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Faculty of Social Sciences
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MASTER'S THESIS

Interaction between Macroprudential and Monetary Policies, and Bank Runs

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, July 31, 2017

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Abstract

The thesis focuses on the interaction between macroprudential and monetary policies in the presence of bank runs. In particular, it is examined whether the two policies should be conducted separately or jointly, and whether the occurence of a bank run affects the result. Furthermore, it is studied how a bank run impacts the efficiency of the two policies.

The baseline results suggest that cooperation between the two policies is less efficient than when they are determined separately. The reason might be a coordination issue that arises because the same objective is being assigned to both policies in the cooperative case. On the other hand, when facing a bank run the cooperative regime achieves a higher degree of financial stability by reducing the probability of a next run. This is caused by the fact that cooperating authorities choose more aggresive macroprudential policy when a bank run occurs. A bank run itself does not change the ranking of the two policy regimes. However, an occurence of a bank run induces higher efficiency of both policies, irrespective of the regime in place. In addition, the policies are more effective when they face financial shocks, as opposed to a productivity shock.

Abstrakt

Tato práce je zaměřena na koordinaci monetárních a makroprudenčních politik v přítomnosti „runů" na banky. Především je zkoumáno, zdali by tyto dvě politiky měly být koordinované a tedy v kompetenci jedné centrální autority, a nebo jestli by měly být rozhodovány nezávisle. Dále se práce soustředí na to, jestli je tento výsledek ovlivněn případným runem na banku a jak taková událost působí na efektivitu obou politik.

Výsledky simulací zkoumaného modelu naznačují, že koordinovat monetární a makroprudenční politiky je méně efektivní, než je rozhodovat samostatně. Důvod může být ten, že v případě koordinace je oběma politikám přidělen stejný cíl. Toto může způsobit neefektivitu daných politik, jelikož obě musí být určeny tak, aby splňovaly monetární i makroprudenční cíle. Na druhou stranu koordinace politik v přítomnosti runu na banku snižuje pravděpodobnost dalšího „runu" a tedy přispívá k větší finanční stabilitě. Důvodem je to, že pokud nastane run na banku, tak v případě koordinace daná centrální autorita volí agresivnější makroprudenční politiku a tím eliminuje pravděpodobnost dalšího runu. Run na banku sám o sobě nemá vliv na rozhodnutí, jestli by politiky měly být praktikovány koordinovaně nebo nezávisle. Avšak run způsobuje, že se monetární i makroprudenční politika stávají účinnějšími. Účinnost je také ovlivněna typem šoku, kterému daná ekonomika čelí. V případě šoků zasahujících finanční sektor dosahují obě politiky větší efektivity než v případě šoků ovlivňujících produktivitu.

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Acronyms

BCBS Basel Committee on Banking Supervision

EBA European Banking Authority

SIFI Systematically Important Financial Institution

LTV Loan-to-value

DTI Debt-to-income

SES Systemic Expected Shortfall

VaR Value-at-Risk

Master's Thesis Proposal

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Proposed topic	Interaction between Macroprudential and Monetary Policies, and Bank Runs

Motivation After the crisis in 2007, it was apparent that the current regulatory framework is not sufficient for achieving financial stability. In particular, a new design was needed that would take into account the linkages between particular financial institutions and the corresponding threats, as this perspective was omitted from the previous framework. Consequently, macroprudential policies came into play.

For a suitable design of any macroprudential policy it is necessary to understand its interactions with other policies, in particular the monetary ones, as these also directly affect the financial sector. Since both macroprudential and monetary policies operate through the same channels, they might have a substantial impact on each other. Therefore, it is essential for a regulator to know the effects in play in order to achieve the highest efficiency of both policies.

The thesis will be focused on studying the interaction between macroprudential and monetary policies in the presence of bank runs. Since bank runs played a significant role in the recent crisis, it is important to involve them into the analysis and study how the two policies behave when a run occurs. In particular, it will be studied whether macroprudential and monetary policies should be conducted jointly or separately, and how is this decission affected by an occurence of a bank run. Moreover, it will be examined what is the effect of a prospective cooperation between policies on financial stability.

Hypotheses

> Hypothesis #1: When a bank run occurs, coordinated policies are more efficient than the ones determined separately.

Hypothesis #2: A bank run affects the efficiency of macroprudential and monetary policies.

Hypothesis #3: The efficiency of macroprudential and monetary policies depends on the type of shocks hitting the economy.

Hypothesis #4: Financial stability, proxied by a probability of a bank run occurence, differs among the policy regimes (coordinated vs. non-coordinated policies).

Methodology   The model studied in the thesis will be based on Gerali et al. (2010) and Angelini, Neri and Panetta (2014). In particular, the latter paper examines the interaction between macroprudential and monetary policies in a DSGE model with financial frictions that is based on Gerali et al. (2010). Therefore, the approach of modelling the interaction will be adopted from Angelini, Neri and Panetta (2014). However, the banking sector will be handled differently. Namely, it will be based on Gertler and Kiyotaki (2015). The authors study bank runs which occur as sunspots with an endogenous probability. Hence, while a bank run is an exogenous event, its probability of occurence depends on endogenous variables and therefore on economic conditions.

The framework described above will be used to study the effects of bank runs on the interaction between macroprudential and monetary authorities. The model will be simulated using Matlab and the robustness of obtained results will be checked by examining models involving alternative values of parameters, different types of shocks and of policy rules.

Expected Contribution   According to the author's best knowledge, there does not exist any literature examining the interaction between macroprudential and monetary policies in the presence of bank runs. Hence, the main contribution will be the assessment of an effect that bank runs have on the efficiency of the two policies and on the decission of whether they should be conducted jointly or separately. In this framework, it will be also studied how coordination between the policies contributes to financial stability which will be proxied by a probability of a bank run occurence.

Outline

1. Introduction

2. Literature review

3. Description of the model

4. Simulation results

5. Conclusion

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Chapter 1

Introduction

When the crisis occured in 2007, it became clear that the current regulatory mechanism is inadequate for achieving financial stability. Highly leveraged financial institutions and excessive credit growth caused the collapse of the financial system and a severe disruption of financial intermediation that impacted economies all over the world. As the regulatory policies were aimed mostly on individual instutions, systemic risk threatening the whole sector was not handled. Consequently, the crisis implied a need for a different regulatory design that would concern also various channels between financial instutions and their mutual interconnectedness.

The macroprudential approach to financial regulation possesses the above mentioned features. It considers a market in question as a whole, with all its connections between individual participants. Therefore, macroprudential regulation focuses mostly on these linkages and possible issues stemming from them.

There is a broad variety of macroprudential tools being used these days. Their appropriateness differ with the pursued objective and with the form of systemic risk that a particular tool should tackle. Therefore, it is essential for every regulatory authority to clearly define any targets that a particular regulation should achieve. Furthermore, measures of systemic risk in the economy are significant for the design of any macroprudential policy, as they equip regulators with important information about possible threats.

In addition to the features described above that are necessary for the design of macroprudential policy, there is one more aspect that needs to be taken into account by the responsible authority. It is vital to consider any effects that a macroprudential regulation can have on other policies, and vice versa. In particular, since macroprudential policies affect the financial market, there is an interaction between them and monetary policy. Both macroprudential and monetary policies focus on the banking sector and therefore operate through the same channels. Consequently, they might influence each other. However, it is not ex-ante clear whether the impact of one

policy on the other will be reinforcing or mitigating. But both situations can have a negative effect on the objectives in question - price and financial stability.

The main purpose of this thesis is to examine the interaction between macroprudential and monetary policies in the presence of bank runs. As bank runs form a natural consequence of an excessive risk in the economy and moreover they played a key role in the recent crisis, it is important to study the performance of macroprudential policies when bank runs matter.

The model presented in this work is based on Angelini, Neri and Panetta (2014), Gerali et al. (2010) and on Gertler and Kiyotaki (2015). In particular, two policy regimes are studied - one in which monetary and macroprudential authorities cooperate and one where they act separately. The cooperative regime is characterized by the two authorities choosing the optimal policy parameters in order to minimize a joint loss function, while in case of non-cooperation each of the authorities minimize its own policy loss. The two regimes are ranked based on the values of minimized loss functions and based on a welfare measure. This approach is adopted from Angelini, Neri and Panetta (2014). As of the banking sector, which is modelled in a way similar to Gertler and Kiyotaki (2015), banks may be subject to runs with the probability of such an event being endogenous. Therefore, the two regimes are also evaluated according to their effect on the probability of a bank run.

According to the simulation results obtained from the baseline model, it is found that the non-cooperative regime is preferable over the cooperative one both in terms of joint minimized loss and overall welfare. In particular, before the run occurs the non-cooperating authorities attain lower both monetary and macroprudential policy loss. These authorities also perform more aggresive policies, as compared to jointly operating authorities. After the bank run, the non-cooperative regime maintains lower minimized joint loss, i.e. a sum of monetary and macroprudential policy losses. However, the cooperating authorities deliver lower macroprudential loss and this implies that their macroprudential policy is more efficient. In particular, after the bank run the cooperative macroprudential policy becomes more aggresive, as compared to the periods before the run. Consequently, the probability of a next bank run is lower in the cooperative regime compared to the non-cooperative one. Hence, despite the fact that cooperating authorities are not that efficient in conducting monetary policy and that they deliver lower total welfare, cooperation is clearly closer to achieving financial stability by conducting better macroprudential policy.

The result that non-cooperating authorities are more efficient in terms of minimized joint loss is similar to the one obtained in De Paoli and Paustian (2013). The authors find that when monetary and macroprudential policies are assigned too similar targets, there might be a coordination issue which causes less efficient outcomes to occur. Since the cooperation regime as considered here involves minimization of a

joint loss function, it can be said that the two policies are trying to achieve the same objectives, i.e. to minimize the same loss function. Hence, the findings presented in this work confirm the one in De Paoli and Paustian (2013).

Simulation results obtained from alternative models, which involve different parameter values and shocks hitting the economy as compared to the baseline model, confirm the original finding that cooperation is less efficient than separately operating authorities. This conclusion is not affected by an occurence of a bank run. The only exception is the case when the policy rules are adjusted so that both monetary and macroprudential instruments respond to the same variables. In that case, cooperation dominates non-cooperation in terms of minimized joint loss function. Therefore, in order the cooperating authorities to operate more efficiently it is necessary to set similar policy rules. Moreover, the simulation results show that a bank run induces higher efficiency of both monetary and macroprudential policies, irrespective of the regime in place. Namely, when the authorities reoptimize their policy rules after a bank run occurs, they manage to achieve lower values of policy losses and higher levels of welfare. In addition, both policies are more efficient when they face financial shocks, as compared to a productivity shock.

The thesis is organized as follows. Chapter 2 reviews macroprudential policy literature, focusing on macroprudential objectives and available tools. Chapter 3 describes various forms of systemic risk, its indicators and bank runs, as these are the key feature of the studied baseline model. Chapter 4 then summarizes the possible sources of the interaction between monetary and macroprudential policies, and depicts particular effects that one policy can have on the other. This chapter also provides the baseline model that is used to study the two policy regimes in the presence of bank runs. Simulation results of the baseline and alternative models can be found in Chapter 5. All corresponding tables and figures are presented in Appendix. Chapter 6 concludes.

Chapter 2

Macroprudential policy

Prior to the crisis in 2007 it was believed that the financial system is stable in the sense that there is no need for any policy interventions, as stated in Yellen (2011). There was a slight pressure on deregulating financial markets, as those were assumed to work the best by themselves. At that time most world economies were experiencing booms with periods of increasing GDP and decreasing unemployment. These prosperous conditions led to a rise in credit flows. Consumers were borrowing to the highest extent, while financial institutions were increasing leverage and consequently taking on more risk. This process led to tensions especially in the mortgage market. Housing prices were steadily rising which only contributed to excessive borrowing and risk-taking.

When the housing bubble collapsed, high degree of leverage led to deterioration of banks' balance sheets. As banks used short-term deposits to finance their long-term investments, arisen liquidity mismatch contributed further to the worsening of the overall state of the economy. Furthermore, many financial institutions were interlinked which amplified the propagation of negative effects of the bubble collapse. Since depositors perceived the worsening situation, several bank runs occured. The occurance hinged on beliefs that an individual depositor had about others' beliefs - the concept well-known from the Keynesian beauty contest (Allen, Morris and Shin, 2006). Another consequence of the bubble collapse was a severe disruption of financial intermediation which slowed down the economic growth and the desired recovery of the system.

The crisis gave important lessons to policymakers and central bankers all over the world. A need for macroprudential surveillance emerged and urged the development of suitable measures and tools that would prevent a similar crisis from occuring again. However, there is still an ongoing debate on what the objectives of any macroprudential policy should be and on what is the optimal design of those policies.

The term "macroprudential" was used for the first time in 1970s (Borio, 2011) and its

appearence in research publications has been steadily increasing since 2007 (Galati and Moessner, 2013). This indicates the increasing interest in macroprudential regulation in light of the last crisis. *Macroprudential* essentially means "...following a top-down approach, working out the desirable safety standard for the system as a whole and, from there, deriving that of the individual institutions within it." (Borio, 2011) However, more definitions are at hand, e.g. the ones addressing the connection of macroprudential policy to financial stability, systemic risk or SIFIs.

In general, macroprudential should form a counterpart to microprudential approach of financial regulation. According to Clement (2010), one of the distinctive features of macroprudential policy design as compared to a microprudential one is that it focuses solely on the economy as a whole. It aims on mitigating systemic risk, i.e. risk that threatens the whole financial system, not only individual institutions. The risk is perceived as an endogenous phenomenon with origins in the behavior of financial market participants. On the contrary, microprudential approach focuses itself on individual institutions and on protection of their depositors and investors, taking any systemic risk as exogenous.

Based on Clement (2010) and Borio (2011), macroprudential regulation possesses two dimensions - time dimension and cross-sectional dimension. The former one concerns the business cycle and procyclicality. Therefore, macroprudential policy with respect to time dimension should aim on building cushions which would slow down the credit growth in good times and restrict the credit decline in bad times. The cross-sectional dimension involves interconnections among financial institutions and transmission channels of disruptive shocks. Consequently, macroprudential policy should focus in this case on the whole system and assess the importance of every institutions with respect to the overall stability.

The next subsections focus on two important features regarding the design of macroprudential policies - macroprudential objectives and tools. As is written in detail below, each macroprudential instrument is designed to aim specific type of systemic risk. Therefore, knowing the precise objectives of macroprudential policy, i.e. the type of systemic risk, is essential for the choice of suitable tools.

Section 2.1 aims on describing objectives of macroprudential policies. In particular, it comprises of various definitions of financial stability which is usually assumed to be the main goal of any macroprudential policy. Section 2.2 describes available macroprudential measures that can be used to tackle systemic risk in various forms. Subsection 2.2.1 is devoted to Basel III, a macroprudential policy that has not been fully implemented yet but which has a strong potential in terms of achieving long-term financial stability.

