to accept short-term deviations of inflation and output from their respective target values or an increase in systemic risk. Hence, burdening monetary policy with systemic risk management can give rise to an increase in macroeconomic volatility. Yet this policy arrangement seems unavoidable, given the insufficiency of macroprudential regulation. Put bluntly, I consider leaning-against-the-wind policy as a necessary evil resulting from the inability of financial regulation to tackle systemic risk at the source. Generally, the crisis forced central banks into the role of a "policymaker of last resort," which poses long-term challenges for their independence and the priority of price stability. In the Euro Area, the ECB has been burdened with additional implicit objectives such as easing fiscal pressure on southern member states and alleviating the vicious circle between declines in government solvency and systemic stress in the financial sector. At the same time, significant measures to fix the inherent flaws of the EMU are still lacking to a great extent. Therefore, it has to be doubted whether the ECB will regain the independence associated with its clear-cut price stability objective prior to the crisis.

If one accepts that macroprudential regulation in its current form has its deficiencies, the question is how to incorporate systemic risk considerations into the strategy of monetary policy. It seems most natural to define systemic risk as an intermediate target and to base its measurement on a variety of different indicators. Hence, short-term macroeconomic analysis should be complemented with an analysis of medium-term threats to financial stability. If systemic risk builds up, the policy stance should be tightened, even if this amounts to sacrificing short-term macroeconomic stability. The modification of the ECB's two-pillar strategy by changing the purpose of the monetary pillar into a tool for systemic risk diagnosis appears to be a promising framework in this respect. An interesting alternative is to incorporate the stage of the financial cycle into output gap measures, which would yield an automatic reaction to financial imbalances without the disadvantages of an intermediate target approach. Moreover, there are various proposals to equip monetary policy with a second instrument, which would enable central banks to use the policy rate for macroeconomic stabilization and the second instrument for systemic risk management.

Several of the aforementioned aspects deserve further research in the future. For instance, the exploration of the risk-taking channel and the mechanisms linking the policy stance to financial risk-taking is still at an early stage. So far, there are only few examples of models explicitly embedding the risk-taking channel into a fully-fledged macro-financial setup. However, it would be highly informative for policymakers to be able to rely on more detailed and empirically applicable models of the risk-taking channel. Moreover, it is desirable to merge the modeling of the risk-taking channel with a rigorous representation of systemic externalities. Besides, it is equally important to pursue further research on optimal monetary policy in a leaning-against-the-wind context to provide policymakers with additional guidance on how to optimally trade-off short-term price stability and medium-run systemic risk management. Likewise, a more detailed analysis of the potential risks and benefits of conceivable additional instruments is necessary. In addition, the interaction between monetary policy and macroprudential supervision should be scrutinized in more detail. Especially the macroeconomic effects of a change in the macroprudential policy stance and its implications for monetary policy deserve closer theoretical and empirical examination. All in all, it can be conjectured that the question of how to optimally incorporate financial stability considerations into monetary policy frameworks will be a significant part of the future research landscape.

Part III

Appendix

Appendix A

Selected Proofs and Derivations

A.1 Acharya-Santos-Yorulmazer Model

Equation (4.12) in the main text can be obtained by rearranging Equation (4.11).

$$\begin{aligned}
q_d &= \alpha(1-\alpha)(1-p_{SF}) + (1-\alpha)^2(1-p_{FF}) \\
&= (\alpha-\alpha^2)(1-p_{SF}) + (1-2\alpha+\alpha^2)(1-p_{FF}) \\
&= \alpha-\alpha^2-\alpha p_{SF}+\alpha^2 p_{SF}+1-2\alpha+\alpha^2-p_{FF}+2\alpha p_{FF}-\alpha^2 p_{FF} \\
&= 1-\alpha+2\alpha p_{FF}-p_{FF}+\alpha^2 p_{SF}-\alpha p_{SF}-\alpha^2 p_{FF} \\
&= 1-\alpha+\alpha p_{FF}-p_{FF}+\alpha p_{FF}-\alpha p_{SF}+\alpha^2 p_{SF}-\alpha^2 p_{FF} \\
&= (1-\alpha)(1-p_{FF})-\alpha(p_{SF}-p_{FF})+\alpha^2(p_{SF}-p_{FF}) \\
&= (1-\alpha)(1-p_{FF})+(\alpha^2-\alpha)(p_{SF}-p_{FF}) \\
&= (1-\alpha)(1-p_{FF})+\alpha(\alpha-1)(p_{SF}-p_{FF}) \\
&= (1-\alpha)(1-p_{FF})-\alpha(1-\alpha)(p_{SF}-p_{FF})
\end{aligned} \tag{A.1}$$

Finally, since Equation (4.10) implies that $q_s = (1-\alpha)(1-p_{FF})$, it holds that

$$q_d = q_s - \alpha(1-\alpha)(p_{SF}-p_{FF}) \tag{A.2}$$

which replicates Equation (4.12) in the main text.

A.2 Fire-Sale Model of Stein

The social utility function (4.36) in the main text is obtained in several steps (Stein, 2012, p. 17). First, it is assumed that households have a fixed endowment of Y, from which I is allocated to banks and W to patient outside investors. Therefore it holds that

$$C_0 = Y - I - W. \tag{A.3}$$

Expected consumption in $t = 2$ is given by

$$E(C_2) = p(f(I) + g(W)) + (1-p)(\lambda I + g(W - M) + M). \tag{A.4}$$

In the good state with probability p, projects by banks and POIs deliver steady payoffs and consumers receive the proceeds $f(I) + g(W)$. In the bad state occurring with probability $(1-p)$, investment projects by banks only make λI on expectation. Moreover, households receive M and the payoff $g(W - M)$ from outside investor projects. The latter decrease in M since outside investors partly acquire bank projects instead of investing in their own projects. Recall that Equation (4.27) defines household utility as

$$U = C_0 + \beta E(C_2) + \gamma M. \tag{A.5}$$

Substituting for C_0 and C_2 yields

$$\begin{aligned} U = {} & Y - I - W \\ & + \beta\Big(p(f(I) + g(W)) + (1-p)(\lambda I + g(W - M) + M)\Big) \\ & + \gamma M \end{aligned} \tag{A.6}$$

In a last step, Y can be dropped as it is a constant. Moreover, each term is multiplied with $R^B = 1/\beta$ to express utility uniformly in terms of consumption in $t = 2$. This yields

$$\begin{aligned} U = {} & -R^B I - R^B W \\ & + \Big(p(f(I) + g(W)) + (1-p)(\lambda I + g(W - M) + M)\Big) \\ & + \gamma R^B M \end{aligned} \tag{A.7}$$

Recall that $R^B = 1/\beta$ and $R^M = 1/(\beta + \gamma)$. A last rearrangement step is then to express γR^B as follows:

$$\begin{aligned}\gamma R^B &= \frac{\gamma}{\beta} = \frac{\beta + \gamma - \beta}{\beta} \\ &= \frac{\frac{1}{\beta} - \frac{1}{\beta+\gamma}}{\frac{1}{\beta+\gamma}} \\ &= \frac{R^B - R^M}{R^M}.\end{aligned} \tag{A.8}$$

Collecting terms gives

$$\begin{aligned}U = \{pf(I) + (1-p)\lambda I - IR^B\} + M\frac{(R^B - R^M)}{R^M} \\ pg(W) + (1-p)\{g(W-M) + M\} - WR^B,\end{aligned} \tag{A.9}$$

which corresponds to the social utility function (4.36) in the main text.

Derivation of the FOCs for the Social Planner

The social planner likewise has to account for the collateral constraint $m \leq \frac{k\lambda}{R^M}$. The Lagrangian $\mathscr{L}^P$ reads as follows:

$$\begin{aligned}\mathscr{L}^P = \{pf(I) + (1-p)\lambda I - IR^B\} + M\frac{(R^B - R^M)}{R^M} \\ pg(W) + (1-p)\{g(W-M) + M\} - WR^B - \eta^P(m - \frac{k\lambda}{R^M}),\end{aligned} \tag{A.10}$$

where η^P henceforth denotes the Lagrange Multiplier of the social planner problem. First, the FOC with respect to m is derived. For that purpose, it needs to be recalled that $M = mR^M I$. Moreover, the social planner endogenizes the fire sale discount, such that

$$k = \frac{1}{g'(W-M)} = \frac{1}{g'(W - mR^M I)} \tag{A.11}$$

which again clarifies that the fire sale discount is actually a function of M, i.e., the reliance on short-term debt. The Lagrangian can consequently be rewritten as follows:

$$\begin{aligned}\mathscr{L}^P = \{pf(I) + (1-p)\lambda I - IR^B\} + mI(R^B - R^M) + pg(W) \\ + (1-p)\{g(W - mR^M I) + mR^M I\} - WR^B \\ - \eta^P(m - \frac{\lambda}{R^M}\frac{1}{g'(W - mR^M I)}).\end{aligned} \tag{A.12}$$

Taking the FOC with respect to m gives

$$\begin{aligned}\frac{\partial \mathscr{L}^P}{\partial m} &= I(R^B - R^M) + (1-p)R^M I - (1-p)g'(W - mR^M I)R^M I \\ &- \eta^P + \eta^P \frac{\lambda}{R^M}\frac{g''(W - mR^M I)R^M I}{\Big(g'(W - mR^M I)\Big)^2} = 0.\end{aligned} \tag{A.13}$$

The term $(1-p)R^M I - (1-p)g'(W - mR^M I)R^M I$ can be written more compactly as follows:

$$\begin{aligned}&(1-p)R^M I - (1-p)g'(W - mR^M I)R^M I \\ &= (1-p)I(R^M - g'(W - mR^M I)R^M) \\ &= (1-p)I(R^M - \frac{1}{k}R^M) \\ &= (1-p)I(R^M \frac{k-1}{k}) \\ &= -(1-p)I\frac{1-k}{k}R^M.\end{aligned} \tag{A.14}$$

For a last step, recall that the net excess return for patient investors was defined as $z = (1-k)/k$, which allows to simplify notation further to

$$-(1-p)IzR^M. \tag{A.15}$$

Hence, the FOC can be finally simplified to

$$I\{(R^B - R^M) - (1-p)zR^M\} = \eta^P(1 - \frac{g''(\cdot)}{(g'(\cdot))^2}\lambda I) \tag{A.16}$$

which corresponds to (4.38) in the main text. Taking the FOC with respect to I yields

$$\begin{aligned}\frac{\partial \mathscr{L}^P}{\partial I} &= pf'(I) + (1-p)\lambda - R^B + m(R^B - R^M) \\ &+ (1-p)mR^M - (1-p)g'(W - mR^M I)R^M m \\ &+ \eta^P \frac{\lambda}{R^M} \frac{g''(W - mR^M I)R^M m}{\Big(g'(W - mR^M I)\Big)^2} = 0\end{aligned} \tag{A.17}$$

Akin to the former derivation, the term $(1-p)mR^M - (1-p)g'(W - mR^M I)R^M m$ can be rewritten to $-(1-p)mzR^M$. Hence the FOC simplifies to

$$pf'(I) + (1-p)\lambda - R^B + m(R^B - R^M) - (1-p)mzR^M = -\eta^P \frac{g''(\cdot)}{\Big(g'(\cdot)\Big)^2}\lambda m \tag{A.18}$$

which is (4.39) in the main text.