2.1   Objectives

The primary objective of any macroprudential policy is financial stability. However, as emphasized by Galati and Moessner (2013), there is no agreement on what financial stability exactly means. One possible definition considers financial stability to be an ability of the economy to withstand an exogenous shock, as stated in Allen and Wood (2006). Another option, following Houben, Kakes and Schinasi (2004), is to focus towards allocative efficiency, systemic risk and propagation of shocks, since a stable economy should be able, according to the authors, to allocate resources, to identify and avoid unnecessary system-wide risks and to absorb shocks. Macroeconomic policy can also aim on mitigating the probability of financial distress phases that might have harmful economic impact. This is connected to repressing the banks' behavior that is unhealthy for the economy. For instance, lowering bank's leverage, mitigating moral hazard or removing liquidity mismatch in bank's balance sheet. Furthermore, sufficient emphasis should be put on interconnectedness of the financial system and channels between individual institutions. Consequently, one possible objective might be a build-up of a set of indicators that would monitor and assess these linkages. This objective would comply with the cross-sectional dimension of macroprudential regulation. Regarding the time dimension, a suitable objective would be a creation of financial buffers that would act countercyclically and prevent the system from taking on excessive risk in good times.

In addition, objectives of any macroprudential regulation have to be alligned with other policies, such as fiscal or monetary ones. Indeed, there exists ongoing research on this issue which is discussed later. At the end, the interaction of macroprudential and monetary policies is the main focus of this work.

As stated in Lim et al. (2011), there are four categories of macroprudential objectives usually seen in practice. All of them tackle the issue of systemic risk in different forms: excessive credit flows, excessive leverage, liquidity mismatch and capital flows volatility. Identifying the objective is necessary for a proper design of macroprudential policy tools. As is described later for every objective described above there exists a suitable macroprudential regulation tool, while others might be inadequate in the particular case.

2.2   Tools

There is a broad variety of macroprudential tools being used these days. In addition to these, some countries employ also monetary, fiscal and exchange rate-related instruments in order to achieve prudential goals, according to Lim et al. (2011). The authors also state that most countries prefer easily implementable instruments with

a low degree of implementation lags and with a low probability of subsequent regulatory arbitrage. The arbitrage may arise especially in highly interlinked financial markets where individual institutions are not independent of each other. Furthermore, regulatory authorities prefer instruments that attain a high degree of effectivity without distorting the relevant market. Usually many instruments are used at the same time in order to achieve the highest efficiency. On the other hand, it might be cumbersome to administratively manage more instruments. There are several types of tools, each of them being suitable for aiming different objective. Lim et al. (2011) identify three classes of instruments: credit-, liquidity- and capital-related.

Tools focused on credit contain LTV ratios, constraints on credit growth and DTI ratios. These instruments are used to mitigate credit and asset price growth. They can aim specific objectives and therefore minimize the cost of regulation, as is emphasized by Lim et al. (2011). For instance, LTVs can be designed to address specific loans in a particular market. Moreover, these tools are usually managed to act countercyclically in order to limit excessive credit growth in boom and to constrain excessive credit contraction in recession. Consequently, as is reported in Lim et al. (2011), they are being adjusted frequently to achieve the countercyclical effect.

Liquidity-related instruments comprise of requirements on reserves and limits on currency and maturity/liquidity mismatch, as is described in Lim et al. (2011). They are used to address liquidity risk, i.e. a risk of insufficient liquidity in financial markets. Moreover, according to Lim et al. (2011), the intruments serve to limit the risk stemming from foreign capital inflow and currency fluctuations. Liquidity measures are frequently used in emerging economies which are usually more prone to liquidity risk, since the financial markets are less developed. In addition, these tools are used in the presence of small financial markets as is usually the case of emerging economies. Furthermore, managed and fixed exchange rate regimes are often accompanied by liquidity tools. This again corresponds to emerging countries.

Capital-related measures consist of countercyclical capital requirements, dynamic provisioning and constraints on profit distribution. Lim et al. (2011) maintain that these tools are employed in order to limit the risk of excessive leverage. They act countercyclically, hence they create buffers to absorb the effects of negative shocks. While the usage of most capital instruments is based on discretion, dynamic provisioning, for example, can be employed based on rules, i.e. on some particular formula which adjusts itself over the business cycle.

There are several factors which affect the choice of macroprudential instruments. One of them is the stage of development of a particular country and of the corresponding financial market. Prior to the crisis in 2007, developing countries used to employ macroprudential tools more frequently than developed countries, as is noted by Lim et al. (2011). The authors maintain that this extensive usage by developing

countries was caused by a need to avoid severe market failures that often occur in less developed financial markets. However, the crisis has induced also these countries to increase the usage of prudential measures. Another criterion for the choice of macroprudential tools is an exchange rate regime. As is emphasized in Lim et al. (2011), countries bounded with the obligation of fixed exchange rate are limited in their usage of interest rate as a tool to mitigate systemic risk. Therefore, these countries tend to use macroprudential tools more extensively. This supports the statement that developing countries make use of prudential instruments more frequently, since many developing countries, such as African countries, employ fixed exchange rates (or managed floating). The type of shocks hitting the economy provides another benchmark for deciding about suitable tools. A shock that is assumed to affect financial markets in a considerable way is the one in the form of capital inflow. Especially in small economies, such as those in developing countries, excessive capital growth might lead to a credit increase significant enough to impede financial stability. According to Lim et al. (2011), those countries then tend to choose credit-related instruments to soften the rise in capital.

To sum up, a vital pressumption for choosing the right macroprudential tools is to define clear objectives that should be achieved by the particular policy. Since different instruments are suitable for different types of systemic risk, knowing the type of potential risk and consequently setting the right goals is the key to a succesful macroprudential policy. In general, prudential measures should address the two dimensions mentioned above: the time and cross-sectional dimension. As of the former one, the instruments should act countercyclically, i.e. create buffers that limit credit growth in good times and mitigate credit contraction in downturns. Regarding the cross-sectional dimension, the tools should aim on the transmission channels between individual financial institutions that transfer and amplify system-wide shocks. As stated in Yellen (2011), the existing instruments do so by posing restrictions on banks' balance sheets and by limiting bank lending in booms in order to mitigate any negative procyclical effects.

Subsection 2.2.1 describes one of the most actual macroprudential policies - Basel III. Despite the fact that its implementation has not finished yet, the policy is worth mentioning, since it possesses some distinctive features which might help achieving financial stability.

2.2.1   Basel III

As the former Basel II accord proved inadequate during the last crisis, the need for strengthening of the banking supervision has emerged. Basel III is a common regulatory framework created by BCBS in 2010 in reaction to the failure of Basel II

(BCBS, 2011). Basel III is currently being implemented in the EU with the expected finalisation in 2019. While the accord is supposed to enhance financial stability, there has been a controversy about its impact on economic growth and banking industries. One of the main reasons of the severity of the last crisis, according to BCBS (2011), was excessive leverage maintained by banks. In response to that, Basel III sets a maximal leverage ratio that has to be attained by the banking institutions. The purpose of controlling banks' leverage is also to foster higher capital quality and the quantity of such capital. Another critical factor playing an essential role during the crisis was insufficient liquidity buffer held by banks. Consequently, when the credit crunch occured banks were not able to cover the losses by additional liquidity which led to a further worsening of credit intermediation. Therefore, Basel III sets out strengthened liquidity requirements, as described in BCBS (2013). In addition, the accord introduces net stable funding ratio requirements, as described in BCBS (2014). The purpose is to build a stable funding profile with respect to banks' assets. It also aims on reducing liquidity mismatch risk, as maturity transformation was one of the key elements governing the 2007 crisis.

While addressing leverage and liquidity buffers has a microprudential nature, Basel III regulation tackles also macroprudential perspectives. In particular, it focuses on cyclicality underlying the business cycle. It introduces countercyclical capital buffers which are designed to mitigate the procyclical effects of bank lending. Namely, capital requirements should increase in response to an excessive credit growth to ensure that banks have enough capital when facing system-wide shocks. In addition to countercyclical buffers, Basel III also enhances credit risk coverage, focusing especially on counterparty credit risk. It proposes analytics to measure such risk and a method for its evaluation, as stated in BCBS (2011).

As has been already mentioned above, there are concerns regarding the effects of Basel III on GDP, economic growth and bank lending. Considering these potential negative effects, Basel III might even impede financial stability by supporting the occurence of a system-wide distress.

Repullo and Saurina (2011) state that countercyclical capital requirements, as set out by Basel III, do not act countercyclically as they decrease with high GDP growth and increase when the growth is low. Consequently, banks are able to rise credit to an excessive extent in good times, while they are required to limit lending in bad times. This mechanism opposes the purpose of Basel III to build countercyclical buffers in order to mitigate the negative cyclical effects of the business cycle. The authors propose that capital requirements should be revisited in order to achieve countercyclicality.

Angelini et al. (2011) estimate the impact of Basel III regulation on the level of on economic performance in the long-term, on economic fluctuations and on bank credit

volatility. The authors find that capital and liquidity requirements have a negative effect on steady state output and on welfare which is measured by consumption. However, it is emphasized that the estimates may not be robust and might involve a certain degree of uncertainty, since it is difficult to compute a rigorous measure of the effect. In addition to Angelini et al. (2011), Slovik and Cournede (2011) also provide negative estimates of the impact of Basel III regulation on the GDP growth. Regarding economic fluctuations, Angelini et al. (2011) find that tighter capital requirements dampen output volatility, despite the decrease being moderate. Countercyclical buffers further contribute to reducing output volatility. However, as emphasized by the authors, this result is not robust as it depends on specific model assumptions and parameterization.

On the contrary, Allen et al. (2012) argue that there might not be any negative effects of enhanced banking regulation on output in the long-run. Furthermore, the authors state that the cost of credit may not be affected as well, or that the effect can be of little importance. However, this does not hold for risky clients, whose credit cost might rise substantially after introducing Basel III regulation. Moreover, Allen et al. (2012) maintain that if banks react to the regulation by reducing credit, economic growth might be threatened. In addition, the authors suggest to employ banks' clients into the discussions about banking regulation as their willingness to hold long-term bank liabilities instead of short-term deposits needs to be enhanced. Unlike Allen et al. (2012), Mustilli, Campanella and D'Angelo (2017) find, examining banking data from 2014, that there is a negative relationship between Basel III capital requirements and the amount of credit in the economy. Their empirical analysis suggests that introducing Basel III measures resulted in a credit crunch. The contraction in bank lending might have been caused by increased credit costs which was induced by employing the new regulatory framework. This contradicts the prediction of Allen et al. (2012) that the impact of Basel III on lending costs will be negligible. Furthermore, Mustilli, Campanella and D'Angelo (2017) suggest that in order to limit risk banks are forced to invest more into government bonds which are associated with lower rates of return and consequently with lower bank profits. As a results, financial institutions may become more vulnerable than when investing into other types of assets. The same conclusion provide Allen et al. (2012) who argue that banks are forced into government bond investments due to stringent liquidity requirements.

The disparateness between predictions and subsequent empirical estimates described above can be explained by different national charasteristics regarding banking industries. This issue is tackled by Howarth and Quaglia (2016). The authors argue that the implementation of Basel III might have a different impact on output growth depending on the features of the particular banking sector. Three countries are ex-

amined: Germany, United Kingdom and France. Howarth and Quaglia (2016) claim that in countries like Germany, the regulation is more likely to have a negative effect on bank lending. Consequently, the regulators should be more focused on the impact of the requirements on economic growth. On the other hand, countries such as United Kingdom, i.e. countries having banks with strong capital positions, would be more concerned with the regulatory measures themselves as the adverse effects on economic growth are not very likely.

Despite any potential difficulties, Basel III forms a promising step towards financial stability. It fosters cautious behavior in banking industries in terms of credit growth, balance sheet structure and risk exposure. The regulatory framework provides an important guidance on risk management and banking supervision. While the accord might still contain some shortcomings, it is a significant prudential measure that has the potential of bringing the economy closer to financial stability.

The last two sections described macroprudential objectives and tools. Clearly, defining these two features is essential for several reasons. Firstly, according to Ingves (2011), a reasonable degree of transparency in the conduct of macroprudential policy is required in order to prevent it from political pressures that might impede a successful policy implementation. Macroprudential authority should be able to undertake actions which involve short-term costs in order to achieve long-term goals leading to financial stability. At the same time, the authority should be always responsible for its actions, as is emphasized by Ingves (2011). For all these reasons, it is necessary for the objectives and instruments of any macroprudential policy to be clearly defined. Moreover, stating clear objectives in the beginning of the regulation process might help justify unfavorable policy actions that may arise later. In addition, knowing the precise formulation of macroprudential objectives allows the authority to distinguish between them and, if necessary, rank them based on relative importance.

In addition to clearly defined objectives and available instruments, macroprudential authority also needs to be equiped with information and analytical tools regarding systemic risk. Detecting and measuring the degree of systemic risk in the economy is essential for any macroprudential policy to be successful. Therefore, Chapter 3 is aimed on indicators and measures of systemic risk.

Chapter 3

Systemic Risk

As has been already emphasized in Section 2.1, there is no consensus on the exact definition of systemic risk. "...systemic risk may be hard to define but they know it when they see it, ..." (Bisias et al. 2012) While this might be a true statement, there is still need for a clear definition of systemic risk. Various measures of and approaches to systemic risk hinge on its precise definition. Not only that suitable analytical tools differ by the definition, but also required set of data, measurement output or periods to be analyzed depend on what is called systemic risk.

Since there are many possibilities of how to define systemic risk, consequently there are also many available tools to measure it. As it cannot be said unambiguously which of the measures should be preferred, it seems optimal and desirable to employ a set of indicators. Only this way the highest possible efficiency can be achieved, because the issue is tackled from different angles so that blindspots are eliminated. Otherwise, there will always be a risk of missing some important source of systemic risk which may have serious consequences for assessing financial stability. Consequently, the supervisory authority should design a robust strategy for systemic risk measurement which does not overlook any significant mechanisms. In addition, the authority has to decide how frequently the measurements are conducted, in which industries and on what kind of data (aggregated vs. disaggregated), as is pointed out by Bisias et al. (2012). Furthermore, according to the authors, the measuring tools have to be updated regularly in order to produce reliable results, since financial markets are innovated frequently and therefore have dynamic environment. Those are responsibilities that might be lethal for the economy and its financial stability if they are not handled correctly.

Conducted measurements and systemic risk analyses are necessary for several reasons, as described in Bisias et al. (2012). Firstly, they help macroprudential authorities target SIFIs and hence aim prudential regulations on the most vulnerable industries. Secondly, they indicate periods when macroprudential policies should be

tightened. Thirdly, ex-post analyses of financial distress contribute significantly to broad understanding of systemic risk and therefore help building efficient regulatory policies. On the other hand, the analyses might also discover weaknesses of existing policies which enables their improvement over time.

According to Bisias et al. (2012), despite the usefulness of systemic risk metrics, there are considerable limitations that regulatory authorities have to bear in mind. As stated above, financial markets possess a dynamic structure which is not easily modelled. Consequently, the forecasts have to be interpreted with caution, since other important aspects might be in play that are not captured by the analytical model. Hence, the authorities may find themselves in a situation in which they have to make a regulatory decision not solely based on estimation results. Instead, they need to rely on their own judgment that cannot be supported by exact numbers. But even if the forecasts can be deemed reliable, there is still a considerable degree of discretion in the hands of authorities. In this case, regulators face two issues, as described in Bisias et al. (2012). Firstly, an early action against possible systemic threat may cause a disruption of services of the particular financial institution and therefore forcing it out of business. On the other hand, delaying regulatory intervention imposes a considerable risk on the economy by not addressing possible threats. It cannot be said ex-post which of the two options involves lower social cost and hence should be chosen by the regulator. In general, according to the authors, regulator's decision in this case depends on her attitude towards risk. But it surely applies that high accuracy of systemic risk measures can help eliminate the possibility of decision errors. The better indicators are at regulator's disposal, the better decision can she make regarding the timing of corrective actions.

Except the caveats mentioned above, there is another issue concerning the evaluation of estimation processes. The so called Lucas critique, based on Lucas (1976), clearly applies for the systemic risk measurement. The critique says that the effects of a particular policy change cannot be estimated using only historical data, since the decision rules (such as technology or consumption functions) are not insensitive to the policy change (Lucas, 1976). Therefore, using crisis-period data for estimating systemic risk might be misleading as agents act differently in crisis and non-crisis periods. In addition, indicators of systemic risk may by themselves alternate agents' behavior. This can even lead to a self-fulfilling prophecy issue[1] - observing an indicated high level of systemic risk, agents might take risky actions in order to rescue themselves which would lead to even higher level of system-wide risk. It brings up a question of whether risk indicators should be public or not. As emphasized by Bisias et al. (2012), making the forecasts public has the advantage of spreading the information of potential risk which can force market participants to behave more

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[1]Self-fulfilling crises are well-described in Cole and Kehoe (2000).

cautiously. On the other hand, the effect might be exactly the opposite leading to a worsening of the current situation. In this case, not publishing the indicators seems like a good option, since it would prevent the agents from altering their behavior negatively.

The possibility of negative change in agents' behavior stems from the fact that individual institutions cannot correctly assess the impact of their individual actions on the overall stability of the financial system. Furthermore, as mentioned in Bisias et al. (2012), while financial stability is beneficial for everyone, individual firms may find it optimal to take actions that impede the stability. Hence, financial institutions share benefits of the stability but there is no mechanism that would internalize the cost of hurting financial stability by institutions' individual actions. Therefore, there is a need for corrective measures that would impose additional cost on firms negatively affecting financial stability. Indicators of systemic risk are in this case useful tools for determining which SIFIs should bear those additional cost, such as Pigouvian taxation. They can also indicate the size and timing of the tax.

Based on Bisias et al. (2012), another rationale behind firms' behavior that negatively affects stability is moral hazard. As institutions expect governmental bailout to come in times of crisis, they may start acting recklessly and hence contribute to the occurence of the crisis itself. The same logic applies to deposit insurance which creates the same issue as described above - individual institutions do not bear the costs of their irresponsible actions.

The above lines emphasize the importance of systemic risk measures. However, there are also caveats, such as Lucas critique, that have to be approached with caution. Section 3.1 is focused on particular indicators of systemic risk. While there exist many tools with microfoundations, most attention will be devoted to macroprudential measures, such as stress tests, as those are the most important ones for the design of macroprudential policies.

3.1   Indicators

As has been already mentioned, indicators of systemic risk can have either microprudential or macroprudential nature. Microfounded measures are aimed on individual institutions, in particular on SIFIs. They require firm-level data to perform analytics which makes them more difficult to conduct as compared to macroprudential indicators which use aggregated datasets. On the other hand, microprudential measures provide a useful insight into stability of financial market participants. However, relying only on micro-based tools might be misleading as this approach neglects possible imbalances stemming from market interconnectedness. In particular, a single "unhealthy" institution can be a threat to the whole industry and potentially to the

whole economy if market participants are linked to each other, especially throught their balance sheets. Therefore, it is necessary to apply also macroprudential approach in order to assess correctly all the effects of financial imbalances. That means assessing not only the impacts on individual institutions, but also on the system as a whole. The relationship between the financial system network and systemic risk is captured in Acemoglu, Ozdaglar and Tahbaz-Salehi (2015). The authors assess the impact of interconnectedness between financial institutions on the likelihood of systemic failures. They show that if the amount of shocks hitting the economy is sufficiently large, then a less interlinked financial market is less prone to systemic risk. The reason is that the links between individual institutions provide transition channels for negative shocks. Hence, based on Acemoglu, Ozdaglar and Tahbaz-Salehi (2015), it is not sufficient to study the resilience of a single financial institution to shocks. An emphasis has to be put on examining linkages in the particular financial market. In addition, according to Acharya (2009), systemic risk arises as a result of correlation between banks' assets. Therefore, "...regulating each bank's risk cannot capture fully the risks that could propagate through a nexus of contracts" (Acharya, 2009). For this reason, the rest of this subsection is focused on macroprudential measures, as they are vital for the correct assessment of system-wide risk.

It has been emphasized above that timing plays a key role in the regulatory process. Macroprudential policymaker has to decide not only whether and how to apply a particular corrective action, but also when it should be done so. The costs of acting too quickly or too slowly are described in the first part of Section 3. Hence, the time dimension of systemic risk indicators is particularly significant in order to help the regulatory process. Consequently, following Bisias et al. (2012), the risk analytics can be clasified into three categories: ex-ante, contemporanous and ex-post.

3.1.1   Ex-ante

Ex-ante indicators should serve the same purpose as weather forecasts - issuing reasonably accurate warnings against upcoming "hurricanes" and other negative conditions, as mentioned by Bisias et al. (2012). By providing an early warning against emerging imbalances they give regulators enough time to intervene and therefore to limit potential upcoming losses. For that purpose ex-ante measures should possess a reasonable degree of forecast power. Examples of such measures involve SES indicators, stress tests, and credit risk predictions.

Financial stress tests is a useful tool for analyzing financial weaknesses and imbalances. They are used worldwide by regulatory and supervisory authorities such as EBA. The tests provide simulations of responses of financial markets and their institutions to particular adverse scenarios. These scenarios may contain a drop in GDP,

a rise in unemployment or a sudden contraction in credit supply. European Banking Authority (2017) provides a description of stress-testing that will be conducted in 2018. The test includes credit risk, market risk and counterparty credit risk, and operational risk. In particular, banks have to estimate the effects of these risks on their net interest incomes and profit and loss accounts (European Banking Authority, 2017). Another example of credit risk stress-testing is Vazquez, Tabak and Souto (2012).

Despite their potential benefits regarding identification of systemic vulnerabilities, stress tests have certaing limitations that were proved by their inability to indicate the risk prior to the 2007-crisis. According to Borio, Drehmann and Tsatsaronis (2014), it is important not to have unreasonable expectations about what the tests can do. The authors maintain that the tests are best suited for crisis management rather than indicating systemic vulnerabilities. Alfaro and Drehmann (2009) suggest three features that a well-designed test should possess. First, it is essential to use the correct model. In particular, stress-testing assumptions should be in line with historical data. Second, the scenarios should maintain both severity and plausibility. Last, the tests have to be robust. The authors emphasize that stress-testing results should be interpreted with caution and that they should be seen only as a starting point for further regulatory discussion.

A complement to stress testing are SES indicators, as described in Acharya et al. (2017). This approach allows to predict institutions that highly contribute to the overall system-wide risk. The identification of such institutions is critical, since "unless the external costs of systemic risk are internalized by each financial institution, the institution will have the incentive to take risks that are borne by all" (Acharya et al. 2017). Therefore, SES measures help predicting the institutions that might be a threat to financial stability. In addition to SES, Xie and Zhao (2016) use a MES method to estimate a marginal contribution of a bank to the overall risk in the China's banking sector. They also examine various factors affecting MES using panel-data regressions.

3.1.2 Contemporaneous

Contemporaneous indicators should be updated on a high-frequency basis in order to provide regulators with the most up-to-date information about the current state of the economy. The indicators include fragility measures, such as the one described in Billio et al. (2012). In their work the authors estimate a network relationships connecting financial institutions which can serve as a prediction of financial crisis periods. In addition to the fragility measures, SES and MES tools as described in Acharya et al. (2017) and Xie and Zhao (2016) might also possess a contemporanous

nature if daily data is used for the estimation. Daily VaR measures such as the one proposed by Fuertes and Olmo (2013) also form an appealing alternative for contemporaneous risk management.

3.1.3 Ex-post

Ex-post crisis analysis plays an important role in the field of macroprudential regulation. Firstly, according to Bisias et al. (2012), it enables regulators to learn from the foregone distress and hence helps improving current regulation and policy interventions. Secondly, early ex-post reports may prevent public or financial agents from herd behavior and therefore stop worsening of an ongoing crisis. Thirdly, post-crisis research helps determine the causes and factors affecting the likelihood of the crisis occurence.

Hellwig (2009) analyzes the recent subprime-mortgage crisis, especially its sources and transition channels that caused worldwide spreading of the crisis. The author maintains that the financial sector was not sufficiently regulated which contributed to the uprise of financial distress. Moreover, some regulatory mechanisms created a downward accelerator spiral that worsened the situation. This indicates a wrong design of the regulations in place prior to the crisis.

Schwaab, Koopman and Lucas (2016) determine industry- and country-specific factors affecting systemic risk conditions. They find that there exist world-common factors causing default variation. Hence, there is a credit cycle present in world economies. Moreover, there is a correlation between finacial lending standards and default risk. Since the relationship is negative, a contraction in the standards might lead to a higher degree of systemic risk. Therefore, the authors suggest that the bank lending conditions should be included in stress-testing scenarios in order to capture the mentioned effects.

To sum up, there is a large variety of systemic risk indicators and they can be categorized in many ways. The time-categories described in this section reflect the importance of the time dimension of macroprudential regulations. As macroprudential authorities face not only the issue of what corrective actions to take but also when to take them, precise and reliable indicators of systemic risk are necessary for a successful conduct of any macroprudential policy.

Systemic risk brings many threats to financial markets, one of them being a possibility of bank runs. As bank runs played an important role in the 2007-crisis and since they are a significant part of this work, the next section is focused on them.

3.2   Bank Runs

Bank run is a natural culmination of excessive systemic risk in the economy. A bank run usually stands in the beginning of every financial crisis, causing financial distress and recession. Governments in an effort to prevent a particular bank from bankrupcy, that might occur as a consequence of a bank run, often undertake expensive and sometimes controversial bailouts. Consequently, banks might in anticipation of a governmental rescue take on more systemic risk which creates a moral hazard problem.

Papers concerning bank runs differ especially with respect to the sources of runs. One class of models considers beliefs of depositors as a source of possible bank runs. Diamond and Dybvig (1983) and similar models belong to this category. In these models banks are subject to a run whenever depositors expect other depositors not to roll over their deposits. When a depositor believes that the others are not going to roll over, she will not roll over as well, as the deposit payments in case of a run depend on the place in a queque - the sooner a depositor withdraws, the higher the share of promised deposit payment she receives. Another class involves models that connect bank runs to fundamentals. One example of such framework is Gertler and Kiyotaki (2015). The authors describe an economy where bank runs are modelled as sunspots but the probability of an existence of sunspot equilibria is endogenous and depends on banks' balance sheet conditions. The fact that financial risk in the economy is connected to fundamentals is examined also in Gertler, Kiyotaki and Queralto (2012). However, as noted in Kiss, Rodrigueq-Lara and Rosa-Garcia (2017) bank runs may be caused by neither expectations nor fundamentals. The authors show that depositors withdraw, even though it is not rational, when they observe other depositors withdrawing. This type of bank runs is called panic bank runs.

Regarding governmental bailouts, Keister and Narasiman (2016) study the relationship between the moral hazard issue and whether a bank run is driven by expectations or fundamentals. The authors find that the same policy intervention is optimal for both situations of expectaions-driven and fundamentals-driven bank runs as long as some other policy is in place which corrects fot the incentive distortion caused by the bailout.

Another way of categorizing bank runs literature is based on where the run occurs - retail-level or wholesale-level. The papers mentioned above consider bank runs on retail-level, i.e. the disruption of funds occurs between a retail bank and its depositors. However, a bank run can occur also on a wholesale-level, i.e. a bank borrows from other banks and when a wholesale-level run occurs this intermediation channel is disrupted. Wholesale runs are modelled for example in Gertler, Kiyotaki and Prestipino (2016). The work depicts how the existence of wholesale runs is affected

by the degree of leverage and the total amount of wholesale borrowing. In addition to retail and wholesale runs, there are also papers examining double runs, i.e. bank runs occuring at both retail and wholesale level. For instance, Ippolito et al. (2016) describe a model where a wholesale-level bank run disrupts the intermediation of funds between banks and therefore affects bank's liability side of the balance sheet, while a retail-level bank run comes from firms which limit their usage of banking loans and therefore run on the asset side of bank's balance sheet. The authors find using empirical crisis-data that under certain circumstances there is a relationship between wholesale liquidity risk and the probability of a retail-level bank run. Furthermore, their results suggest that banks imposed to risk apply some form of risk management and lend mostly to firms that are less likely to run if a wholesale run occurs.

This chapter provided an overview of systemic risk indicators and also described a natural result of an excessive risk in the economy - bank runs. Both bank runs and systemic risk indicators are essential for designing macroprudential policies. The indicators equip regulators with useful information regarding the current state of the economy. Regarding bank runs, as one of the main goals of any macroprudential regulation is preventing bank runs from occuring, it is necessary to understand not only their potential sources, but also all their possible forms in order to apply the best regulatory design.

There is one more aspect that is important for determining a suitable macroprudential policy - the relationship between macroprudential regulations and other policies, such as monetary ones. Therefore, Chapter 4 examines the interaction between macroprudential and monetary policies. In the first part of the chapter, relevant literature concerning the underlying issue is reviewed. In the second part, a baseline model of the interaction between the two policies in the presence of bank runs is described.

Chapter 4

Interaction between Macroprudential and Monetary Policies

For a long time price stability was the only target of monetary policies. It was assumed that pursuing this goal together with microprudential regulation will be enough to achieve the overall financial stability. However, the recent crisis in 2007 proved the opposite. Micro-based regulatory measures appeared to be inadequate as they did not manage to prevent the economy from a significant financial distress. Moreover, a question arised asking whether there is not more that can be done by monetary authorities.

This question is examined in Bailliu, Meh and Zhang (2015). The authors focus on the issue of whether monetary authority should address financial imbalances stemming from asset price movements. They also examine whether the imbalances should be tackled by monetary policy only or whether it is better to employ both monetary and macroprudential policies. Their analysis suggests that from a welfare perspective it is more beneficial to use both types of policies.

However, it is still not clear how the two policies affect each other. They use different instruments and pursue different objectives and therefore they do not conflict in these areas. On the other hand, they operate through the same channels. In particular, they both affect behavior of banks and other financial institutions and hence have an impact on borrowing and lending in the whole economy.

There are several ways of how macroprudential and monetary policies can have a negative impact on each other's target. According to Beau, Clerc and Mojon (2011), a loosening of monetary policy by decreasing the policy interest rate might have an adverse effect on financial stability. Since monetary authority aims on stabilizing goods prices and does not take into account asset prices, it may have a destabilizing

impact on the financial market. Suppose that an excessive supply in the goods market forces the central bank to decrease the policy rate. Lower interest rates might induce banks to take on more risk, e.g. through increasing leverage. If the macroprudential authority reacts to the situation by tightening its instruments, a pressure on price stability might arise that will force the monetary authority to decrease the interest rate further. On the other hand, there can also be a positive effect of monetary instruments on macroprudential ones (and vice versa). However, as noted by Smets (2014), the policies reinforcing each other might result in overshooting the original targets and therefore can have a negative impact on the economy.