A.3 Disyatat Model

The Optimal Demand for Labor and Loans by the Firm

Expected profits are

$$\Pi^e = \theta(PN^\beta - (1 + r_L)P_N N) \tag{A.19}$$

and firms maximize profits by optimally choosing N. Differentiation of Π^e with respect to N:

$$\frac{\partial \Pi^e}{\partial N} = \beta\theta PN^{\beta-1} - \theta(1 + r_L)P_N = 0 \tag{A.20}$$

Simplification gives

$$\beta PN^{\beta-1} = (1 + r_L)P_N \tag{A.21}$$

$$N^{\beta-1} = \frac{(1+r_L)P_N}{\beta P} \tag{A.22}$$

$$N = \left(\frac{(1+r_L)P_N}{\beta P}\right)^{\frac{1}{\beta-1}} \tag{A.23}$$

$$N = \left(\frac{\beta P}{(1+r_L)P_N}\right)^{\frac{1}{1-\beta}} \tag{A.24}$$

Nominal loan demand $L^D = P_N N$ equals the nominal wage bill.

Rearrangement of the Household Indifference Condition

Equation (7.23) is derived as follows: It starts from Equation (7.22) which is

$$(1+r_f)L = x(1+R)L + (1-x)(\psi^e - cL) \tag{A.25}$$

As a first step, x is substituted out with by using Equation (7.19), which implies that $x = 1-(1-\theta)q$.

$$\begin{aligned}(1+r_f)L &= (1-(1-\theta)q)(1+R)L + (1-\theta)q(\psi^e - cL) \\ &= (1+R)L - (1-\theta)q(1+R)L + (1-\theta)q(\psi^e - cL) \\ &= (1+R)L + (1-\theta)q\left[\psi^e - cL - (1+R)L\right]\end{aligned} \tag{A.26}$$

As shown in Disyatat (2011, pp. 720), ψ^e is can be expressed as

$$\psi^e = \omega\left[1 + \frac{\int_{\underline{u}}^{u^*} ug(u)du}{G(u^*)}\right] \tag{A.27}$$

where $g(u)$ is the density function of u, and $G(u)$ denotes the cumulative distribution function of u.[1] It can be exploited that $G(u^*) = \Pr(u < u^*) = q$ to obtain

[1] Expanding the integral and subsequent simplification gives (7.21) in the main text. In general, the probability density function of a continuous random variable u which is uniformly distributed over some interval $[\underline{u}, \overline{u}]$ is given by $g(u) = \frac{1}{\overline{u}-\underline{u}}$. The cumulative distribution function at some point u^* is given by $\frac{u^*-\underline{u}}{\overline{u}-\underline{u}}$. See for instance Balakrishnan and Nevzorov (2004, pp. 107).

$$\psi^e = \omega\left[1 + \frac{\int_{\underline{u}}^{u^*} ug(u)du}{q}\right]. \tag{A.28}$$

Plugging (A.28) into (A.26) gives

$$\begin{aligned}(1+r_f)L &= (1+R)L - (1-\theta)qcL \\ &+ (1-\theta)q\left[\omega\left(1+\frac{1}{q}\int_{\underline{u}}^{u^*} ug(u)du\right) - (1+R)L\right]\end{aligned} \tag{A.29}$$

which completes the first step of rearrangement. Equation (7.17) in the main text implies that $(1+R)L = \omega u^* + \omega$. This expression is used to rearrange the last term of the right-hand-side of (A.29) as follows:

$$\begin{aligned}&(1-\theta)q\left[\omega\left(1+\frac{1}{q}\int_{\underline{u}}^{u^*} ug(u)du\right) - (1+R)L\right] \\ &= (1-\theta)q\left[\omega\left(1+\frac{1}{q}\int_{\underline{u}}^{u^*} ug(u)du\right) - \omega u^* - \omega\right] \\ &= (1-\theta)q\omega\left[\frac{1}{q}\left(\int_{\underline{u}}^{u^*} ug(u)du\right) - u^*\right] \\ &= (1-\theta)\omega\left[\left(\int_{\underline{u}}^{u^*} ug(u)du\right) - u^*q\right]\end{aligned} \tag{A.30}$$

Since $q = G(u^*) = \int_{\underline{u}}^{u^*} g(u)du$, a further simplification is given by

$$\begin{aligned}&(1-\theta)\omega\left[\left(\int_{\underline{u}}^{u^*} ug(u)du\right) - u^*q\right] \\ &= (1-\theta)\omega\left[\int_{\underline{u}}^{u^*} ug(u)du - u^*\int_{\underline{u}}^{u^*} g(u)du\right] \\ &= (1-\theta)\omega\left[\int_{\underline{u}}^{u^*} (u-u^*)g(u)du\right]\end{aligned} \tag{A.31}$$

Equation (A.31) can be simplified further if the integral is expanded. Note that the density function of u is $g(u) = \frac{1}{\overline{u}-\underline{u}}$.

$$
\begin{aligned}
&(1-\theta)\omega\left[\int_{\underline{u}}^{u^*}(u-u^*)g(u)du\right] \\
&= (1-\theta)\omega\left[\int_{\underline{u}}^{u^*}ug(u)du - \int_{\underline{u}}^{u^*}u^*g(u)du\right] \\
&= (1-\theta)\omega\left(\left[\frac{1}{2}\frac{1}{\overline{u}-\underline{u}}u^2\right]_{\underline{u}}^{u^*} - \left[\frac{1}{\overline{u}-\underline{u}}u^*u\right]_{\underline{u}}^{u^*}\right) \\
&= (1-\theta)\omega\left[\frac{1}{2}\frac{1}{\overline{u}-\underline{u}}u^{*2} - \frac{1}{2}\frac{1}{\overline{u}-\underline{u}}\underline{u}^2 - \frac{1}{\overline{u}-\underline{u}}u^{*2} + \frac{1}{\overline{u}-\underline{u}}u^*\underline{u}\right] \qquad \text{(A.32)} \\
&= -\frac{1}{2}(1-\theta)\omega\left[\frac{1}{\overline{u}-\underline{u}}u^{*2} + \frac{1}{\overline{u}-\underline{u}}\underline{u}^2 - \frac{1}{\overline{u}-\underline{u}}2u^*\underline{u}\right] \\
&= -\frac{1}{2}(1-\theta)\omega\frac{1}{\overline{u}-\underline{u}}\left[u^{*2} - 2u^*\underline{u} + \underline{u}^2\right] \\
&= -\frac{1}{2}(1-\theta)\omega\frac{(u^*-\underline{u})^2}{\overline{u}-\underline{u}}
\end{aligned}
$$

In a last step, $q = G(u^*) = \frac{u^*-\underline{u}}{\overline{u}-\underline{u}}$ allows to write

$$-\frac{1}{2}(1-\theta)\omega\frac{(u^*-\underline{u})^2}{\overline{u}-\underline{u}} = -\frac{1}{2}(1-\theta)\omega(\overline{u}-\underline{u})q^2 \qquad \text{(A.33)}$$

Taking this term back to (A.29) yields

$$(1+r_f)L = (1+R)L - (1-\theta)cqL - \frac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}q^2 \qquad \text{(A.34)}$$

Rearranging terms gives

$$\frac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}q^2 + (1-\theta)cqL - (1+R)L + (1+r_f)L = 0 \qquad \text{(A.35)}$$

Using $(1+R)L = \omega u^* + u^*$ once more yields

$$\frac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}q^2 + (1-\theta)cqL - \omega u^* - \omega + (1+r_f)L = 0 \qquad \text{(A.36)}$$

Finally, using $u^* = q(\overline{u}-\underline{u}) + \underline{u}$ from Equation (7.18) delivers Equation (7.23) in the main text:

$$
\begin{aligned}
&\frac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}q^2 + (1-\theta)cqL - \omega u^* - \omega + (1+r_f)L \\
&= \frac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}q^2 + (1-\theta)cqL - \omega(q(\overline{u}-\underline{u}) + \underline{u}) - \omega + (1+r_f)L \\
&= \frac{(1-\theta)\omega(\overline{u}-\underline{u})}{2}q^2 + \left[(1-\theta)cL - \omega(\overline{u}-\underline{u})\right]q - \omega(1+\underline{u}) + (1+r_f)L \\
&= 0
\end{aligned}
\tag{A.37}
$$

From this expression, one can finally infer the critical loan quantities L_L and L_H, as it is outlined in the main text.