Another channel through which monetary authority has an impact on macroprudential policies is through the effect of a monetary policy on the behavior of banks. In particular, De Nicolo et al. (2010) describe the connection between monetary policy and risk-taking by banks. The authors emphasize that there are several channels through which the effect operates. One example of monetary policy inducing risk taking is through leverage, as is mentioned above. Loosening of monetary policy has a positive effect on asset prices which implies higher net worth of a bank. As stated in De Nicolo et al. (2010), banks react to higher net worth (i.e. lower leverage) by increasing their demand for assets. This boosts asset prices even more and makes the market more fragile. Another channel, as described in De Nicolo et al. (2010), finds itself in the limited liability problem. As banks do not have enough "skin in the game", they behave riskier than they normally would. In particular, banks do not internalize any effects that their risky behavior have on investors and depositors. This creates a moral hazard problem which can be overcome by posing restrictions on banks such that they have to bear a higher share of loss in case of failure. How much a bank can lose usually depends on its value and profits. Therefore, since monetary easing has a positive impact on bank profits, it mitigates bank risk-taking as failure becomes more costly.

The above arguments suggest that the two policies may affect each other and in order to prevent negative externalities from occuring it is neccesary to know the direction and size of such effects and under which circumstances they might occur. There are several papers examining the issue at hand.

Angeloni and Faia (2013) use the framework of Diamond and Rajan (2001) to model an economy in which banks lend funds to households and entrepreneurs who then finance risky projects. Financial risk in this model stems from the uncertainty about the payoff of a particular project. Angeloni and Faia (2013) then use this setup to examine the interaction between monetary and macroprudential policies. The authors find that the best policy mix that mitigate financial imbalances is the one consisting of countercyclical capital requirements and monetary policy that lean against the wind.

A different approach is adopted by De Paoli and Paustian (2013). They build a model where firms borrow from banks in order to finance wage costs. However, their borrowing ability is limited by a borrowing constraint which depends on firms' net worth. One of the main findings in this setup is that non-cooperating authorities should act conservatively. Furthermore, if the macroprudential authority is assigned a target that is similar to the one of monetary authority, there might be coordination issues arising in equilibrium. The authors use a welfare function in order to rank particular policy arrangements.

The problem regarding similar policy targets arises also in Gelain, Lansing and Mendicino (2013). The model involves a housing market and housing capital acts as a collateral for impatient households who are subject to a borrowing constraint. The authors study different types of policy regimes and also different forms of expectations adopted by agents. Their analysis suggests that when monetary policy responds to housing prices and credit growth, resulting inflation is highly volatile. In particular, when monetary policy tackles the financial stability issue it misses its own target - price stability. However, the authors note that these results might depend on the type of expectations formed by agents.

Another work focusing on housing market and employing borrowing constraints is Rubio and Carrasco-Gallego (2016). Their model involves three types of agents - savers, borrowers and banks. Borrowers are limited by a borrowing constraint while banks are restricted by a macroprudential policy in the form of capital requirements. In this framework it is found that higher capital requirements induce tighter monetary policy. Moreover, macroeconomic policy in this setup achieves financial stability without jeopardizing the monetary target of price stability.

The approach adopted in this thesis for examining the interaction between the two policies is taken from Angelini, Neri and Panetta (2014). They study the cooperation between monetary and macroprudential authorities by allowing them to minimize a joint loss function. This case is then compared with the one when each authority minimizes its own loss function taking the other's policy as given. The two regimes are ranked based on the minimized loss and on a welfare criterion.

However, the model described in this chapter differs from Angelini, Neri and Panetta (2014) in modelling the banking sector. The one used here follows Gertler and Kiyotaki (2015). In particular, banks may be subject to a run if their assets are not enough to cover the liabilities. Moreover, banks are constrained not only by the macroprudential policy in the form of capital requirements, they also face a moral hazard problem which further restrics their leverage ratio.

The rest of the chapter describes the baseline model. The discussion of simulation results can be found in the following chapter.

4.1   The Baseline Model

The baseline model consists of four types of agents - households (savers), entrepreneurs (borrowers), goods retailers and bankers. In addition, there are two authorities, one conducting monetary policy and the other one setting macroprudential regulation.

Households consume and invest in capital. They rent the capital and supply labor to entrepreneurs who pay them a rental rate r_t and a wage w_t. In addition, households save in the form of deposit holdings in banks. They received a promised interest rate R_t^d unless a bank run occurs. In that case, they get a rate R_t^{d*} which is strictly lower than the promised rate. However, households do not anticipate any bank runs and therefore only the promised rate enters their optimization problem.

Entrepreneurs consume and produce consumption goods. They use capital and labor as production inputs. In the baseline model, production is subject to a productivity shock. Entrepreneurs sell the final products to goods retailers who apply a markup over the wholesale price p_t^w and subsequently sell the final goods to households. Moreover, as entrepreneurs are impatient consumers, they take loans from banks.

Goods retailers buy consumption goods from entrepreneurs, add a markup to the wholesale price and then sell the final goods to households who aggregate them using a CES aggregator.

Banks provide short-term deposits to households and long-term loans to entrepreneurs. However, the amount of loans is limited by a capital requirement set every period by the macroprudential authority. Furthermore, bankers face a moral hazard problem of whether or not to divert the raised funds for private use. Since the incentive constraint depends on leverage, too high leverage induces depositors not to roll over their deposits and forces banks into liquidation.

Monetary and macroprudential authorities set the policy rules in order to minimize the respective loss functions. In case of non-cooperation, the authorities make decisions separately and take each other's policy as given. When the authorities cooperate they minimize a joint loss function and hence take into consideration the effects of one policy on an objective of the other.

4.1.1   Households

Households derive their utility from consumption of goods and the amount of labor. Each period they invest into deposit holdings and capital. However, holding capital is costly with the costs being quadratic. Households then provide capital and labor to entrepreneurs who use these inputs to produce consumption goods. Therefore,

households' optimization problem is to maximize the intertemporal utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^h - \frac{L_t^{1+\xi}}{1+\xi} \right) \tag{4.1}$$

subject to the budget constraint

$$C_t^h + D_t + K_t + \frac{\delta}{2}(K_t^2) = w_t L_t + r_t K_{t-1} + \frac{R_t^d}{\pi_t} D_{t-1} \tag{4.2}$$

The left-hand side of (4.2) consists of households' expenses, i.e. consumption, deposit holdings and cost of acquiring capital in t which is parameterized by δ. The right-hand side then represents households' resources containing wage payments, rental of capital and interest payment from deposits invested in $t-1$, where π_t is the inflation of consumption goods prices. Moreover, R_t^d is the gross nominal interest rate on deposits held from $t-1$ to t and ξ is an inverse of the Frisch elasticity.

Solving the optimization problem with respect to deposit holdings, labor and capital yields the following first-order conditions

$$\beta \frac{C_t^H}{C_{t+1}^H} \frac{R_{t+1}^d}{\pi_{t+1}} = 1 \tag{4.3}$$

$$\frac{1}{C_t^H} w_t = L_t^{\xi} \tag{4.4}$$

$$\beta \frac{C_t^H}{C_{t+1}^H} r_{t+1} = 1 + \delta K_t \tag{4.5}$$

4.1.2 Entrepreneurs

Entrepreneurs produce consumption goods and take loans from banks. They are perfectly competitive and they sell the goods at a wholesale price to retailers who aggregate them and sell to households. Entrepreneurs employ labor and capital provided by households to produce consumption goods according to the production function

$$y_t = \epsilon_t^y K_t^{\alpha} L_t^{1-\alpha} \tag{4.6}$$

where the first term is a productivity shock equal to $\epsilon_t^y = exp(-z_t)$ with $z_t = \rho_z z_{t-1} + e_t$ and α is capital productivity. Each entrepreneur maximizes the utility function

$$E_0 \sum_{t=0}^{\infty} \Lambda^t \ln C_t^e \tag{4.7}$$

facing the budget constraint

$$C_t^e + \frac{R_t^b}{\pi_t} B_{t-1} + w_t L_t + r_t K_{t-1} = p_t^w y_t + B_t \tag{4.8}$$

and the production function (4.6). R_t^b is the gross nominal interest rate on loans from $t-1$ to t. $p_t^w = \frac{P_t^w}{P_t}$ is the wholesale price relative to retailers' price.

Every entrepreneur then chooses the amount of loans, capital and labor which gives the following conditions

$$\Lambda \frac{C_t^E}{C_{t+1}^E} \frac{R_{t+1}^b}{\pi_{t+1}} = 1 \tag{4.9}$$

$$r_{t+1} = \alpha p_{t+1}^w \frac{y_{t+1}}{K_t} \tag{4.10}$$

$$w_t = (1-\alpha) p_t^w \frac{y_t}{L_t} \tag{4.11}$$

4.1.3 Goods Retailers

Retailers in this economy, similarly as in Gerali et al. (2010), act as branders - they buy consumption goods at the wholesale price from entrepreneurs, differentiate them without any cost, add a markup over p_t^w and sell the goods to households who aggregate them according to CES aggregator. Moreover, prices charged to households are sticky implying that retailers face quadratic adjustment costs parameterized by κ^p. Therefore, every retailer chooses $P_t(j)$, a price that is charged for variety j, to maximize the profit

$$E_0 \sum_{t=0}^{\infty} \Gamma^t \left(P_t(j) y_t(j) - P_t^w y_t(j) - \frac{\kappa^p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{i_p} \pi_{ss}^{1-i_p} \right)^2 P_t y_t \right) \tag{4.12}$$

subject to a household's demand for variety j derived from the CES aggregator problem

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon^d} y_t \tag{4.13}$$

In the above equations, i_p is the weight of previous period inflation in price adjustment cost and π_{ss} is the steady state inflation. Furthermore, ϵ^d is the elasticity of substitution.

After plugging (4.13) into (4.12), the first-order condition with respect to $P_t(j)$ reads

$$1 - \epsilon^d + p_t^w \epsilon^d = \kappa^p \left(\pi_t - \pi_{t-1}^{i_p} \pi_{ss}^{1-i_p} \right) \pi_t - \Gamma \kappa^p \left(\pi_{t+1} - \pi_t^{i_p} \pi_{ss}^{1-i_p} \right) \pi_{t+1}^2 \frac{y_{t+1}}{y_t} \tag{4.14}$$

where $p_t^w = \frac{P_t^w}{P_t}$, $\pi_t = \frac{P_t}{P_{t-1}}$ and $P_t(j) = P_t$, $y_t(j) = y_t$ in equilibrium.

4.1.4 Bankers

The banking sector modelled here corresponds to the one in Gertler and Kiyotaki (2015). Banks are owned by bankers. Each banker issues short-term deposits, holds long-term assets in the form of loans provided to entrepreneurs and accumulates net worth from retained earnings. In order to limit the possiblity of accumulating enough net worth to cover all the asset holdings, bankers have a finite lifetime. With probability σ a particular banker will survive to the next period and with probability $1 - \sigma$ she will exit the industry. Therefore, the expected lifetime of every banker is $\frac{1}{1-\sigma}$.

Every period there are new bankers entering the industry who replace the exiting ones. They start operating with an initial endowment equal to w^b. The endowment is received only in the first period when the banker enters the industry.

When a banker exits she derives utility at the end of period t from consumption as given by

$$E_0 \sum_{t=0}^{\infty} \beta^{t+1} (1 - \sigma) \sigma^t c_{t+1}^b \tag{4.15}$$

$(1 - \sigma)\sigma^t$ is the probability of exiting in period $t + 1$, while c_{t+1}^b is the terminal consumption of an exiting banker. Moreover, it is assumed that bankers use the same discounting β as households.

For continuing bankers, net worth n_t is accumulated according to

$$n_t = R_t^b b_{t-1} - R_t^d d_{t-1} - \frac{\kappa^b}{2} \left(\frac{n_{t-1}}{b_{t-1}} - \nu_{t-1} \right)^2 n_{t-1} \tag{4.16}$$

The first two terms in the above equation are interest payments from loans and deposits, respectively. The last term represents quadratic adjustment costs parameterized by κ^b and faced by a banker whenever her net worth to loan ratio diverts from the policy target ν set by the macroprudential authority. In particular, ν is a capital requirement set every period in order to limit excessive bank lending. The quadratic cost term distinguishes the model presented here from the one in Gertler and Kiyotaki (2015) as their work does not involve any macroprudential policy measures.

For entering bankers in t, net worth is equal to the initial endowment

$$n_t = w^b \tag{4.17}$$

while the exiting bankers in the same period use their net worth for consumption

$$n_t = c_t^b \tag{4.18}$$

Furthermore, the following identity holds

$$b_t = n_t + d_t \tag{4.19}$$

i.e. every period the amount of loans has to be financed by accumulated net worth and newly issued deposits.

The reason why bankers are constrained in their ability to raise deposits is that they face a moral hazard problem. Every period bankers face a choice between diverting part of the assets b_t and selling them at a secondary market using the raised profits for personal purposes, and operating honestly, i.e. keeping the assets until $t+1$, collecting the corresponding interest payments and paying the depositors the promised rate of return. It is assumed, as in Gertler and Kiyotaki (2015), that bankers cannot divert all of the assets but only a small fraction θ in order not to be exposed. The risk involved in assets diversion is that depositors can force the bankers into bankrupcy.

Depositors will provide funds to banks only if those have no incentive to divert assets. In particular, bankers will not divert any assets if the bank's value, i.e. present discounted future profits earned from operating honestly, exceeds one-shot profit from diverting funds. Namely, the bank's value represents the cost of diverting funds, as the value is lost in case of bankrupcy. Moreover, it is assumed that the diverted assets are sold at a price equal to unity. Therefore, the incentive constraint has the following form

$$\theta b_t \leq V_t \tag{4.20}$$

Banker's value V_t depends on her survival probability. With probability $1 - \sigma$ a banker exits the industry and consumes her net worth in the upcoming period. With probability σ a banker continues to operate and her value is equal to V_{t+1}. Consequently, the value in period t can be stated recursively as

$$V_t = E_t \left(\beta(1 - \sigma)n_{t+1} + \beta\sigma V_{t+1} \right) \tag{4.21}$$

Now let us write the growth of net worth as

$$\frac{n_{t+1}}{n_t} = R_{t+1}^b \frac{b_t}{n_t} - R_{t+1}^d \frac{d_t}{n_t} - \frac{\kappa^b}{2} \left(\frac{n_t}{b_t} - \nu_t \right)^2 \tag{4.22}$$

By applying equation (4.19) the net worth growth equation results into

$$\frac{n_{t+1}}{n_t} = (R_{t+1}^b - R_{t+1}^d)\phi_t + R_{t+1}^d - \frac{\kappa^b}{2} \left(\frac{1}{\phi_t} - \nu_t \right)^2 \tag{4.23}$$

where ϕ_t is bank's leverage and is defined as

$$\phi_t = \frac{b_t}{n_t} \tag{4.24}$$

Hence, leverage is a ratio of bank's assets to its net worth. High leverage means that bank issues too many loans or that its net worth is too small. Furthermore, it can be seen that there is a negative relationship between the macroprudential measure ν_t and bank's leverage ϕ_t. In particular, when ν_t rises it forces the leverage to go down and therefore limits excessive bank lending.

Now, following Gertler and Kiyotaki (2015), as the bank's value V_t is constant returns to scale, the banker's problem can be transformed into maximizing her value per unit of net worth, $\psi_t = \frac{V_t}{n_t}$, by choosing ϕ_t with respect to the incentive constraint (4.20). Hence, dividing (4.21) by n_t gives

$$\psi_t = \max_{\phi_t} E_t \left(\beta(1-\sigma)\frac{n_{t+1}}{n_t} + \beta\sigma\psi_{t+1}\frac{n_{t+1}}{n_t} \right) \tag{4.25}$$

Employing equation (4.23) yields

$$\psi_t = \max_{\phi_t} E_t \left\{ \beta\Omega_{t+1}[\, (R_{t+1}^b - R_{t+1}^d)\phi_t + R_{t+1}^d - \frac{\kappa^b}{2}\left(\frac{1}{\phi_t} - \nu_t\right)^2]\right\} \tag{4.26}$$

The banker's problem as formulated by the equation above applies an adjusted discount factor

$$\Omega_{t+1} = 1 - \sigma + \sigma\psi_{t+1} \tag{4.27}$$

It is a probability adjusted discount factor that represents an average value of an additional unit of net worth. An exiting banker determined with probability $1 - \sigma$ values an additional unit of net worth simply as unity, since this unit is just consumed. On the other hand, for a continuing banker (with probability σ) the additional unit is valued as ψ_{t+1}, i.e. the next period's value per unit of net worth.

Equation (4.26) can be interpreted as in Gertler and Kiyotaki (2015). The term

$$\mu_t = E_t \left\{ \beta\Omega_{t+1}(R_{t+1}^b - R_{t+1}^d) \right\} \tag{4.28}$$

represents a marginal value of loans over deposits, while

$$\eta_t = E_t \left\{ \beta\Omega_{t+1}R_{t+1}^d \right\} \tag{4.29}$$

is a marginal cost of deposits. The last term

$$\xi_t^b = E_t \left\{ \beta \Omega_{t+1} \frac{\kappa^b}{2} \left(\frac{1}{\phi_t} - \nu_t \right)^2 \right\} \tag{4.30}$$

is the adjustment cost per unit of net worth. Hence, equation (4.26) can be rewritten as

$$\psi_t = \max_{\phi_t} \left\{ \mu_t \phi_t + \eta_t - \xi_t^b \right\} \tag{4.31}$$

Dividing the incentive constraint (4.20) by n_t yields

$$\theta \phi_t \leq \psi_t = \mu_t \phi_t + \eta_t - \xi_t^b \tag{4.32}$$

Since the left-hand side of (4.32) is positive, the right-hand side has to be positive as well in order the inequality to hold. In particular, let us assume that $\eta_t - \xi_t^b \geq 0$. Consequently, the following has to hold in order to achieve the binding case of inequality (4.32)

$$0 < \mu_t < \theta \tag{4.33}$$

Assuming that the above condition holds, equation (4.32) can be restated as

$$\phi_t = \frac{\eta_t - \xi_t^b}{\theta - \mu_t} \tag{4.34}$$

4.1.5 Aggregation

Summing across all banks, the aggregate leverage is equal to

$$\Phi_t = \frac{B_t}{N_t} \tag{4.35}$$

where B_t is the amount of all loans in the industry and N_t is total net worth of all bankers.

Total net worth consists of the net worth of entering and continuing bankers. Fraction $1-\sigma$ of new bankers has net worth equal to the initial endowment w^b, while fraction σ of continuing bankers has net worth composed of loan interest payments net deposit interest payments and adjustment costs, i.e.

$$N_t = \sigma (R_t^b B_{t-1} - R_t^d D_{t-1} - \frac{\kappa^b}{2} \left(\frac{N_{t-1}}{B_{t-1}} - \nu_{t-1} \right)^2 N_{t-1}) + W^b \tag{4.36}$$

where $W^b = (1 - \sigma)w^b$ is the total amount of initial endowments and D_t is the amount of all deposits. Similarly, the aggregate consumption of all bankers is equal to net worth of all exiting bankers who are determined with probability $1 - \sigma$

$$C_t^b = (1 - \sigma)(R_t^b B_{t-1} - R_t^d D_{t-1} - \frac{\kappa^b}{2} \left(\frac{N_{t-1}}{B_{t-1}} - \nu_{t-1} \right)^2 N_{t-1}) \tag{4.37}$$

In addition to the aggregation in the banking industry, total output in the economy is defined as

$$Y_t = C_t^h + C_t^e + C_t^b + \frac{\delta}{2}(K_t^2) \tag{4.38}$$

Total output consists of consumption of households, entrepreneurs and bankers, and of the cost of capital acquisition by households.

Furthermore, there are two types of capital in the economy. The first one is held by households and used for production of consumption goods. The second one is acquired by banks which transform it into loans. The total amount of available capital is equal to 1. Therefore, the following identity holds

$$1 = K_t + B_t \tag{4.39}$$

4.1.6 Monetary Policy

The interest rate on deposits, R^d, is subject to monetary policy. The monetary authority sets the level of interest rate in period t based on its previous value, its steady state, the level of current output Y_t and this period inflation π_t as follows

$$R_{t+1}^d = (1 - \chi_r)R_{ss}^d + \chi_r R_t^d + (1 - \chi_r) \left[\chi_\pi(\pi_t - \pi_{ss}) + \chi_y(Y_t - Y_{t-1}) \right] \tag{4.40}$$

R_{ss}^d is the steady state value of the interest rate, R_t^d is the interest rate on deposits held from $t - 1$ to t and therefore determined in the previous period, $\pi_t - \pi_{ss}$ represents a deviation of inflation from its steady state value and the last term, $Y_t - Y_{t-1}$, is the difference between this and previous period's gross output.

If the monetary authority reacts positively to the output growth, then the interest rate will increase in good times. Consequently, it becomes more costly for banks to issue short-term deposits. This directly affects the probability of a bank run equilibrium existence, as will be seen later.

In case of non-cooperation between monetary and macroprudential authorities, monetary authority chooses parameters χ_r, χ_π and χ_y in the policy rule (4.40) in order to minimize the following loss function

$$L^{cb} = \sigma_\pi^2 + k_y \sigma_Y^2 + k_r \sigma_{\Delta R^d}^2 \tag{4.41}$$

This specification is adopted from Angelini, Neri and Panetta (2014). σ^2 is a variance of the respective variable. Parameters k_y and k_r are weights of output and interest rate variances in the loss function, respectively. ΔR^d is the difference between current and previous period's interest rate.

4.1.7 Macroprudential Policy

The form of macroprudential policy used here is the same as in Angelini, Neri and Panetta (2014). The macroprudential authority chooses the capital requirement ν_t in period t according to the following policy rule

$$\nu_t = (1 - \chi_\nu)\nu_{ss} + \chi_\nu \nu_{t-1} + (1 - \chi_\nu)\left[\chi_b \left(\frac{B_t}{B_{ss}} - \frac{Y_t}{Y_{ss}}\right)\right] \tag{4.42}$$

ν_{ss} is the steady state level of capital requirements and ν_{t-1} is the policy target from the previous period. The last term represents the growth rate of loans as compared to the growth rate of total output. B_{ss} and Y_{ss} stand for the steady states of loans and total output, respectively. Furthermore, if chi_b is positive, then whenever the growth rate of loans is higher than the one of output the macroprudential authority reacts by increasing capital requirements so that it puts a downward pressure on bank leverage and therefore lending.

Similarly to monetary authority, the macroprudential authority sets the policy parameters χ_ν, and χ_b to minimize the loss function

$$L^{mc} = \sigma^2_{B/Y} + k_{mp}\sigma^2_Y + k_\nu \sigma^2_{\Delta\nu} \tag{4.43}$$

σ^2 again stands for variance and parameters k_{mp} and k_ν are the corresponding weights. $\Delta\nu$ is the difference between current and previous level of capital requirements.

4.1.8 Interaction Between Policies

In the specification above macroprudential and monetary policies work independently of each other. This is determined by the fact that both authorities minimize their own loss function. Therefore, they do not take effects of the other policy into account. However, if the two policies are jointly determined, i.e. they are chosen by the same authority, they can take the other into account and therefore perform more efficiently. Consequently, cooperating authorities minimize the joint loss function

$$L = \sigma^2_\pi + (k_y + k_{mp})\sigma^2_Y + k_r\sigma^2_{\Delta R^d} + \sigma^2_{B/Y} + k_\nu \sigma^2_{\Delta\nu} \tag{4.44}$$

This approach is adopted from Angelini, Neri and Panetta (2014). Hence, the evaluation of effectiveness of cooperation and non-cooperation of the two policies will be based on comparing the sum of separated loss functions with the jointly minimized loss. The economy will face different kinds of shocks and some of them will be followed by a run on the banking industry. It will be examined witch of the two regimes is more suitable in terms of total policy loss and agents' total consumption.

4.1.9 Bank Runs

The description of bank runs follows Gertler and Kiyotaki (2015). In particular, only unanticipated bank runs are considered here. It means that households believe exante, when their current deposit holdings mature, that no run will occur in the next period. As will be explained later, in case of a bank run households get a smaller interest payment $\hat{R}^d$ from their deposits than in case of no bank run occurence. If households anticipated the occurence of a bank run, they would take into account the possibility of lower deposit return. However, in the case considered here, households do not expect any bank run to come and hence they assume they will get the policy rate R^d in the next period.

Bank run may occur if households decide not to roll over their deposits. This might happen for two reasons, as specified in Gertler and Kiyotaki (2015). Firstly, a household assumes that other households will not roll over their deposits. Secondly, this absence of funds will force banks into liquidation and may leave them with zero net worth. As can be seen from the incentive constraint (4.20), zero net worth violates the condition and consequently banks have an incentive to divert their assets and exit the industry.

Bank runs in Gertler and Kiyotaki (2015) differ considerably from the famous Diamond-Dybvig (1983) framework. In the latter model, depositors are paid the interests based on their position in the line. As they are paid sequentially, arriving late might cause a loss of saved deposits and corresponding interest payments. Therefore, depositors have an incentive not to roll over their deposits and consequently a bank run may occur. On the other hand, in Gertler and Kiyotaki (2015) all depositors receive the same interest $\hat{R}^d$ in case of a run. Runs arise because a depositor can assume that the others will not roll over their deposits and hence leave a bank without net worth. Consequently, that depositor will not roll over as well.

Since the agents (households, entrepreneurs, bankers) are homogenous, a bank run occurs at the same time in all banks. Hence, a bank run in this model means a run on the whole banking system, which is the same as in Gertler and Kiyotaki (2015). Households decide every period whether to roll over their deposits or not. If they decide not to roll over, banks are forced to liquidation. In that case, banks need to sell

their assets which corresponds to collecting the loan payments. When a run occurs, banks receive an interest $\hat{R}^b$ from their asset holdings. As was stated earlier, banks are forced to exit the industry whenever $n_t \leq 0$. Since net worth equals payments from asset holdings net payments from deposits and capital requirement cost, a bank run is possible in t if

$$\hat{R}_t^b B_{t-1} \quad < \quad R_t^d D_{t-1} + \frac{\kappa^b}{2} \left(\frac{N_{t-1}}{B_{t-1}} - \nu_{t-1} \right)^2 N_{t-1} \tag{4.45}$$

Following Gertler and Kiyotaki (2015), recovery rate x_t is defined as

$$x_t = \frac{\hat{R}_t^b B_{t-1}}{R_t^d D_{t-1} + \frac{\kappa^b}{2} \left(\frac{N_{t-1}}{B_{t-1}} - \nu_{t-1} \right)^2 N_{t-1}} \tag{4.46}$$

Consequently, a bank run is possible whenever $x_t < 1$.
Equation (4.46) can be rewritten using the definition of leverage as

$$x_t = \frac{\hat{R}_t^b \Phi_{t-1}}{R_t^d (\Phi_{t-1} - 1) + \frac{\kappa^b}{2} \left(\frac{1}{\Phi_{t-1}} - \nu_{t-1} \right)^2} \tag{4.47}$$

It is immediate that x_t is increasing in $\hat{R}_t^b$ and decreasing in R_t^d. The effect of ϕ_{t-1} can be seen from the first-order derivative which is equal to

$$\frac{\hat{R}_t^b A_t - \hat{R}_t^b \Phi_{t-1} \left[R_t^d - \kappa^b \left(\frac{1}{\Phi_{t-1}} - \nu_{t-1} \right) \frac{1}{\Phi_{t-1}^2} \right]}{A_t^2} \tag{4.48}$$

where A_t is the denominator in (4.47). As the denominator in (4.48) is always positive, the sign of the numerator is decisive for determining the sign of the derivative. Rearrranging the numerator gives

$$-R_t^d + \frac{\kappa^b}{2} \left(\frac{1}{\Phi_{t-1}} - \nu_{t-1} \right)^2 + \kappa^b \left(\frac{1}{\Phi_{t-1}} - \nu_{t-1} \right) \frac{1}{\Phi_{t-1}} \tag{4.49}$$

Summing the first two terms yields a negative number according to the assumption taken by the incentive constraint (4.34). The last term is negative whenever $\frac{1}{\Phi} < \nu$. In that case, the derivative (4.48) is negative and x_t is decreasing in leverage.
As in Gertler and Kiyotaki (2015), the recovery rate x_t as defined here depends only on endogenous variables - $\hat{R}_t^b$, R_t^d and Φ_{t-1}. That means that x_t changes with current economic conditions. The deposit rate and leverage have already been defined in the previous sections of the model. The asset fire-sale rate $\hat{R}_t^b$ is bank run-specific and is going to be defined on the following lines.
If a bank run occurs in t, all banks stop operating and exit the industry. New bankers

emerge but they cannot start operating until one period after the run. The reason for that might be, as described in Gertler and Kiyotaki (2015), that households cannot distinguish new bankers from the ones being subject to the run. Therefore, new bankers wait for the dust to settle before they enter the industry. Furthermore, as banks that are subject to the run are not able to cover their liabilities, households do not receive the full policy interest rate R_t^d on their deposits but only $\hat{R}_t^d$, i.e. only a fraction of the policy rate. In addition, banks under liquidation sell their assets at a fire-sale price $\hat{R}_t^b$. The assets are sold to households which implies that all capital in the economy (equal to unity) is in hands of households

$$1 = K_t \tag{4.50}$$

Consequently, the fire-sale price is determined from household's maximization of utility with respect to capital

$$\hat{R}_t^b = \frac{1+\delta}{\beta} \frac{C_{t+1}^H}{C_t^H} \tag{4.51}$$

In the next period $t+1$, banks start operating again. The total net worth is equal to

$$N_{t+1} = W^b + \sigma W^b \tag{4.52}$$

The first term is the endowment of all bankers starting operating in $t+1$. The second term corresponds to the endowment of new bankers who entered in t but cannot start operating because of the run. Hence, they waited until $t+1$ with the survival probability equal to σ.

Next chapter provides results of numerical simulations and their discussion. In addition to the baseline model, several other models involving alternative parameter values, shocks and specifications are simulated in order to check the robustness of the results provided by the baseline model.

Chapter 5

Simulation Results

This chapter provides results of a numerical simulation of the baseline model and other alternative models derived from the baseline one. Consider the baseline model first.

The economy is subject to a productivity shock. Two cases are considered - one when no bank run occures and second when the economy is hit by a run after the shock arrives. In addition, there are two regimes regarding monetary and macroprudential policies. In the first regime, the two policies operate separately and therefore do not take into account each other's decisions. In the second one, they are determined by the same authority, hence they operate jointly which enables them to perform more efficiently.