Derivation of the Loan-Supply Schedule

The loan-supply schedule has to be specified for three constellations, namely $q = 0$, $q = 1$ and $0 < q < 1$. For this purpose, Equations (7.20) and (7.22), which have to be jointly satisfied in equilibrium, are used to solve for the loan rate $(1 + r_L)$. Recall that (7.20) and (7.22) are the zero-profit condition for banks and the indifference condition for households, respectively, and are given by

$$\theta(1+r_L)L = x(1+R)L + (1-x)\psi^e \tag{A.38}$$

$$(1+r_f)L = x(1+R)L + (1-x)(\psi^e - cL) \tag{A.39}$$

Case 1 (L $\leq L_L$) : q = 0 $\Leftrightarrow x = 1$

If $x = 1$, (A.38) simplifies to

$$\theta(1+r_L)L = (1+R)L \tag{A.40}$$

Equivalently, (A.39) becomes

$$(1+r_f)L = (1+R)L \tag{A.41}$$

Substitution and eliminating L yields

$$(1 + r_L) = \frac{1 + r_f}{\theta} \tag{A.42}$$

implying that for $q = 0$ and hence $L \leq L_L$ credit is supplied elastically at the loan rate depicted in (A.42).

Case 2 ($\mathbf{L}_L < L < L_H$) : 0 < q < 1 $\Leftrightarrow x = 1 - q + \theta q$

If $x = 1 - q + \theta q$, (A.38) transforms to

$$\theta(1 + r_L)L = (1 - q + \theta q)(1 + R)L + (q - \theta q)\psi^e \tag{A.43}$$

and (A.39) consequently reads

$$(1 + r_f)L = (1 - q + \theta q)(1 + R)L + (q - \theta q)(\psi^e - cL) \tag{A.44}$$

Merging (A.43) and (A.44) yields

$$\begin{aligned}
\theta(1 + r_L)L - (q - \theta q)\psi^e &= (1 + r_f)L - (q - \theta q)(\psi^e - cL) \\
\theta(1 + r_L)L &= (1 + r_f)L + (q - \theta q)cL \\
(1 + r_L) &= \frac{1 + r_f}{\theta} + \frac{c(1 - \theta)}{\theta} q
\end{aligned}$$

implying that for $L_L < L < L_H$ the loan rate increases in q (and thus in L), i.e. the loan supply curve becomes positively sloped.

Case 3 ($\mathbf{L} \geq L_H$) : q =1 $\Leftrightarrow x = \theta$

If $q = 1$, the bank defaults with certainty if the borrower firm defaults. Hence, the repayment probability x of the bank is equal to θ, the repayment probability of the firm. If $x = \theta$, (A.38) and (A.39) are given by

$$\theta(1 + r_L)L = \theta(1 + R)L + (1 - \theta)\psi^e \tag{A.45}$$

$$(1 + r_f)L = \theta(1 + R)L + (1 - \theta)(\psi^e - cL) \tag{A.46}$$

and by substitution, one obtains

$$(1 + r_L) = \frac{1 + r_f}{\theta} + \frac{(1 - \theta)c}{\theta} \tag{A.47}$$

from which it follows that loan supply again becomes horizontal at the rate specified in (A.47). Please see the main text for a detailed interpretation in conjunction with a graphical exposition.

A.4 Dell'Arricia-Marquéz Model

Monitoring Decision

The level of monitoring in (8.53) is obtained as follows: Optimal monitoring is given by (8.52), which is

$$\hat{q} = \frac{R - r_D(1 - k)}{c} \tag{A.48}$$

Since rational depositors form model-consistent expectations $E(q|k) = \hat{q}$, the deposit rate can be substituted out by using $r_D = \frac{r^*}{\hat{q}}$. This yields

$$\hat{q} = \frac{R - \frac{r^*}{\hat{q}}(1 - k)}{c} \tag{A.49}$$

which subsequently needs to be solved for $\hat{q}$.

$$\begin{aligned}
\hat{q} &= \frac{R - \frac{r^*}{\hat{q}}(1 - k)}{c} \\
0 &= c\hat{q} - R + \frac{r^*}{\hat{q}}(1 - k) \\
0 &= c\hat{q}^2 - R\hat{q} + r^*(1 - k)
\end{aligned} \tag{A.50}$$

Taking roots of the quadratic equation gives two solutions

$$\hat{q}_1 = \frac{1}{2c}\left(R + \sqrt{R^2 - 4cr^*(1-k)}\right) \tag{A.51}$$

$$\hat{q}_2 = \frac{1}{2c}\left(R - \sqrt{R^2 - 4cr^*(1-k)}\right) \tag{A.52}$$

As explained in the main text, $\hat{q}_1$ is chosen as the relevant solution.

Optimal Leverage

The optimal capital structure as depicted by $\hat{k}$ in (8.56) is derived in several steps. First, Bank profits conditional on the choice of the capital structure k are written as

$$\begin{aligned}
\Pi &= \left(\hat{q}(R - r_D(1-k)) - (r^* + \varepsilon)k - \frac{1}{2}c\hat{q}^2\right)L \\
&= \left(\hat{q}(R - \frac{r^*}{\hat{q}}(1-k)) - (r^* + \varepsilon)k - \frac{1}{2}c\hat{q}^2\right)L \\
&= \left(\hat{q}R - r^* + r^*k - r^*k - k\varepsilon - \frac{1}{2}c\hat{q}^2\right)L \\
&= \left(\hat{q}R - r^* - k\varepsilon - \frac{1}{2}c\hat{q}^2\right)L
\end{aligned} \tag{A.53}$$

which corresponds to (8.54) in the main text. Plugging in the expression for equilibrium monitoring yields

$$\begin{aligned}
\Pi &= \left[\frac{1}{2c}\left(R + \sqrt{R^2 - 4cr^*(1-k)}\right)R - r^* - k\varepsilon \right.\\
&\quad \left. - \frac{1}{8c}\left(R + \sqrt{R^2 - 4cr^*(1-k)}\right)^2\right]L \\
&= \left[\frac{1}{2c}R^2 + \frac{1}{2c}R\sqrt{R^2 - 4cr^*(1-k)} - r^* - k\varepsilon \right.\\
&\quad \left. - \frac{1}{8c}\left(R^2 + 2R\sqrt{R^2 - 4cr^*(1-k)} + R^2 - 4cr^*(1-k)\right)\right]L
\end{aligned} \tag{A.54}$$

Now, taking the derivative with respect to k gives

$$\begin{aligned}\frac{\partial \Pi}{\partial k} &= \Bigg(r^* R \frac{1}{\sqrt{R^2 - 4cr^*(1-k)}} - \varepsilon \\ &- \frac{1}{2} r^* R \frac{1}{\sqrt{R^2 - 4cr^*(1-k)}} - \frac{1}{2} r^* \Bigg) L \\ &= \left(r^* R \frac{1}{2\sqrt{R^2 - 4cr^*(1-k)}} - \varepsilon - \frac{1}{2} r^* \right) L = 0\end{aligned} \tag{A.55}$$

Since L is non-zero for meaningful parameter constellation, the FOC is only satisfied if the term in brackets equals zero, which can be exploited to solve for the optimal level of k:

$$\begin{aligned}r^* R \frac{1}{2\sqrt{R^2 - 4cr^*(1-k)}} &= \varepsilon + \frac{1}{2} r^* \\ r^{*2} R^2 \frac{1}{4(R^2 - 4cr^*(1-k))} &= (\varepsilon + \frac{1}{2} r^*)^2 \\ r^{*2} R^2 \frac{1}{4R^2 - 16cr^* + 16crk} &= \varepsilon^2 + r\varepsilon + \frac{1}{4} r^2 \\ r^{*2} R^2 &= (4R^2 - 16cr^* + 16cr^* k)(\varepsilon^2 + r\varepsilon + \frac{1}{4} r^2) \\ r^{*2} R^2 &= 4R^2 \varepsilon^2 + r^* 4R^2 \varepsilon + r^{*2} R^2 \\ &- 16cr^* \varepsilon^2 - 16cr^{*2} \varepsilon - 4cr^{*3} \\ &+ 16cr^* k\varepsilon^2 + 16cr^{*2} k\varepsilon + 4ckr^{*3}\end{aligned} \tag{A.56}$$

Collecting terms gives

$$\begin{aligned}&16cr^* k\varepsilon^2 + 16cr^{*2} k\varepsilon + 4ckr^{*3} \\ &= 16cr^* \varepsilon^2 + 16cr^{*2} \varepsilon + 4cr^{*3} - 4R^2 \varepsilon^2 - r^* 4R^2 \varepsilon\end{aligned} \tag{A.57}$$

A helpful factorization is

$$\begin{aligned}&16cr^* \varepsilon^2 + 16cr^{*2} \varepsilon + 4cr^{*3} \\ &= 4cr^* (4\varepsilon^2 + 4\varepsilon r^* + r^{*2}) \\ &= 4cr^* (2\varepsilon + r^*)^2\end{aligned} \tag{A.58}$$

and hence

$$\begin{aligned} 4cr^*(2\varepsilon + r^*)^2 k &= 4cr^*(2\varepsilon + r^*)^2 - 4R^2\varepsilon^2 - r^* 4R^2\varepsilon \\ k &= 1 - R^2 \frac{4\varepsilon^2 + 4\varepsilon r^*}{4cr^*(2\varepsilon + r^*)^2} \\ &= 1 - R^2 \frac{\varepsilon(r^* + \varepsilon)}{cr^*(2\varepsilon + r^*)^2} \end{aligned} \tag{A.59}$$

which finally replicates (8.56) in the main text.

Optimal Monitoring Level

The finally optimal monitoring level depicted in (8.57) is obtained by the substitution of (8.56)/(A.59) back into (8.53)/(A.49) which gives

$$\begin{aligned} q &= \frac{1}{c}\left(R - R^2 \frac{\varepsilon(r^* + \varepsilon)}{cq(2\varepsilon + r^*)^2}\right) \\ &= \frac{R}{c} - R^2 \frac{\varepsilon(r^* + \varepsilon)}{c^2 q(2\varepsilon + r^*)^2} \\ 0 &= q - \frac{R}{c} + R^2 \frac{\varepsilon(r^* + \varepsilon)}{c^2 q(2\varepsilon + r^*)^2} \\ &= c^2(2\varepsilon + r^*)^2 q^2 - Rc(2\varepsilon + r^*)^2 q + R^2\varepsilon(r^* + \varepsilon) \end{aligned} \tag{A.60}$$

Solving the quadratic equation yields the following term

$$\hat{q}_{1,2} = \frac{cR(2\varepsilon + r^*)^2 \pm \sqrt{c^2R^2(2\varepsilon + r^*)^4 - 4c^2(2\varepsilon + r^*)^2 R^2\varepsilon(r^* + \varepsilon)}}{2c^2(2\varepsilon + r^*)^2} \tag{A.61}$$

The square root can be simplified as follows:

$$\begin{aligned} &\sqrt{c^2R^2(2\varepsilon + r^*)^4 - 4c^2(2\varepsilon + r^*)^2 R^2\varepsilon(r^* + \varepsilon)} \\ &= \sqrt{c^2R^2(2\varepsilon + r^*)^2\left((2\varepsilon + r^*)^2 - 4\varepsilon(r^* + \varepsilon)\right)} \\ &= cR(2\varepsilon + r^*)\sqrt{(2\varepsilon + r^*)^2 - 4\varepsilon(r^* + \varepsilon)} \\ &= cR(2\varepsilon + r^*)\sqrt{4\varepsilon^2 + 4\varepsilon r^* + r^{*2} - 4\varepsilon r^* - 4\varepsilon^2} \\ &= cRr^*(2\varepsilon + r^*) \end{aligned} \tag{A.62}$$

Again, the solution $\hat{q}_1$ is chosen such that

$$\begin{aligned}\hat{q} &= \frac{cR(2\varepsilon + r^*)^2 + cRr^*(2\varepsilon + r^*)}{2c^2(2\varepsilon + r^*)^2} \\ &= \frac{(2\varepsilon + r^*)R + r^*R}{2c(2\varepsilon + r^*)} \\ &= \frac{2\varepsilon R + 2r^*R}{2c(2\varepsilon + r^*)} \\ &= \frac{R(r^* + \varepsilon)}{c(r^* + 2\varepsilon)}\end{aligned} \tag{A.63}$$

which finally corresponds to (8.57) in the main text.

A.5 Angeloni-Faia Model

Optimal Deposit Ratio

As argued in the main text, the optimal value of the deposit ratio d_t lies in the interval $\lambda(R_t^A + h) < R_t d_t < R_t^A + h$. The precise value of d_t can be determined by finding the maximum of the payoff function. Conditional on the choice of the interval, payoffs are given by (8.61) and read

$$\begin{aligned}\Pi(x_t) = &\frac{1}{2h}\int_{-h}^{R_t d_t - R_t^A} \frac{(1+\lambda)(1-c)(R_t^A + x_t)}{2} dx_t \\ &+ \frac{1}{2h}\int_{R_t d_t - R_t^A}^{h} \frac{(R_t^A + x_t) + R_t d_t}{2} dx_t\end{aligned} \tag{A.64}$$

In a first step, the integral has to be expanded. Expansion of the first integral by using $\tau = (1+\lambda)(1-c)$ for notational simplicity gives:

$$
\begin{aligned}
&\int_{-h}^{R_t d_t - R_t^A} \frac{\tau(R_t^A + x_t)}{2} dx_t \\
&= \left[\frac{\tau R_t^A}{2} x_t + \frac{\tau}{4} x_t^2 \right]_{-h}^{R_t d_t - R_t^A} \\
&= \frac{\tau R_t^A}{2}(R_t d_t - R_t^A) + \frac{\tau}{4}(R_t d_t - R_t^A)^2 + \frac{\tau R_t^A}{2} h - \frac{\tau}{4} h^2 \\
&= \frac{\tau}{2} R_t^A R_t d_t - \frac{\tau}{2}(R_t^A)^2 + \frac{\tau}{4} R_t^2 d_t^2 \\
&- \frac{\tau}{2} R_t^A R_t d_t + \frac{\tau}{4}(R_t^A)^2 + \frac{\tau R_t^A}{2} h - \frac{\tau}{4} h^2 \\
&= \frac{\tau}{4} R_t^2 d_t^2 - \frac{\tau}{4}(R_t^A)^2 + \frac{\tau R_t^A}{2} h - \frac{\tau}{4} h^2
\end{aligned}
\tag{A.65}
$$

Expanding the second integral yields

$$
\begin{aligned}
&\int_{R_t d_t - R_t^A}^{h} \frac{(R_t^A + x_t) + R_t d_t}{2} dx_t \\
&= \left[\frac{1}{2} R_t^A x_t + \frac{1}{4} x_t^2 + \frac{1}{2} R_t d_t x_t \right]_{R_t d_t - R_t^A}^{h} \\
&= \frac{1}{2} R_t^A h + \frac{1}{4} h^2 + \frac{1}{2} R_t d_t h \\
&- \left[\frac{1}{2} R_t^A (R_t d_t - R_t^A) + \frac{1}{4}(R_t d_t - R_t^A)^2 + \frac{1}{2} R_t d_t (R_t d_t - R_t^A) \right] \\
&= \frac{1}{2} R_t^A h + \frac{1}{4} h^2 + \frac{1}{2} R_t d_t h \\
&+ \frac{1}{2} R_t R_t^A d_t + \frac{1}{4}(R_t^A)^2 - \frac{3}{4} R_t^2 d_t^2
\end{aligned}
\tag{A.66}
$$

Adding up both integrals in their expanded form gives payoffs as a function of d_t:

$$
\begin{aligned}
\Pi(d_t) = \frac{1}{2h} \Bigg(& \frac{\tau}{4} R_t^2 d_t^2 - \frac{\tau}{4}(R_t^A)^2 + \frac{\tau R_t^A}{2} h - \frac{\tau}{4} h^2 \\
& + \frac{1}{2} R_t^A h + \frac{1}{4} h^2 + \frac{1}{2} R_t d_t h \\
& + \frac{1}{2} R_t R_t^A d_t + \frac{1}{4}(R_t^A)^2 - \frac{3}{4} R_t^2 d_t^2 \Bigg)
\end{aligned}
\tag{A.67}
$$

It is now possible to take the FOC with respect to d_t:

$$\frac{\partial \Pi}{\partial t} = \frac{1}{2h}\left(\frac{\tau}{2}R_t^2 d_t + \frac{1}{2}R_t h + \frac{1}{2}R_t R_t^A - \frac{3}{2}R_t^2 d_t\right) = 0 \tag{A.68}$$

It is convenient to simplify the expression via multiplication with $\frac{4h}{R_t}$ to obtain

$$\tau R_t d_t + h + R_t^A - 3R_t d_t = 0 \tag{A.69}$$

Reintroducing $\tau = (1+\lambda)(1-c)$ yields

$$(1+\lambda)(1-c)R_t d_t + h + R_t^A - 3R_t d_t = 0 \tag{A.70}$$

which corresponds to (8.62) in the main text. In a last step, one needs to solve for d_t

$$\begin{aligned} (1+\lambda)(1-c)R_t d_t + h + R_t^A - 3R_t d_t &= 0 \\ R_t d_t(1 - c - c\lambda + \lambda - 3) &= -h - R_t^A \\ R_t d_t(2 - \lambda + c + c\lambda) &= h + R_t^A \\ d_t &= \frac{1}{R_t}\frac{h + R_t^A}{2 - \lambda + c(1+\lambda)} \end{aligned} \tag{A.71}$$

which is (8.63) in the main text.

Appendix B

Additional VAR Results

Variable	Mean	Std. Dev.	Min.	Max.	Observations
Funding Risk Indicator	-0.37	0.407	-1.03	1.13	98
Non-Financial Leverage Indicator	0.102	0.867	-1.77	2.46	98
HP-filtered RRPPI	0	2.583	-11.363	6.237	98
Excess Bond Premium	-0.058	0.396	-0.892	0.881	98
Non-Core Liability Growth (yoy)	8.535	7.839	-8.199	22.8	98
Real GDP growth	3.373	2.198	-3.42	9.029	98
CPI inflation	3.047	1.521	-1.95	6.850	98

Note: RRPPI = Real Residential Property Price Index, yoy = year-on-year, HP-filtered = Hodrick-Prescott filtered.