The productivity shock follows an AR(1) process as defined by

$$z_t = \rho_z z_{t-1} + e_t \tag{5.1}$$

where e_t is a zero mean normal random variable. The shock hitting the economy is equal to 5%.

When performing the policy exercise of finding optimal parameters in order to minimize the loss functions, it is found that the solution depends on the choice of initial parameter guesses. This implies that the problem has local minima. The same problem was encountered in Angelini, Neri and Panetta (2014). Therefore, the same procedure as theirs is used here. A set of uniformly distributed random numbers is constructed and those are sequentially used as initial parameter guesses for finding the optimal policy parameters. For χ_r, χ_π, χ_y, χ_ν and χ_b the intervals from which the random numbers are drawn are as follows: $[0, 1]$, $[1.7, 3]$, $[0, 1]$, $[0, 1]$ and $[-5, 5]$, respectively. The same intervals are used in Angelini, Neri and Panetta (2014) expect the ones for χ_r and χ_ν. The authors fix these two parameters at 0.99 and let only the other three to be chosen optimally in order to minimize the loss functions. Here all policy parameters are allowed to be chosen optimally.

In particular, for every policy parameter there are 200 random numbers generated from uniform distribution with intervals as specified above. Those 200 numbers are used as 200 initial parameters in finding the optimal parameters. The final optimal value of a particular parameter is equal to an average of the resulting values (generated as a response to 200 different initial guesses). The exercise described above was used for both cooperation and non-cooperation case.

The two policy regimes are also ranked according to a welfare measure. The one used here is the same as in Angelini, Neri and Panetta (2014) and is based on Schmitt-Grohe and Uribe (2007). In particular, welfare is measured as an average of the discounted sum of per-period utilities.

The rest of the chapter is organized as follows. Section 5.1 describes the choice of parameter values. Sections 5.2 discusses the simulation results of the baseline model when no bank run occurs and with a bank run occuring in period 3. Section 5.3 shows the results of a model considering different parameter values. Sections 5.4 and 5.5 involve results of two alternative cases, namely when the economy is hit by a monetary policy shock and by a net worth shock, respectively. Lastly, Section 5.6 comprises of the results of a model with differently specified policy rules.

5.1   Calibration of Parameters

The values of calibrated parameters can be seen in Table A.1. The values of β, ξ, Λ, α, Γ, ϵ^y, κ^p, i_p and κ^b are taken from Gerali et al. (2010). β, Λ and Γ are the discount rates of households/bankers, entrepreneurs and good retailers, respectively. For simplicity households share the same discount rate with bankers, and entrepreneurs discount rate equals the one of retailers. The fact that households' discount rate is bigger that the one of entrepreneurs implies that households are patient, i.e. they are depositors, while entrepreneurs are impatient, i.e. they borrow funds from banks. Parameters κ^p, κ^b and i_p are estimated in Gerali et al. (2010). Since the model described in Chapter 4 is a simplified version of the one in Gerali et al. (2010), it appears appropriate to use the same estimates.

Parameters δ, W^b, σ, ρ_z have the same values as in Gertler and Kiyotaki (2015). Survival probability equal to 0.95 implies an expected survival time $\frac{1}{1-\sigma}$ equal to 20 periods. If one period is one quarter, then the expected survival is 5 years. θ equal to 0.2534 corresponds to the leverage egual to 2 in the steady state. Hence, θ was chosen in order to achieve this target value of leverage.

k_r, k_Y, k_{mp} and k_ν are chosen as in Angelini, Neri and Panetta (2014).

5.2   Baseline Model

This section describes the results obtained from the baseline model. Subsection 5.2.1 provides results of a simple case when no bank run occurs after the shock hits. On the other hand, Subsection 5.2.2 considers a case when a bank run occurs in period 3.

5.2.1   Recession without a Run

Figure A.1 shows the impulse responses to a 5% productivity shock when no bank run occurs. The green dashed-line corresponds to the cooperative case and the blue full-line stands for the non-cooperation. It can be seen immediately that most variables in question deviate less from the respective steady state under cooperation.

All variables show expected behavior. In response to a negative productivity shock, the total productivity Y_t and consumption of agents go down. Macroprudential authority reacts by increasing the capital requirements which forces banks to lower their leverage and consequently to decrease lending and the amount of deposits. This has a negative effect on banks' net worth and consumption. Capital used in production increases due to decreased capital used on loans. The policy interest rate rises which ensures higher returns on deposits. This also has a negative effect on banks' supply of deposits. The interest rate on loans reacts immediately to the shock by falling bellow its steady state level. However, in case of cooperation the rate increases after the shock and for two periods remains higher than the one obtained in the non-cooperative case. The non-cooperative interest rate starts to increase sharply in the period after the shock occurence.

Table A.2 shows the optimal policy parameters, values of loss functions and welfare. It can be immediately seen that independently determined policies are more successful in terms of minimized loss while coordinated policies deliver higher welfare. However, the difference in welfare levels is very small and hence can be a result of a rounding error. As is apparent from the values of parameters χ_π, χ_y and χ_b, non-cooperating authorities conduct more aggresively both macroprudential and monetary policies. Consequently, the non-cooperative case involves lower level of output and consumption than the cooperative conduct. However, independent policies deliver higher financial stability as is indicated by the level of recovery rate x_t. In addition, they achieve lower values of minimized loss functions. In particular, compared to the cooperative case they attain lower inflation volatility, loan-to-output volatility and lower variance of the monetary instrument. On the other hand, cooperating authorities achieve output stability and lower variance of the macroprudential instrument.

Overall the results suggest that non-cooperation is preferred in terms of stability

while cooperation might be preferred with respect to welfare. The fact that non-cooperation is more successful in achieving the objective of stability corresponds to De Paoli and Paustian (2013). The authors find that assigning too similar targets to the two policies might lead to coordination issues. The same result can be seen here as allowing to minimize the joint loss function is the same as assigning the same objective to the two authorities. Hence, as the authorities are trying to achieve both goals, they end up being less efficient than two authorities performing the two policies separately.

To sum up, the non-cooperating authorities are more efficient in terms of minimized loss while cooperating authorities deliver higher level of total welfare. In addition, the separately operating authorities choose more aggresive policies. Consequently, they attain higher financial stability by inducing higher recovery rate x_t. On the other hand, they deliver lower level of output and consumption than jointly operating authorities.

5.2.2 Recession Followed by a Bank Run

Here, unlike in the case above, it is assumed that a bank run occurs after the shock hits the economy. In particular, the run happens in period 3. Figure A.2 shows impulse responses of the economy to the productivity shock and to a subsequent bank run. As was described in the previous chapter, in the case of a run banks' net worth is wiped out and all bankers exit the industry. No new bankers enter the market until the dust settles, i.e. until the next period after the run.

Until the run happens the policy rules are the same as desribed in Subsection 5.2.1. After the run both macroprudential and monetary authorities choose new optimal policy parameters in order to minimize respective loss functions. The possibility of reoptimization is allowed for because it appears reasonable to assume that authorities want to adjust their behavior to the current crisis.

Variables in question show similar behavior under the two policy regimes. The level of both consumption and output decreases considerably. Interestingly, they both sharply increase in the period after the run, more in the cooperative case than in the non-cooperative one. The reason might be that capital from the run period is used in production in the next period and therefore considerably rises the production of final goods. Regarding the level of employed labor, there is again a sharp decrease when the run occurs which is more severe in the cooperative case. As of macroprudential policy, it is assumed that the requirement is set to 0 when the run occurs as bankers do not operate. After the run the macroprudential policy increases steadily to its steady state level. Due to low capital requirements banks' leverage increases sharply after the run. The increase is more significant when the two authorities do

not coordinate their actions. Consequently, the recovery rate after the run remains lower than for the cooperative case. The interest rate on loans goes steeply up after the run which makes loans more expensive for entrepreneurs. On the other hand, the deposit rate declines when the run hits. The decline is more severe for independetly operating authorities.

Figure A.3 displays the movements of variables in periods following the bank run. It can be seen that under the joint conduct the levels of consumption and output are higher than under non-cooperation. The same holds for the amount of loans in the economy and net worth. In addition, leverage is lower which is caused by higher capital requirements. On the other hand, cooperation induces lower employment and less capital in production. The recovery rate is higher when the two authorities are coordinated which indicates lower probability of another run.

Table A.3 displays optimal policy parameters and welfare levels. As has been already noted both authorities reoptimize after the run occurs. Hence, the parameters in the table are the new reoptimized parameters. Similarly, welfare levels are computed from the period after the run onwards as those corresponds to the new policy rules. It can be immediately seen that independent authorities perform better than cooperating ones both in terms of joint minimized loss and total welfare. While cooperating authorities achieve a lower value of macroprudential loss they attain a higher value of monetary loss. This is especially due to higher inflation volatility than in the non-cooperative case. Regarding welfare the cooperative regime brings higher entrepreneurial welfare than the non-cooperative regime but lower welfare of households and bankers. In particular, the non-cooperative regime delivers higher total welfare.

One of the possible explanations of why coordinated policies perform worse in terms of welfare than independent ones is as follows. Since jointly operating authorities impose higher capital requirements, they force banks to hold lower leverage than in the non-cooperative case. Moreover, they choose lower policy interest rate as compared to non-cooperative case which reduces cost of funds for banks. Consequently, both these actions contribute to lowering the probability of the next bank run (as they increase the recovery rate). However, due to the fact that agents do not anticipate any bank runs they do not take the probability of a run into account when taking decisions. Therefore, probability of a run plays no role in agents' welfare. Consequently, while the actions of coordinated authorities help stabilize the economy, i.e. decrease the probability of the next run, they deliver lower welfare to the agents as they restrict banks in providing funds to the economy.

In addition, as was already hinted in the previous subsection according to De Paoli and Paustian (2013) assigning the two authorities very similar targets may result in coordination problems. In particular, as the two authorities try to stabilize all the

relevant variables in the joint loss function they can end up trading off the stability of one variable for the stability of another.

To conclude, when a bank run occurs non-cooperative policies perform better than coordinated ones both in terms of minimized loss and total average welfare. While jointly determined policies improve stability by decreasing the probability of the next run, they harm agents' welfare due to restricting bank lending. Moreover, despite the fact that the cooperative regime delivers higher joint loss and lower total welfare, it achieves higher consumption and output than the non-cooperative regime.

When comparing the no run and bank run cases, it is immediate from Tables A.2 and A.3 that after the run both regimes achieve lower policy losses and higher welfare levels than their no-run counterparts. In particular, both regimes perform tighter macroprudential policies after the run which is apparent from higher values of parameter χ_b. Moreover, the variances of the key variables are lower after the run, except the variance of macroprudential instrument in the cooperative case.

5.3 Alternative Parameterization

This section examines the effect of different parameter values on final results. Firstly, the weight parameters contained in the loss functions will be set to alternative values. Secondly, the diversion rate θ will be increased.

5.3.1 Weight Parameters

The original parameters representing the weight of output variance in the corresponding loss function were set at $k_Y = k_{mp} = 0.5$. Table A.4 shows the results when those parameters are set at $k_Y = k_{mp} = 0.25$. Decreasing the parameters implies lower importance of output variance in the objectives of the two policies. The table displays both cases of no bank run and a bank run happening in period 3. Moreover, it distinguishes the cooperative regime (denoted with C) and the non-cooperative one (denoted with NC).

As is apparent from the table the cooperative regime achieves lower overall welfare and higher minimized loss than the case of non-cooperation. This confirms the conclusions from Section 5.2 that there are coordination issues when the two policies are dealing with similar objectives. In particular, cooperating authorities are more successful in minimizing the variance of output and macroprudential tool both in case of no run and a run in period 3. However, they perform worse regarding the inflation and loan-to-output volatilities. The fact that cooperating policies deliver

lower variance of output and higher inflation volatility than non-cooperation policies can be seen also in tables A.2 and A.3. Hence, the trend holds also for lower values of k_Y and k_{mp}. Hence, it seems that the cooperative regime is more suited for output stability while the non-cooperative regime wins in inflation stability. Moreover, compared to the baseline model the minimized losses are now higher which indicates less efficiency of the policies. In addition, after the bank run the values of χ_π, χ_y and χ_b all decrease which implies that both regimes apply less tight policies after the run. However, it still holds that the loss values of total welfare improve after the run in both regimes.

Table A.5 displays the case when parameters k_r and k_ν are increased from their original values of 0.1 to 0.5. Increasing the parameters means that stability of the instruments becomes more important in policies' objectives. In this case the situation is less straightforward that in the previous case of decreasing the output weight parameters. Looking at a no run case first it is immediate that the cooperative regime achieves lower joint loss than the non-cooperative conduct. Namely, macroprudential loss is lower when the two authorities cooperate while monetary loss is lower for the non-cooperative regime. Interestingly, cooperating authorities conduct more strict monetary policy and less tight macroprudential policy after the run (as compared to the situation before the run), while non-cooperative regime induces less tight both policies after the run happens. Furthermore, cooperating authorities are again more successful in stabilizing output and less successful in minimization of inflation variance than non-cooperating authorities. In addition, both regimes provide the same level of total average welfare. The bank run case leads to different conclusions. The cooperative regime's minimized joint loss is higher than the non-cooperative one's loss. On the other hand, welfare is higher in case of cooperation. Let us look at the minimized losses first. The monetary policy loss of both regimes is lower than in the no run case. However, the cooperative regime's macroprudential loss is higher than previously, while the one of non-cooperative regime is lower. The rise in macroprudential loss of jointly operating authorities can be attributed to a significant increase in the volatility of loan-to-output ratio which is now higher than the one of non-cooperating authorities. Moreover, the macroprudential policy conducted by cooperating authorities is less tight than before the run, as can be seen from the decrease in parameter χ_b. Consequently, the joint loss of cooperative regime is higher than the loss of the separate conduct. On the other hand, coordinated authorities deliver higher welfare to both households and bankers as compared to the case of non-cooperation. As of entrepreneurs, their welfare is higher under non-cooperation. However, total welfare is higher for jointly operating authorities.

To sum up, a decrease in the weight of output in both loss functions does not change the conclusion from the baseline model that non-cooperative conduct is preferable

both in terms of minimized loss and total welfare. On the other hand, increasing the weight of instruments' variance in the respective loss functions does not provide straightforward conclusions. While cooperative regime is preferable in the case of no bank run, since it delivers lower minimized loss, the situation reverses when the run happens. However, in this case the cooperative regime achieves higher level of total welfare.

5.3.2   Diversion Rate

Diversion rate θ determines what fraction of bank's assets can a banker divert for personal use and not be detected by depositors. As θ increases the incentive constraint 4.20 gets tighter which limits the level of leverage that a banker can hold. This section examines an increase of θ from its baseline value of 0.2534 to 0.8962. Table A.6 corresponds to this new parameter specification. Let us start by looking at the no bank run case first. The cooperation regime achieves higher welfare but also a higher value of joint minimized loss as compared to the non-cooperative conduct. While the cooperating authorities manage to minimize the monetary loss, they do not do so in case of macroprudential loss which is higher that the one for separately deciding authorities. For the first time in the analysis the cooperating policies stabilize inflation better than the non-cooperating authorities. On the other hand, they perform worse in output stabilization. Cooperating authorities also induce higher volatility of both instruments. Moreover, both regimes perform tighter macroprudential policies as compared to all the previous cases above. Therefore, higher θ induces the capital requirements to react more to changes in total output and the amount of loans. However, after the run the macroprudential policies in both regimes become less tight, as parameter χ_b decreases. Regarding welfare, cooperation delivers higher welfare for entrepreneurs while welfare of the other two groups is the same for the two regimes. However, the difference in entrepreneurial welfare is very small and can be caused due to a rounding error. As for the case of a bank run occurence, the results suggest the same conclusions as for the no run situation. Cooperation attains higher welfare but also a higher loss than non-cooperation. The most significant differences in volatilities are the ones of loan-to-output ratio and of macroprudential instrument. Variances of both variables are higher for the cooperative regime. However, this regime maintains a lower value of monetary minimized loss as compared to non-cooperation.