Table B.1: *Additional Summary Statistics*

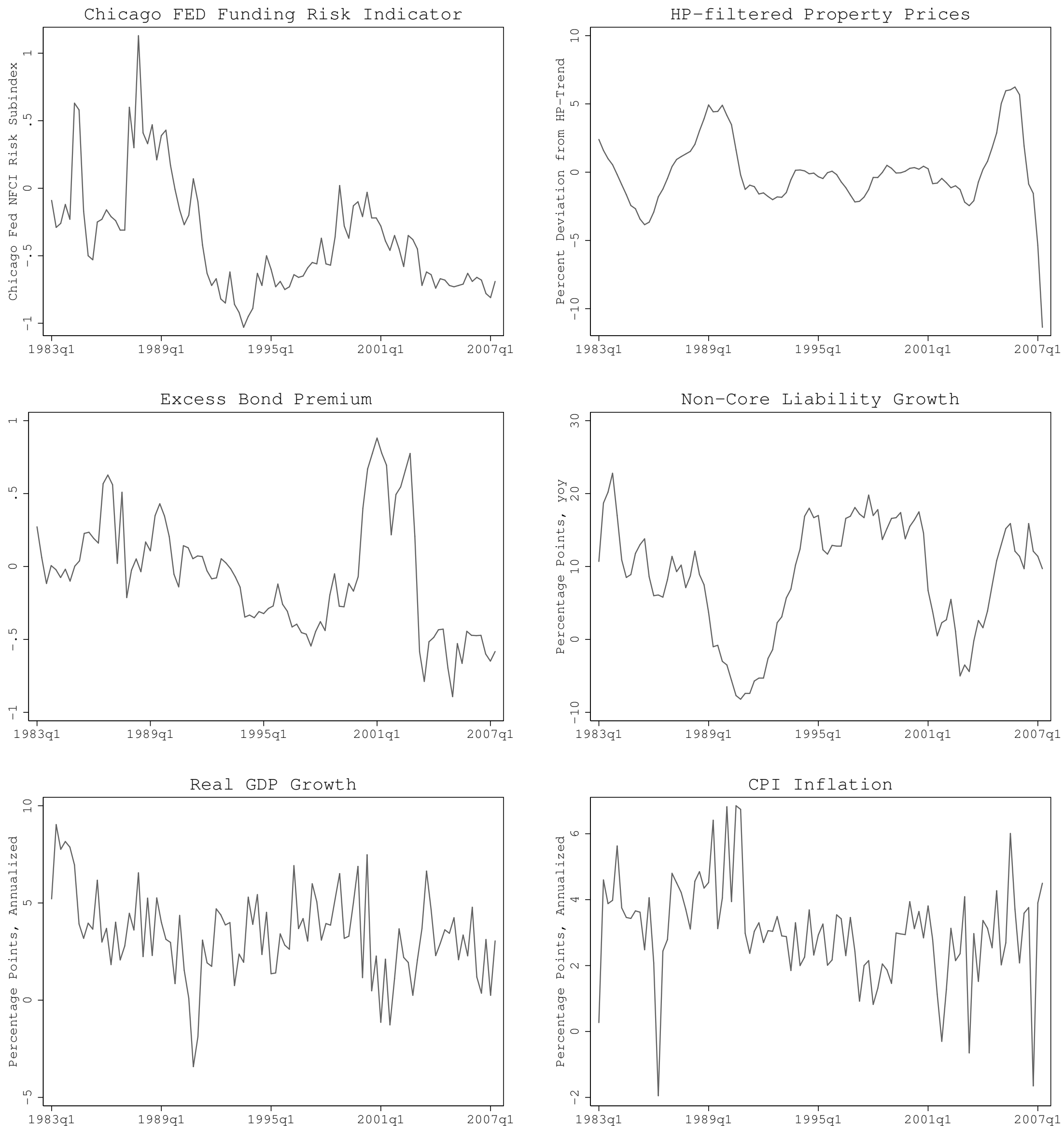


Figure B.1: *Additional Time Series Plots*

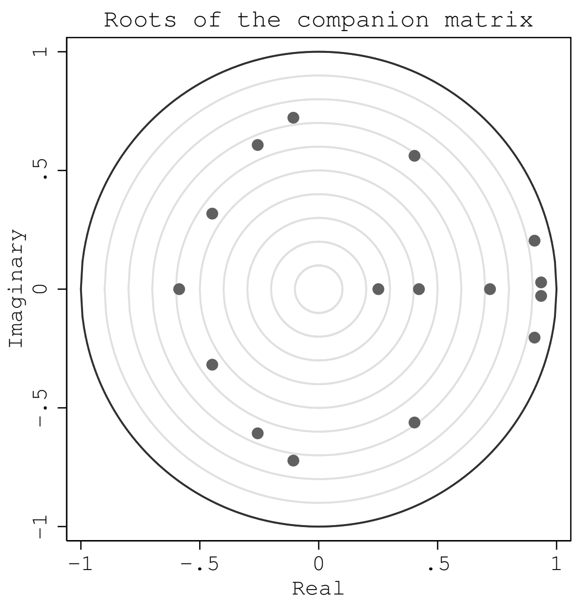


Figure B.2: *Eigenvalue-Based Stability Test of the Baseline VAR*

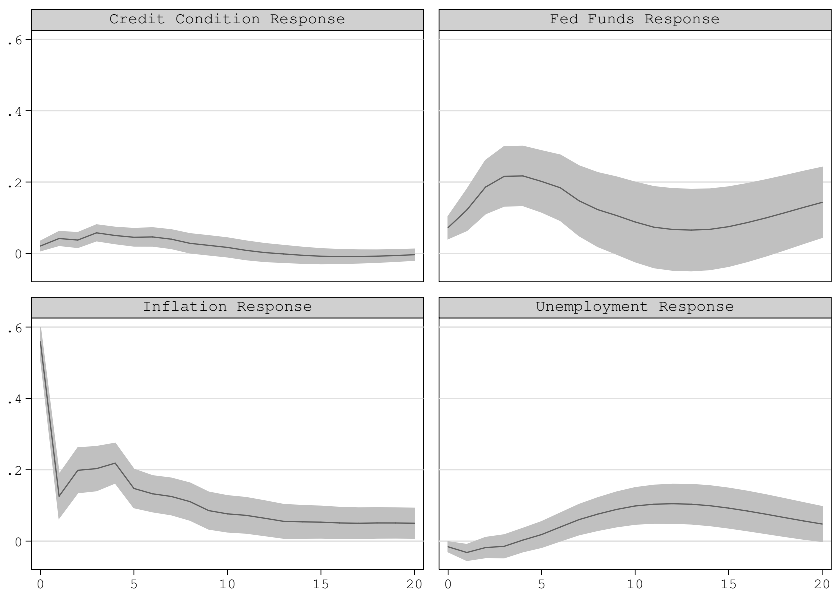


Figure B.3: *Inflation Shock in the Baseline VAR*

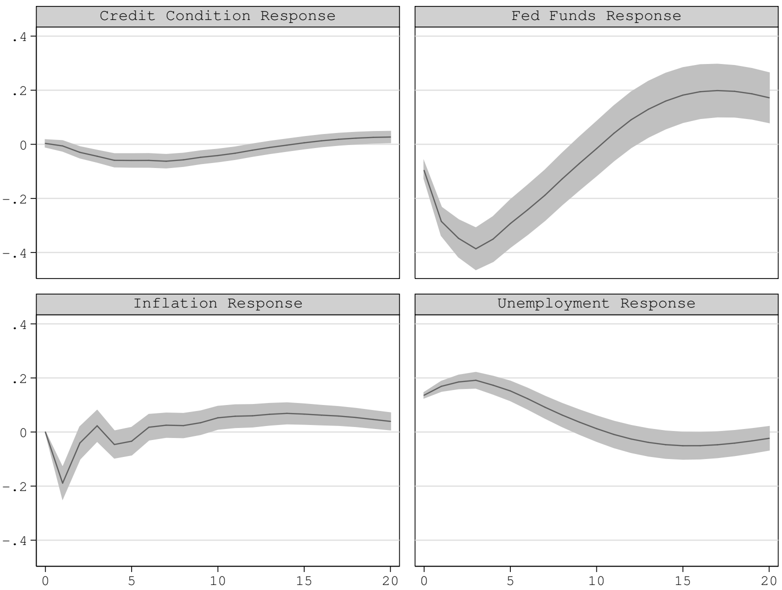


Figure B.4: *Unemployment Shock in the Baseline VAR*

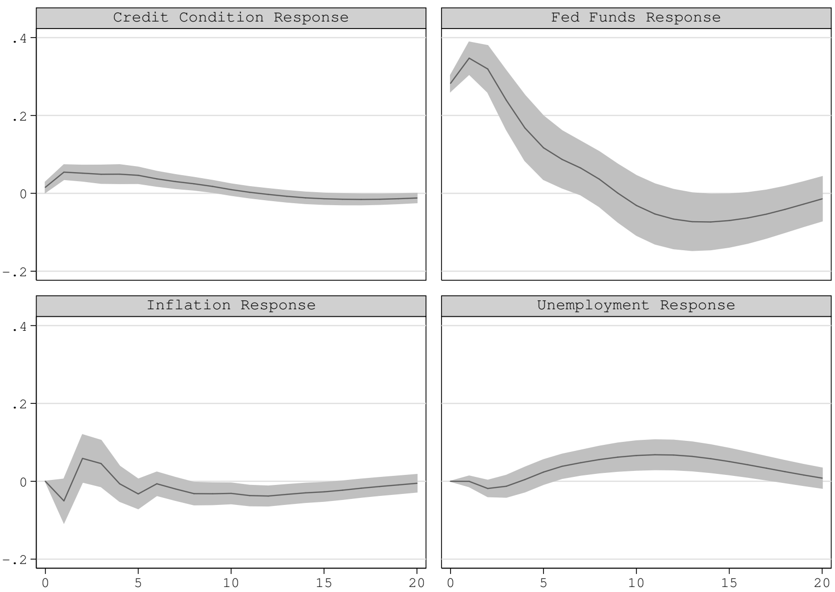


Figure B.5: *Policy Shock with Alternative Ordering*

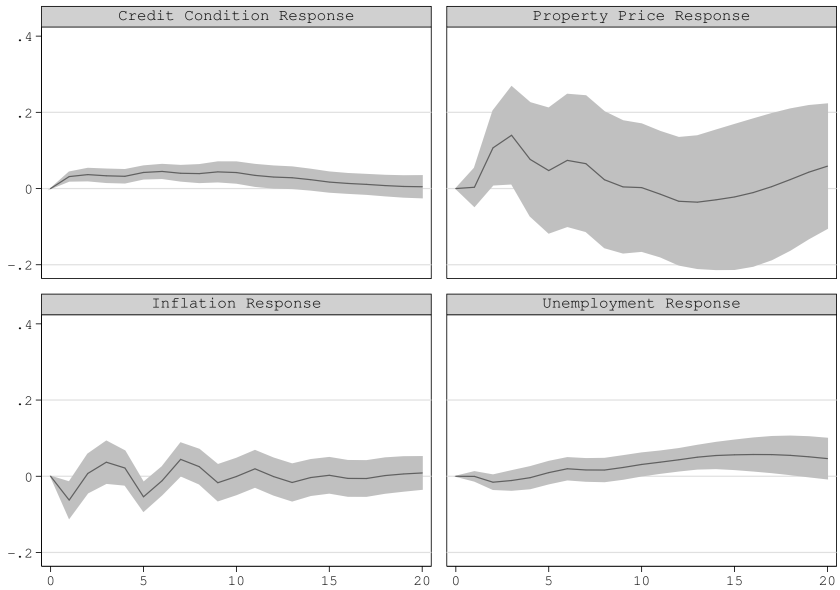


Figure B.6: *Policy Shock in VAR augmented with Property Prices*