To conclude, a higher level of the diversion rate favorizes non-cooperative regime in terms of minimized joint loss. On the other hand, cooperating authorities deliver higher welfare, especially in the case of a bank run occurence. Therefore, it is not

straighforward which regime should be preferred in this case as the decision depends on the measure (loss vs. welfare) that is chosen to rank them.

5.4 Monetary Policy Shock

This section considers an alternative monetary policy shock that replaces the productivity shock being in place until now. The monetary policy rule now looks as follows

$$R_{t+1}^d = (1 - \chi_r)R_{ss}^d + \chi_r R_t^d + (1 - \chi_r)\left[\chi_\pi(\pi_t - \pi_{ss}) + \chi_y(Y_t - Y_{t-1})\right] + z_t^r$$

with z_t^r following the same AR(1) process as z_t given by equation 5.1. The size of the shock is again equal to 5%. Furthermore, all parameters are set at their baseline values as displayed in Table A.1.

Figure A.4 shows the impulse responses when a monetary shock hits and no bank run occurs. Clearly the cooperative regime generates more volatility in the displayed variables. In particular, the cooperative regime reacts to the monetary policy shock by setting higher capital requirements as compared to the non-cooperative case. Therefore, this causes the leverage to fall more in response to the shock, namely to 0.1% below its steady state in the cooperative regime compared to 0.05% in the non-cooperative case. Consequently, the amounts of loans, deposits and net worth are all lower than their non-cooperative counterparts. Therefore, the increase in the recovery rate after the shock hits is higher for cooperating authorities as those apply tighter capital requiremets. The recovery rate then stays above the steady state value until it converges and it remains higher for the cooperative regime than for the non-cooperative one. As of the interest rates, they both display the same movements under the two regimes differing only in magnitude. The policy rate increases after the shock and then sequentialy falls below its steady state. The fall is more significant when the authorities cooperate. The interest rate on loans decreases immediately when the shock occurs and as in the case of policy rate the magnitude is larger for the cooperating authorities. Regarding the production inputs, both capital and labor increase and the rise is more significant for the cooperative case. This implies higher goods production as compared to the non-cooperative regime. Last but not least, consumption levels of both households and bankers fall after the shock. However, the bankers' consumption do not fall immediately but rather sequentialy. The same conclusion as before applies here - the fall in consumption levels is worse for the cooperative case. The same goes for output which falls to 0.125% below its steady state compared to the non-cooperative 0.075%.

Looking at Table A.7 it can be seen that the non-cooperating authorities achieve

lower minimized loss in both policies and jointly. In particular, volatilities of all variables entering the loss functions are lower in the non-cooperative regime (column NC). It is also apparent that the non-cooperative regime conducts less tight macroprudential policy as compared to the one performed by cooperating authorities. Welfare is the same under the two regimes for all groups of agents.

Figure A.5 corresponds to the case when a bank run happens in period 3. Let us start by looking at the banking sector. It can be seen that the capital requirements ν_t increase sharply after the run. For the non-cooperative case the increase is more than 100% above its steady state. Consequently, the leverage decreases further after the run. While the amounts of loans and deposits rise above their respective steady states immediately after the run, net worth decreases for one more period before it exceeds its steady state. The after-run increases in loans, deposits and net worth are smaller for the cooperative regime as compared to the non-cooperative one. The policy rate sharply decreases when the run occurs in case of both regimes. However, while the decrease is more than 4% from the steady state in the non-cooperative case, it is less severe for the cooperative regime - about 4%. The cooperative deposite interest rate remains above the non-cooperative one until convergence back to the steady state. The same conclusion holds for the interest rate on loans, as both its increase when the run occurs and a subsequent decrease are smaller for the cooperative regime. As of the production inputs, capital falls immediately after its original increase in the period of run. It is caused by the sharp increase in the amount of loans, i.e. the capital in possession of bankers. However, the fall is only about 2% when the authorities cooperate, while it almost reaches 6% when they act independently. Similar result applies to labor. Its original decrease of more than 10% for the non-cooperative regime is accompanied by a 5% fall in case of cooperation. The amount of labor then converges back to its steady state. Total output rises steeply in the period after the run and the rise is more than two times larger for the non-cooperating authorities as compared to the cooperating ones. The consumption levels of households and bankers steeply increases as well after their decrease in the run period. As in the case of total output, the increases are larger for the non-cooperative regime. Last but not least, the recovery rate goes up immediately after the run when the authorities decide jointly, while it decreases further when the authorities are independent. This further decrease rises the probability of next bank run and causes financial instability in the economy. However, the fall stops in period 9 and the recovery rate rises above its steady state as well. After that it converges back to its steady state.

Table A.7 shows the optimal policy parameters, minimized policy losses, volatilities and welfare levels. The conclusions are the same as in the case of no bank run occuring. The non-cooperative regime maintains lower level of both minimized losses and

also the joint loss. In addition, it achieves higher level of total welfare. In particular, the welfare is higher for households and bankers, while it is lower for entrepeneurs as compared to the cooperative case. Regarding volatilities of the key variables, they are all higher for the cooperative regime.

To sum up, for both cases of no bank run and a bank run occurence the non-cooperating authorities achieve lower minimized losses and the same or even higher welfare than jointly conducting policies. On the other hand, after the run the recovery rate falls significantly when the authorities do not coordinate their actions which rises the probability of a next run occurence.

5.5   Net Worth Shock

This section summarizes the results of another simulation considering a negative shock on net worth. In particular, equation 4.36 now reads as

$$N_t = \sigma(R_t^b B_{t-1} - R_t^d D_{t-1} - \frac{\kappa^b}{2} \left(\frac{N_{t-1}}{B_{t-1}} - \nu_{t-1} \right)^2 N_{t-1}) \cdot exp(-z_t) + W^b \quad (5.2)$$

with z_t following the AR(1) process as in 5.1. The size of the shock is 5%.

Impulse responses to the shock can be seen in table A.6. Interestingly, the depicted variables show similar responses under the two regimes. Net worth continues to decrease few periods after the shock hits. It reaches the value of about 20% below the steady state before it starts to increase back to the steady state. The amount of loans slightly increases after the shock and then decreases to the value of about $1,5\%$ below the steady state. Magnitude of the fall is insignificantly larger for the cooperative regime. Deposits increase in response to the shock with the rise being about 15% above the steady state. The increase in deposits is allowed by increasing leverage. Bankers can set higher leverage in response to the shock because there is only a modest rise of capital requirements when the shock occurs followed by an immediate decrease below the steady state. Consequently, bankers are able to maintain high degree of leverage and hence they do not have to decrease the amount of loans too much in order to match the decrease of net worth. As of the policy rate, it decreases in both regimes in reaction to lower total output. It can be said that this decrease compensates bankers for the loss of net worht caused by the negative shock. The fall of policy rate is larger in magnitude for the cooperative regime. On the other hand, this regime also causes the policy rate to subsequently increase above its steady state level and this increase is larger than in the non-cooperative case. The interest rate on loans falls when the shock occurs and then immediately goes up above the steady state. As for the capital held by households and labor,

they both display modestly higher values for the cooperative regime. In particular, they both increase above their steady states after the shock and these increases are higher when the two authorities cooperate. Regarding total output and consumption of households and bankers, all these variables decrease in response to the net worth shock. While total output and consumption of bankers show almost the same values for both regimes, the household consumption is lower for the cooperative case than the non-cooperative one. The recovery rate falls significantly in case of both regimes. This increases the probability of a bank run occurence. It is caused by the decrease in macroprudential policy conducted by the authorities.

Optimal policy parameters, minimized losses, volatilities and welfare levels can be found in Table A.8. Looking at the policy rules first (no-run column) it can be seen that non-cooperating authorities choose higher values of optimal parameters compared to jointly deciding authorities. The biggest difference is in χ_b, namely 8.8415 in the cooperative case vs. 9.2284 in the non-cooperative one. Consequently, the non-cooperative macroprudential policy reacts more to the movements in the amount of loans and total output. Moreover, all variables entering the loss functions are more volatile in the cooperative case except for the macroprudential instrument. Consequently, the non-cooperative regime achieves lower minimized loss than the cooperative one for both monetary and macroprudential policy. On the other hand, the joint conduct of authorities brings higher welfare for entrepreneurs and, in addition, higher total welfare.

Regarding the bank-run case, it is displayed in Figure A.7. The dynamics are similar to the ones in previous sections considering different shocks. The impulse responses for the periods following the bank run are very similar for the two regimes with the only apparent differences in labor and total output. When the run occurs the amount of labor decreases in both regimes. However, the subsequent return to the steady state level is faster when the authorities cooperate and hence the amount of labor is higher in periods after the run for the case of cooperation. As for the total output, its original fall caused by the bank run is followed by an immediate increase above the steady state. The increase is lower for cooperating authorities and in periods after the run the level of total output is lower in this regime than in the non-cooeprative one.

Returning to the Table A.8 it can be seen that the non-cooperative regime performs better both in terms of minimized loss and welfare. In particular, volatilities of the key variables are all higher in the case of cooperation, even though they are lower than their no-run counterparts. As for the optimal parameters, they are all smaller (for both regimes) compared to the no-run situation. The only exception is χ_r in the cooperatvie chase which increased from 0.5033 in the no-run case to 0.5090 when the run occurs. Moreover, the two sets of cooperative and non-cooperative optimal

parameters are now more alike in terms of magnitude, i.e. the differences between them are smaller than in the no-run situation. The fact that the two sets of policy rules are now more similar can be seen also from the volatilities. Even though the cooperative variances are higher than the non-cooperative ones, the differences between them are smaller than in the no-run case. Last but not least, looking at the welfare levels it is apparent that non-cooperation brings slightly higher welfare to entrepreneurs, while the welfare of households and bankers is the same under both regimes.

In summary, non-cooperation is more efficient in terms of minimized loss in both no-run and run situations. Regarding welfare, when no bank run occurs it is higher under cooperation while when a bank run happends higher total welfare is achieved by the non-cooperative regime. However, the differences in welfare between the two regimes are small in magnitude and therefore might be caused by a rounding error. Furthermore, it can be seen in Figure A.6 that the recovery rate decreases considerably under both regimes when the negative net worth shock hits. It implies that both regimes contributes to financial instability in the economy by increasing the probability of a next bank run.

5.6 Policy Rules

This section examines the simulation results when the two policy rules are adjusted as compared to the baseline model. In particular, the policy rules now look as follows

$$
\begin{aligned}
R_{t+1}^d &= (1 - \chi_r)R_{ss}^d + \chi_r R_t^d + \dots \\
&\quad \dots \ + (1 - \chi_r)\left[\chi_\pi(\pi_t - \pi_{ss}) + \chi_y(Y_t - Y_{t-1})\right] + \dots \\
&\quad \dots \ + (1 - \chi_r)\chi_b\left(\frac{B_t}{B_{ss}} - \frac{Y_t}{Y_{ss}}\right) \quad\quad\quad (5.3) \\
\nu_t &= (1 - \chi_\nu)\nu_{ss} + \chi_\nu \nu_{t-1} + \dots \\
&\quad \dots \ + (1 - \chi_\nu)\left[\chi_{b,mc}\left(\frac{B_t}{B_{ss}} - \frac{Y_t}{Y_{ss}}\right)\right] + \dots \\
&\quad \dots \ + (1 - \chi_\nu)\left[\chi_{\pi,mc}(\pi_t - \pi_{ss}) + \chi_{y,mc}(Y_t - Y_{t-1})\right] \quad\quad (5.4)
\end{aligned}
$$

i.e. the two policy instruments now respond to the same variables. Everything else is the same as in the baseline model, including parameterization and productivity shock.

The respective results can be seen in Table A.9. It is immediate that the cooperative regime achieves lower minimized joint loss both in the no-run and bank-run case. Furthermore, it also attains lower separate monetary and macroprudential losses. Regarding variances of the key variables, cooperating authorities induce lower volatilities of all the variables in question except for the total output volatility. Recalling

simulation results described earlier in the chapter, it was always the case that the cooperative regime achieves higher inflation variance and lower output volatility that the non-cooperating authorities. However, the situation is reversed in this case. After the run all volatilities decrease except for the macroprudential instrument in the cooperative regime. It increases from its no-run value of 0.000768 to 0.001464.

Looking at the optimal parameters, it can be seen that separately operating authorities apply more aggresive monetary policy and slightly less aggresive macroprudential policy than their cooperating counterpart. After the bank run, the cooperative regime increases $\chi_{b,mc}$ and $\chi_{\pi,mc}$ which implies more aggresive macroprudential policy as compared to the pre-run situation. Non-cooperating authorities increase magnitude of these parameters as well but the change is less significant than in the cooperative case. As of the monetary policy, jointly deciding authorities rise the magnitude of χ_b which implies higher sensitivity of the policy rate to the changes in the growth of loans. It still holds that non-cooperating regime performs more aggresive monetary policy, as its optimal parameters are higher in magnitude, however, unlike in the cooperative case, it decreases the magnitude of χ_b after the run.

Regarding welfare, the non-cooperative regime achieves higher total welfare when no bank run occurs, while cooperating authorities deliver higher overall welfare when a bank run happens.

In conclusion, when the two policy rules involve the same variables the cooperative regime dominates the non-cooperative one in terms of minimized loss and also in terms of welfare when a bank run occurs. Therefore, this result implies that for a successful cooperation it is not enough to assign the same targets to the two policies. It is also necessary to adjust the policy rules in a way that they can respond to the same changes in the economy.

To summarize all results described in this chapter, a bank run occurence does not have any effect on the ranking of the two policy regimes based on the values of minimized joint losses. Therefore, a policy regime that is more efficient in terms of minimized loss before the run is also more efficient after the run occurs. However, a bank run induces the two policies in both regimes to be more efficient as compared to their no-run counterparts. In particular, the policies achieve lower values of the loss functions after a run occurs. Hence, a bank run does not affect efficiency across the two policy regimes, but it improves efficiency of both monetary and macroprudential policies as compared to the pre-run situation.

Moreover, both cooperating and non-cooperating authorities find it optimal to reoptimize after the run. In particular, they choose different optimal policy parameters when the run occurs. For instance, in the baseline model both cooperative and non-

cooperative regimes apply more aggresive macroprudential policy in response to the run. As was already stated above, in most cases the reoptimization brings lower values of minimized losses and also higher welfare compared to the no-run case.

There were three types of shocks considered in the simulations - productivity, monetary and net worth shock. In case of monetary and net worth shocks, the volatilities of the key variables are significantly smaller than in the baseline model with a productivity shock. This holds also for the loss functions as they attain lower values when a monetary or net worth shock hits the economy. It implies that monetary and macroprudential policies are more effective in the monetary and net worth shock cases. In particular, the two policies are most effective in the case of a monetary shock. This result seems intuitive as both policies have a direct impact on the banking sector and therefore handle the financial shocks most effectively.