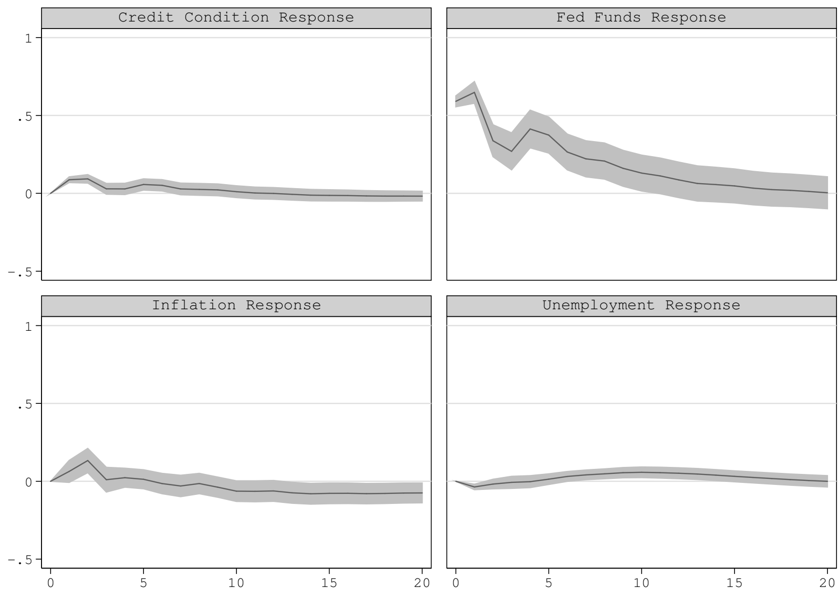


Figure B.7: *Policy Shock with Extended Sample (Q1 1973 - Q3 2008)*

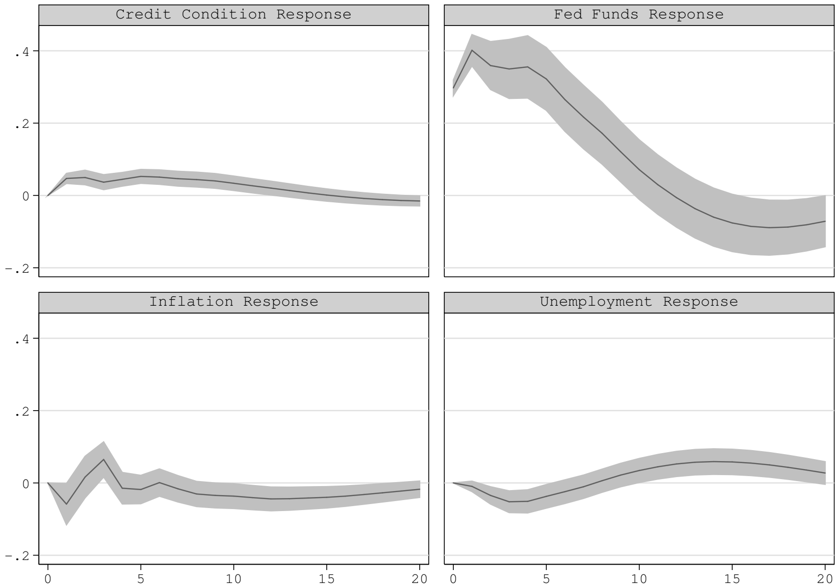


Figure B.8: *Policy Shock in Baseline VAR with $p = 3$*

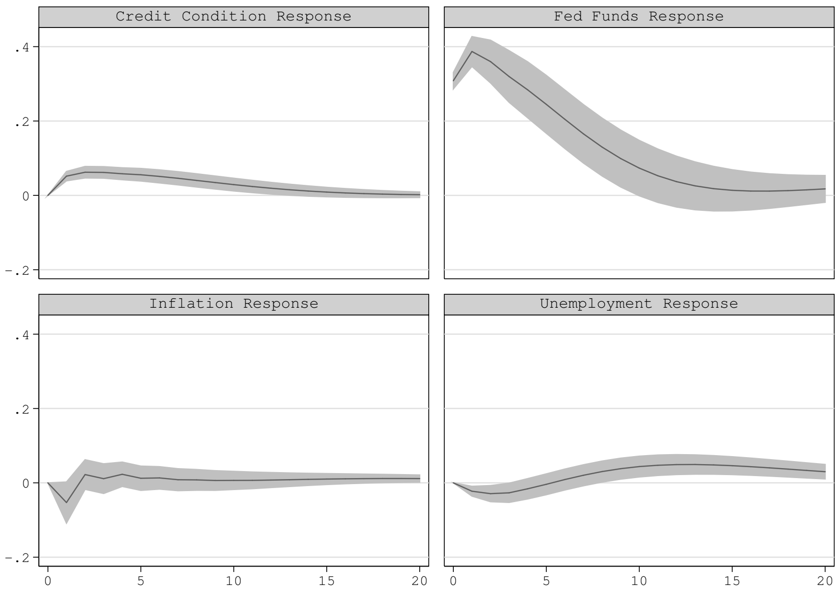


Figure B.9: *Policy Shock in Baseline VAR with $p = 2$*

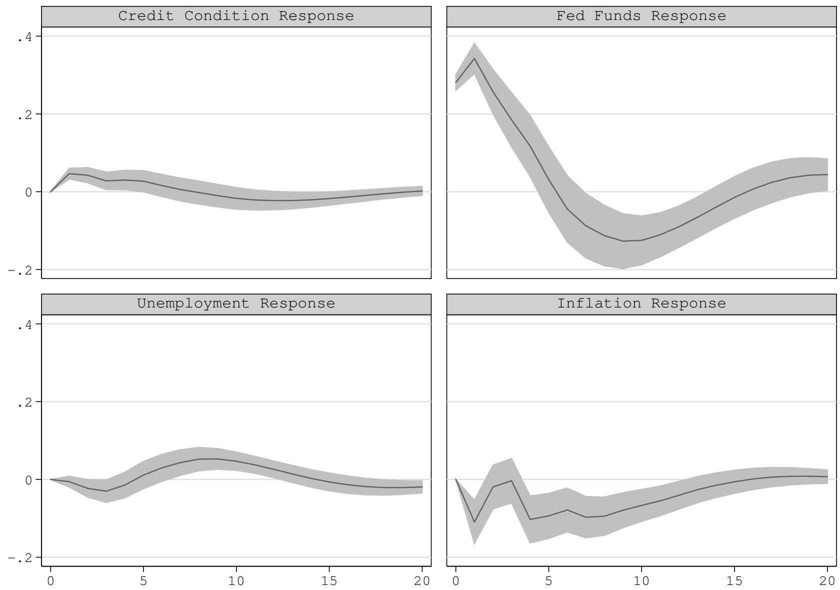


Figure B.10: *Policy Shock in VAR with HP-detrended Series*

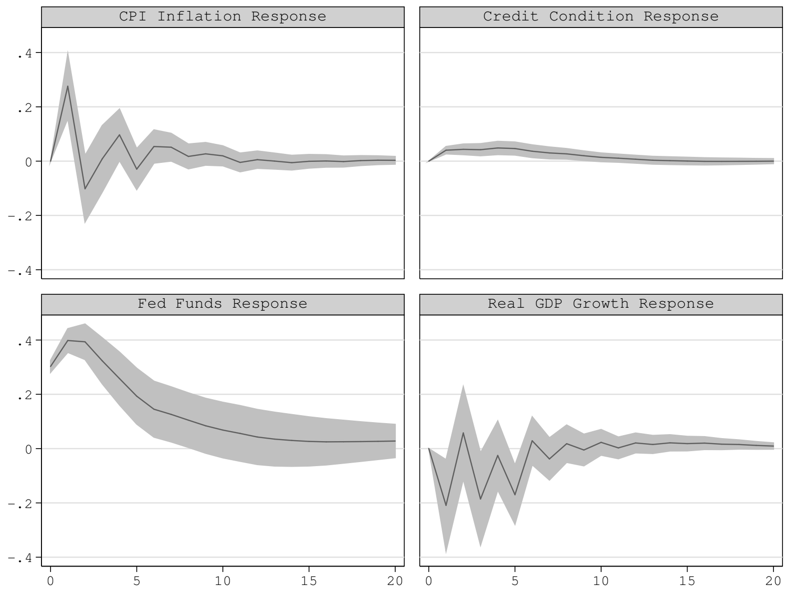


Figure B.11: *Policy Shock with Different Macro Variables*

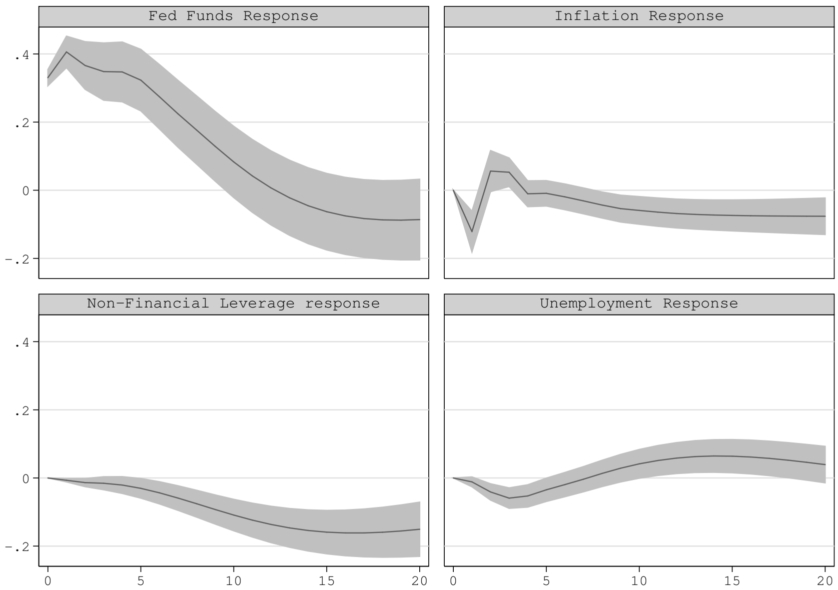


Figure B.12: *Policy Shock with Different Risk-Taking Proxy (NFILEV)*

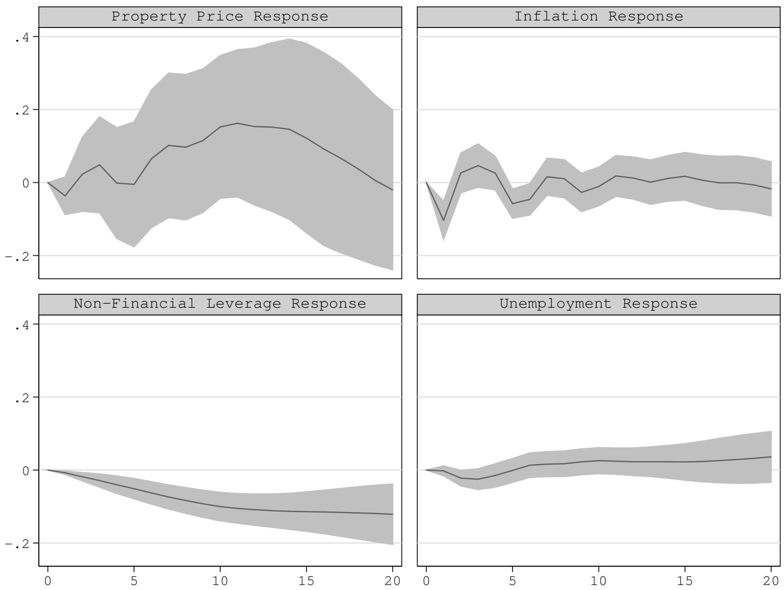


Figure B.13: *Policy Shock with NFILEV and Property Price Control ($p = 4$)*

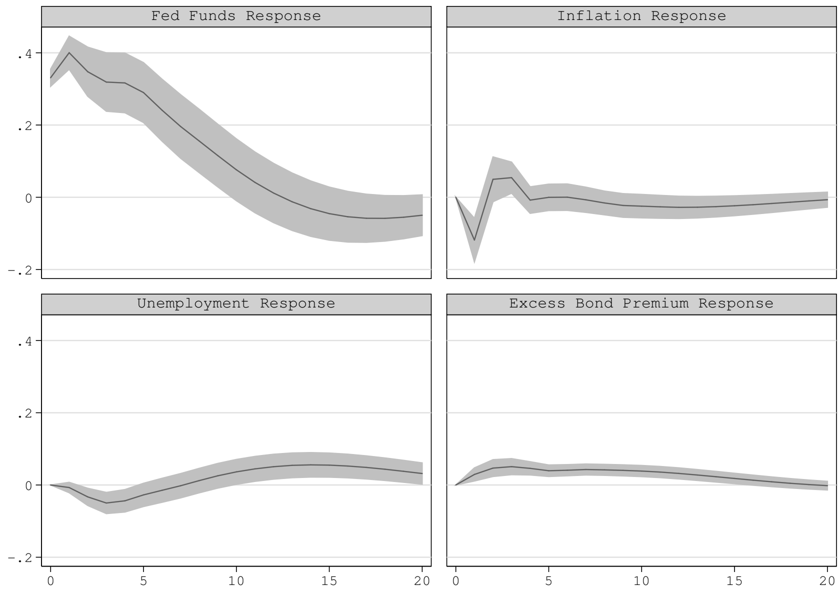


Figure B.14: *Policy Shock with Different Risk-Taking Proxy (EBP)*

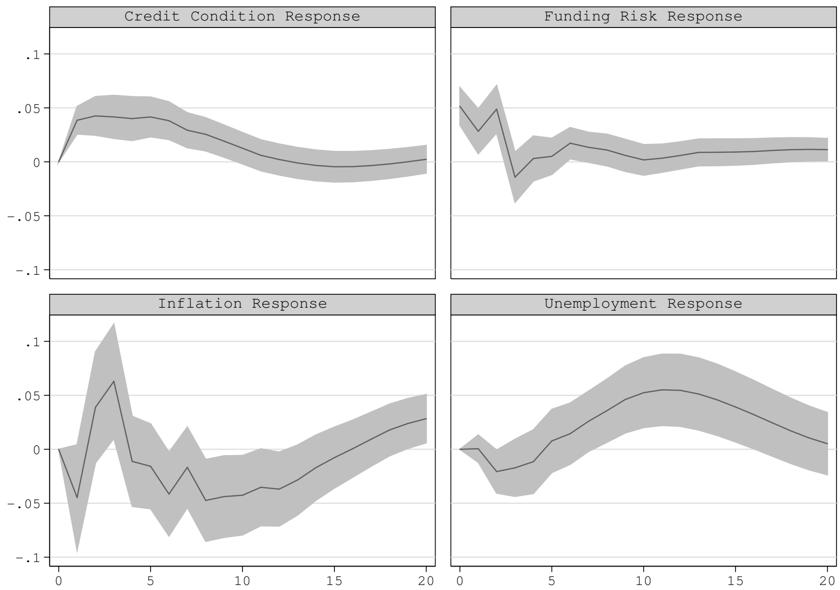


Figure B.15: *Policy Shock in VAR augmented with Funding Risk Indicator*

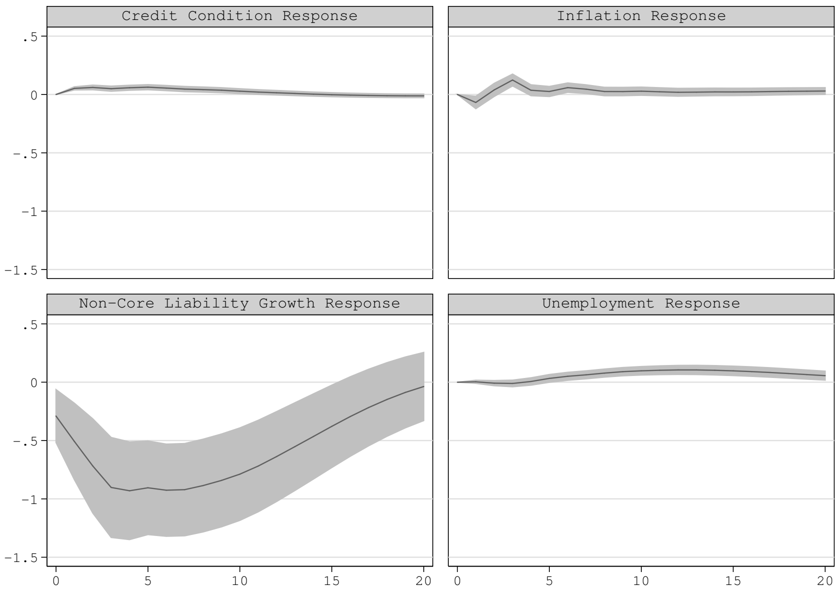


Figure B.16: *Policy Shock in VAR augmented with Non-Core Liabilities (p=3)*

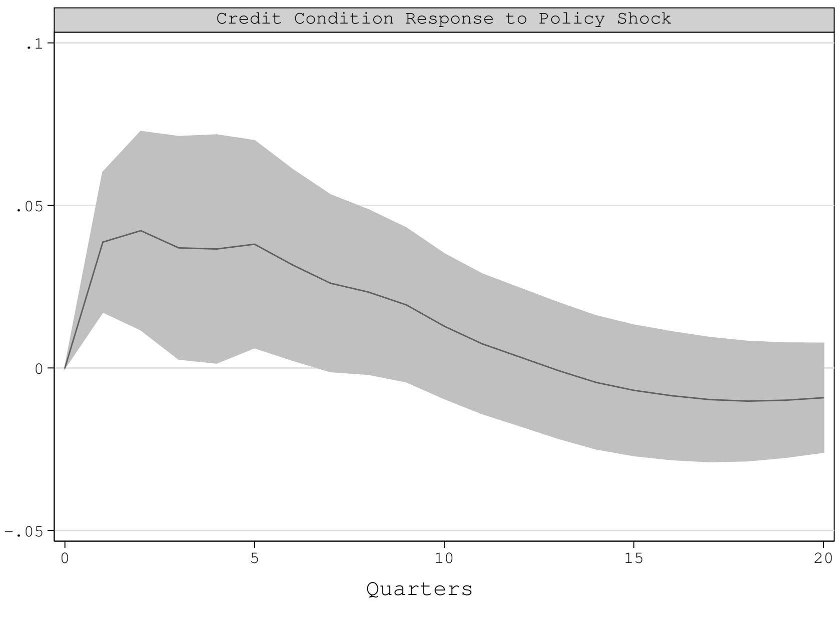


Figure B.17: *Policy Shock and Credit Condition Response with 90% Confidence Band*

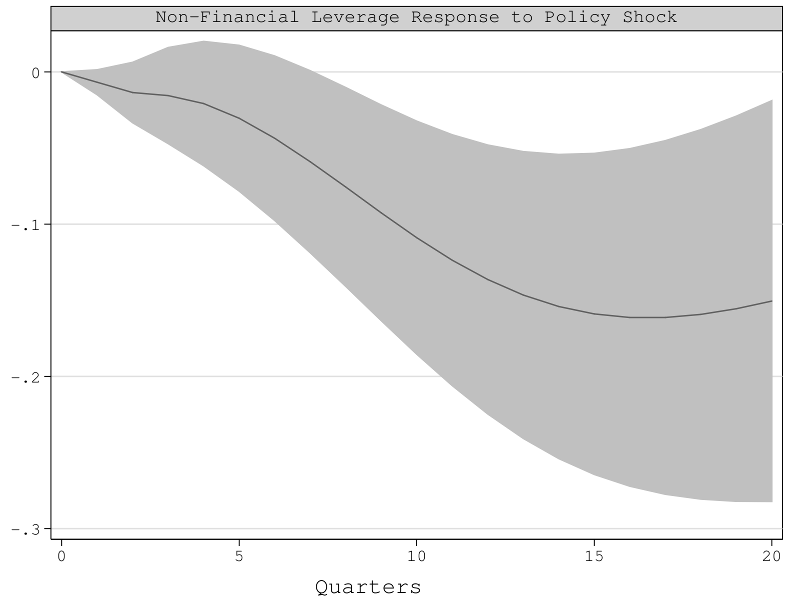


Figure B.18: *Policy Shock and Non-Financial Leverage Response with 90% Confidence Band*

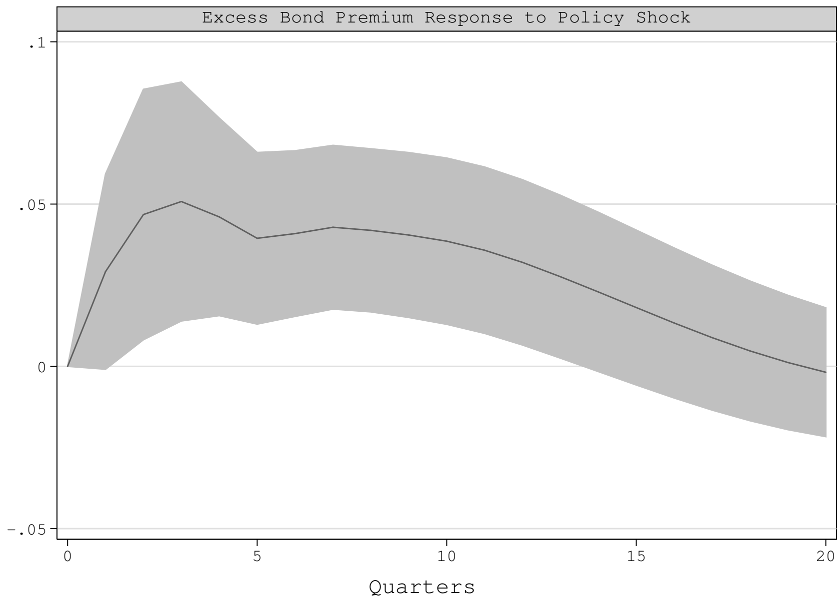


Figure B.19: *Policy Shock and Excess Bond Premium Response with 90% Confidence Band*

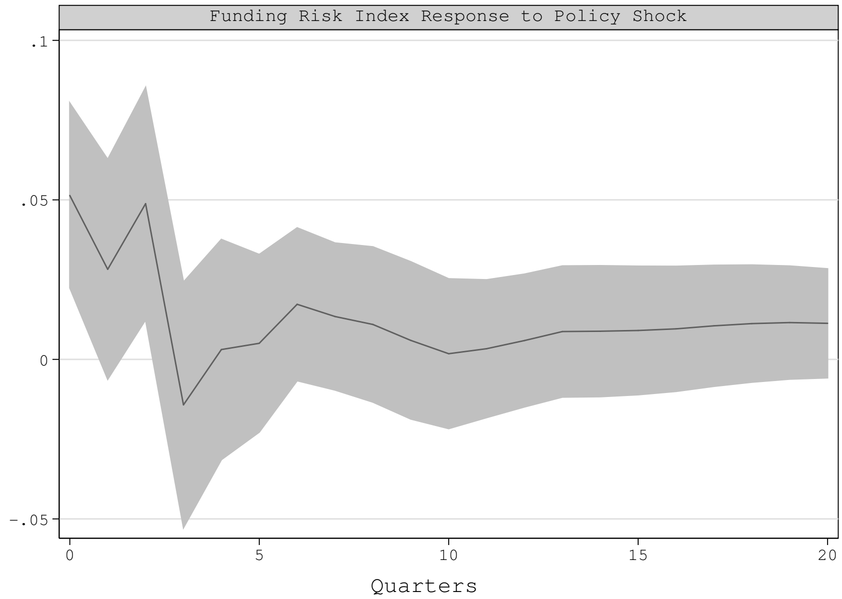


Figure B.20: *Policy Shock and Funding Risk Indicator Response with 90% Confidence Band*

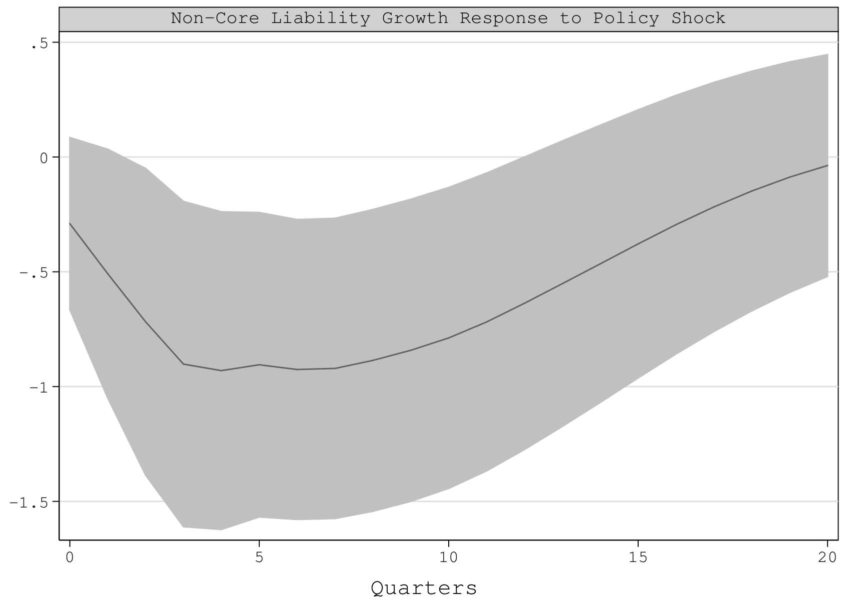


Figure B.21: *Policy Shock and Non-Core Liability Growth Response with 90% Confidence Band*

Variable	Source	Mnemonic	Transformation
Funding Risk Indicator	FED FRED	NFCIRISK	none
NFLI	FED FRED	NFCINONFINLEVERAGE	none
RRPPI	FED FRED	QUSR628BIS	CHP of Log Level * 100
EBP	Gilchrist et al. (2012)	-	-
Non-Core Liabilities	US Flow of Funds	-	yoy growth
Real GDP	FED FRED	GDPC96	LD * 400
CPI	FED FRED	CPIAUCSL	LD * 400

Note: NFLI = Non-financial leverage indicator, LD = Log Difference, CHP = cyclical component of HP-filter ($\lambda = 1600$ as proposed by Ravn and Uhlig (2002)). Non-Core Liabilities consist of three sub-aggregates, with the following Mnemonics in the US flow of funds database: Z1/Z1/FL763135005.Q (Large Time Deposits), Z1/Z1/FL762150005.Q (Repo Liabilities) and Z1/Z1/FL634090005.Q (Money Market Fund Assets). The URL for the web appendix of Glichrist et al. (2012) is: http://www.aeaweb.org/aer/data/june2012/20100787_data.zip

Table B.2: *Data Sources and Transformations*

Variable	ADF statistic	p-value	DF-GLS statistic
GDP Deflator (ann. %chg)	-2.528***	0.0066	-2.054**
Unemployment Rate	-1.764**	0.0406	-1.829
Federal Funds Rate	-2.525***	0.0067	-2.899*
CCI	-2.999***	0.0018	-1.156
Funding Risk Indicator	-1.525*	0.0654	-1.246
Non-Financial Leverage Indicator	-1.853*	-	-1.498
HP-filtered RRPPI	-4.203***	-	-4.009***
Excess Bond Premium	-1.846*	-	-2.128**
Non-Core Liability Growth (yoy)	-1.814**	0.0366	-2.163**
Real GDP growth	-3.903***	0.0001	-3.273***
CPI inflation	-3.358***	0.0006	-2.020**

Note: The ADF test was conducted with a lag order of $p = 4$ and critical values are obtained from Elliott et al. (1996). A drift term was included for any variable where a non-zero mean cannot be ruled out. The DF-GLS test was run with up to 4 lags, and the optimal lag order was chosen according to the criterion proposed by Ng and Perron (1995). For fed funds and the unemployment rate, trend stationarity was used as the alternative hypothesis. One asterisk denotes statistical significance at the 10%-level, two asterisks at 5% and three asterisks at the 1% level, respectively.

Table B.3: *Unit root Tests*

Lag Order p	**AIC**	**HQIC**	**SBIC**	**LM (1)**	**LM (2)**
1	1.64621	1.86479	2.18734	0.00000	0.00017
2	1.12052	1.51395*	2.09455*	0.14505	0.03444
3	1.04407	1.61236	2.451	0.01506	0.20895
4	1.01975*	1.76291	2.85958	0.35777	0.12236

Note: Asterisks mark the optimal lag length according to the respective selection criterion. The columns LM(1) and LM(2) display the p-values of the test of Johansen (1995) for first-order and second-order residual autocorrelation. Note that the null hypothesis is that residuals are not autocorrelated. The p-values reveal that the null is always rejected at some order for $p < 4$.

Table B.4: *Lag Selection Criteria for the Baseline Model*

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