Chapter 6

Conclusion

The main purpose of this thesis is to examine the interaction between macropru-
dential and monetary policies in the presence of bank runs. In particular, it is
being studied how a bank run affects the efficiency of the policies, whether the poli-
cies should be conducted separately or jointly and how the conclusion changes with
an occurence of a bank run. Moreover, it is examined how cooperating and non-
cooperating policies perform facing different types of shocks.

Based on the results of the baseline model, the cooperative regime, i.e. a regime in
which the two policies are determined jointly, is less efficient than the non-cooperative
one in terms of minimized joint loss both before and after the run. However, the
cooperating authorities choose more aggresive macroprudential policy when the run
occurs which delivers a lower value of macroprudential loss and consequently also a
lower probability of a next bank run. This implies higher financial stability of the
economy under the cooperative regime.

The reason of the lower efficiency of jointly conducted policies might be similar to
the one in De Paoli and Paustian (2013). The authors suggest that assigning too
similar objectives to the two policies may cause coordination issues that result in
lower efficiency of the policies. In the context of the baseline model presented in this
thesis, minimizing a joint loss function is equal to assigning the same targets to the
two policies. In particular, the optimal policy parameters for both policy rules are
chosen in order to minimize volatilities of the same variables. Therefore, it might be
the case that cooperating authorities have to trade off a volatility of one variable for
another which causes them to be less efficient.

A bank run does not affect the ranking of policy regimes in terms of minimized loss.
However, it induces both monetary and macroprudential policies to be more efficient
than in the no-run case. Namely, the policies achieve lower values of policy loss
functions and higher values of welfare when they are reoptimized after the run.

Regarding different types of shocks, these also do not play a role in ranking cooper-

ative and non-cooperative policy regimes. However, macroprudential and monetary policies are more efficient in the case of monetary and net worth shocks. They attain lower volatilities of the key variables and hence lower policy losses. In particular, the policies are most efficient when a monetary shock hits the economy. This result seems intuitive, as both monetary and macroprudential policies are aimed on the banking sector and therefore should handle financial shocks most effectively.

Future research should focus on the channels between financial institutions and corresponding systemic threats. As was hinted in the first half of the thesis, these connections might impede financial stability if they are not handled by an appropriate regulation. Therefore, another step in examining the interaction and efficiency of monetary and macroprudential policies may involve wholesale-level bank runs and similar features depicting the risk contained in the relationships between particular institutions.

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Appendix A

Tables and Figures

	Baseline model	
β	0.9943	Discount rate of households and bankers
ξ	1	Inverse of the Frisch elasticity
δ	0.008	Households cost of capital holding
Λ	0.975	Discount rate of entrepreneurs
α	0.25	Capital share in the production function
Γ	0.975	Discount rate of goods retailers
κ^p	28.65	Goods retailers adjustment cost parameter
ϵ^d	6	$\frac{\epsilon^d}{\epsilon^d-1}$ is the mark-up in the final goods market
i_p	0.16	Inflation weight in goods retailers adjustment costs
κ^b	11.07	Bankers adjustment cost parameter
W^b	0.011	Bankers endowment
σ	0.95	Bankers survival probability
ρ_z	0.95	Serial correlation of productivity shock
θ	0.2534	Bankers diversion rate
k_r	0.1	Weight of policy rate variance in the monetary loss function
k_Y	0.5	Weight of output variance in the monetary loss function
k_{mp}	0.5	Weight of loans variance in the macroprudential loss function
k_ν	0.1	Weight of ν in the macroprudential loss function

Table A.1: Calibration of parameters

		Cooperation	Non-cooperation
Monetary policy	χ_r	0.6271	0.0399
	χ_π	2.4846	6.7150
	χ_y	0.5177	0.6330
Macroprudential policy	χ_ν	0.3615	0.3540
	χ_b	0.1676	3.8925
Joint loss		0.0170721	0.0010232
Monetary policy loss		0.0003587	0.0002314
Macroprudential policy loss		0.0167134	0.0007918
Volatilities			
σ^2_π		0.000157	0.000012
σ^2_Y		0.000400	0.000436
$\sigma^2_{B/Y}$		0.016503	0.000261
$\sigma^2_{\Delta R^d}$		0.000017	0.000014
$\sigma^2_{\Delta \nu}$		0.000104	0.003128
Welfare			
Households		-6 212.6	-6 212.7
Entrepreneurs		294.5158	294.5345
Bankers		-6.6658	-6.6664
Total		-5 924.75	-5 924.8319

Table A.2: Baseline model - recession without a run

		Cooperation	Non-cooperation
Monetary policy	χ_r	0.6642	-0.3632
	χ_π	2.6533	6.5808
	χ_y	0.5151	0.6182
Macroprudential policy	χ_ν	0.1945	0.3502
	χ_b	4.8803	3.9716
Joint loss		0.0007797	0.000754
Monetary policy loss		0.0002492	0.0001713
Macroprudential policy loss		0.0005305	0.0005827
Volatilities			
σ^2_π		0.000098	0.000009
σ^2_Y		0.000300	0.000322
$\sigma^2_{B/Y}$		0.000117	0.000186
$\sigma^2_{\Delta R^d}$		0.000012	0.000013
$\sigma^2_{\Delta\nu}$		0.002635	0.002357
Welfare			
Households		-6 209.4	-6 209.1
Entrepreneurs		294.4199	294.4043
Bankers		-6.6638	-6.6636
Total		-5 921.6439	-5 921.3593

Table A.3: Baseline model - bank run

| | | $k_{mp} = k_Y = 0.25$ | | | |
| | | No run | | Bank run | |
		C	NC	C	NC
Monetary policy	χ_r	0.6438	0.1956	0.6505	0.3539
	χ_π	2.5860	4.5536	2.5576	4.2516
	χ_y	0.5482	0.5674	0.5379	0.5594
Macroprudential policy	χ_ν	0.3636	0.3923	0.4187	0.3867
	χ_b	0.9635	1.3664	0.8991	1.2224
Joint loss		0.0029549	0.0018837	0.0023974	0.0015726
Monetary policy loss		0.0002451	0.0001416	0.00018245	0.00010795
Macroprudential policy loss		0.0027098	0.0017421	0.00221495	0.00146465
Volatilities					
σ^2_π		0.000142	0.000032	0.000107	0.000028
σ^2_Y		0.000406	0.000432	0.000297	0.000315
$\sigma^2_{B/Y}$		0.002516	0.001498	0.002083	0.001296
$\sigma^2_{\Delta R^d}$		0.000016	0.000016	0.000012	0.000011
$\sigma^2_{\Delta \nu}$		0.000923	0.001361	0.000577	0.000899
Welfare					
Households		-6 212.7	-6 212.7	-6 209	-6 209
Entrepreneurs		294.5292	294.5315	294.3982	294.3984
Bankers		-6.6662	-6.6663	-6.6639	-6.6639
Total		-5 924.837	-5 924.8348	-5 921.2657	-5 921.2655

Table A.4: Change it the weight of output

| | | $k_r = k_\nu = 0.5$ | | | |
| | | No run | | Bank run | |
		C	NC	C	NC
Monetary policy	χ_r	0.6203	-0.0335	0.5892	0.5632
	χ_π	2.4673	12.4318	2.4796	3.9491
	χ_y	0.4886	1.1381	0.5214	0.5623
Macroprudential policy	χ_ν	0.5373	0.5595	0.5497	0.5595
	χ_b	0.7317	0.5937	0.2972	0.5887
Joint loss		0.0048345	0.005516	0.0085115	0.0042395
Monetary policy loss		0.0003745	0.000224	0.0002735	0.0001915
Macroprudential policy loss		0.0046	0.005292	0.008238	0.004048
Volatilities					
σ_π^2		0.000163	0.000003	0.000118	0.000033
σ_Y^2		0.000405	0.000429	0.000297	0.000308
$\sigma_{B/Y}^2$		0.003999	0.004881	0.008029	0.003750
$\sigma_{\Delta R^d}^2$		0.000018	0.000013	0.000014	0.000009
$\sigma_{\Delta\nu}^2$		0.000517	0.000393	0.000121	0.000288
Welfare					
Households		-6 212.7	-6 212.7	-6 207.5	-6 208.1
Entrepreneurs		294.5277	294.5277	294.2538	294.3217
Bankers		-6.6661	-6.6661	-6.6564	-6.6596
Total		-5 924.8384	-5 924.8384	-5 919.9026	-5 920.4379

Table A.5: Change in the weight of policy instruments

		$\theta = 0.8962$			
		No run		Bank run	
		C	NC	C	NC
Monetary policy	χ_r	0.5209	0.7061	0.6617	0.6729
	χ_π	3.8682	3.2356	3.4107	3.2733
	χ_y	0.7850	0.5512	0.5603	0.5516
Macroprudential policy	χ_ν	-0.4944	-0.0536	-0.3040	-0.0857
	χ_b	12.5847	20.9737	8.8113	16.3512
Joint loss		0.002987	0.0019512	0.002161	0.0015647
Monetary policy loss		0.000353	0.0003799	0.0002705	0.0002776
Macroprudential policy loss		0.002634	0.0015713	0.0018905	0.0012871
Volatilities					
σ_π^2		0.000055	0.000091	0.000057	0.000064
σ_Y^2		0.000593	0.000575	0.000425	0.000425
$\sigma_{B/Y}^2$		0.000581	0.000230	0.000795	0.000271
$\sigma_{\Delta R^d}^2$		0.000015	0.000014	0.000010	0.000011
$\sigma_{\Delta \nu}^2$		0.017565	0.010538	0.008830	0.008036
Welfare					
Households		-5 395.6	-5 395.6	-5 393.2	-5 393.3
Entrepreneurs		240.3915	240.3911	240.3271	240.3311
Bankers		-5.3903	-5.3903	-5.3879	-5.3879
Total		-5 160.5988	-5 160.5992	-5 158.2608	-5 158.3568

Table A.6: Change in the diversion rate

| | | Monetary Policy Shock | | | |
| | | No run | | Bank run | |
		C	NC	C	NC
Monetary policy	χ_r	-3.9714	-4.8388	-3.4524	-3.5825
	χ_π	22.9786	34.5009	21.4319	28.2108
	χ_y	0.5327	0.3225	0.4155	0.5601
Macroprudential policy	χ_ν	0.3518	0.5399	0.3074	0.5352
	χ_b	1.5726	0.8719	0.9853	0.7907
Joint loss		$2.174 \cdot 10^{-6}$	$0.726 \cdot 10^{-6}$	$2.369 \cdot 10^{-6}$	$1.301 \cdot 10^{-6}$
Monetary policy loss		$2.024 \cdot 10^{-6}$	$0.647 \cdot 10^{-6}$	$2.142 \cdot 10^{-6}$	$1.148 \cdot 10^{-6}$
Macroprudential policy loss		$0.150 \cdot 10^{-6}$	$0.079 \cdot 10^{-6}$	$0.227 \cdot 10^{-6}$	$0.153 \cdot 10^{-6}$
Volatilities					
σ^2_π		0.001419^2	0.000796^2	0.001460^2	0.001069^2
σ^2_Y		0.000103^2	0.000059^2	0.000105^2	0.000078^2
$\sigma^2_{B/Y}$		0.000342^2	0.000274^2	0.000454^2	0.000383^2
$\sigma^2_{\Delta R^d}$		0.000216^2	0.000116^2	0.000228^2	0.000154^2
$\sigma^2_{\Delta \nu}$		0.000523^2	0.000143^2	0.000392^2	0.000175^2
Welfare					
Households		-6 210.8	-6 210.8	-6 207.7	-6 207.3
Entrepreneurs		294.4995	294.4995	294.3515	294.3257
Bankers		-6.6654	-6.6654	-6.6616	-6.6603
Total		-5 922.9659	-5 922.9659	-5 920.0101	-5 919.6346

Table A.7: Expansionary monetary policy shock

| | | Net Worth Shock | | | |
| | | No run | | Bank run | |
		C	NC	C	NC
Monetary policy	χ_r	0.5033	0.6553	0.5090	0.6427
	χ_π	2.3974	2.5047	2.3961	2.4969
	χ_y	0.4677	0.4884	0.4674	0.4866
Macroprudential policy	χ_ν	0.4359	0.4369	0.4095	0.4115
	χ_b	8.8415	9.2284	7.6768	7.6863
Joint loss		0.00135	0.00134	0.001069	0.001067
Monetary policy loss		$0.105 \cdot 10^{-6}$	$0.103 \cdot 10^{-6}$	$0.08 \cdot 10^{-6}$	$0.078 \cdot 10^{-6}$
Macroprudential policy loss		0.00135	0.00134	0.001069	0.001067
Volatilities					
σ^2_π		0.000061^2	0.000053^2	0.000059^2	0.000053^2
σ^2_Y		0.000449^2	0.000447^2	0.000389^2	0.000388^2
$\sigma^2_{B/Y}$		0.023577^2	0.022665^2	0.022965^2	0.022945^2
$\sigma^2_{\Delta R^d}$		0.000073^2	0.000048^2	0.000067^2	0.000048^2
$\sigma^2_{\Delta \nu}$		0.089379^2	0.090914^2	0.073558^2	0.073534^2
Welfare					
Households		-6 210.8	-6 210.8	-6 209	-6 209
Entrepreneurs		294.5042	294.5041	294.4172	294.4173
Bankers		-6.6677	-6.6677	-6.6641	-6.6641
Total		-5 922.9635	-5 922.9636	-5 921.2469	-5 921.2468

Table A.8: Contractionary net worth shock

|		Policy Rules			
		No run		Bank run	
		C	NC	C	NC
Monetary policy	χ_r	-1.3810	-4.7352	-2.4001	-1.8711
	χ_π	2.5183	-22.2485	1.9280	-20.1927
	χ_y	0.5193	0.6391	0.5299	0.5565
	χ_b	-0.1224	-12.3061	-3.9802	-10.3387
Macroprudential policy	χ_ν	0.2744	0.5182	0.4141	0.5183
	$\chi_{b,mc}$	0.2330	-0.2102	6.2432	-0.2119
	$\chi_{y,mc}$	0.5174	0.5382	0.3960	0.5398
	$\chi_{\pi,mc}$	4.4601	2.4532	6.4030	2.4598
Joint loss		0.0031462	0.0082895	0.0006759	0.0065898
Monetary policy loss		0.0005459	0.004358	0.000391	0.0032225
Macroprudential policy loss		0.0026003	0.0039315	0.0002849	0.0033673
Volatilities					
σ_π^2		0.000334	0.004217	0.000222	0.003123
σ_Y^2		0.000405	0.000209	0.000265	0.000152
$\sigma_{B/Y}^2$		0.002321	0.003576	0.000006	0.003097
$\sigma_{\Delta R^d}^2$		0.000094	0.000365	0.000018	0.000235
$\sigma_{\Delta\nu}^2$		0.000768	0.002510	0.001464	0.001943
Welfare					
Households		-6 212.7	-6 212.5	-6 207.1	-6 210.1
Entrepreneurs		294.5327	294.5394	294.3144	294.4324
Bankers		-6.6663	-6.6664	-6.6584	-6.6643
Total		-5 924.8336	-5 924.627	-5 919.444	-5 922.3319

Table A.9: Alternative policy rules
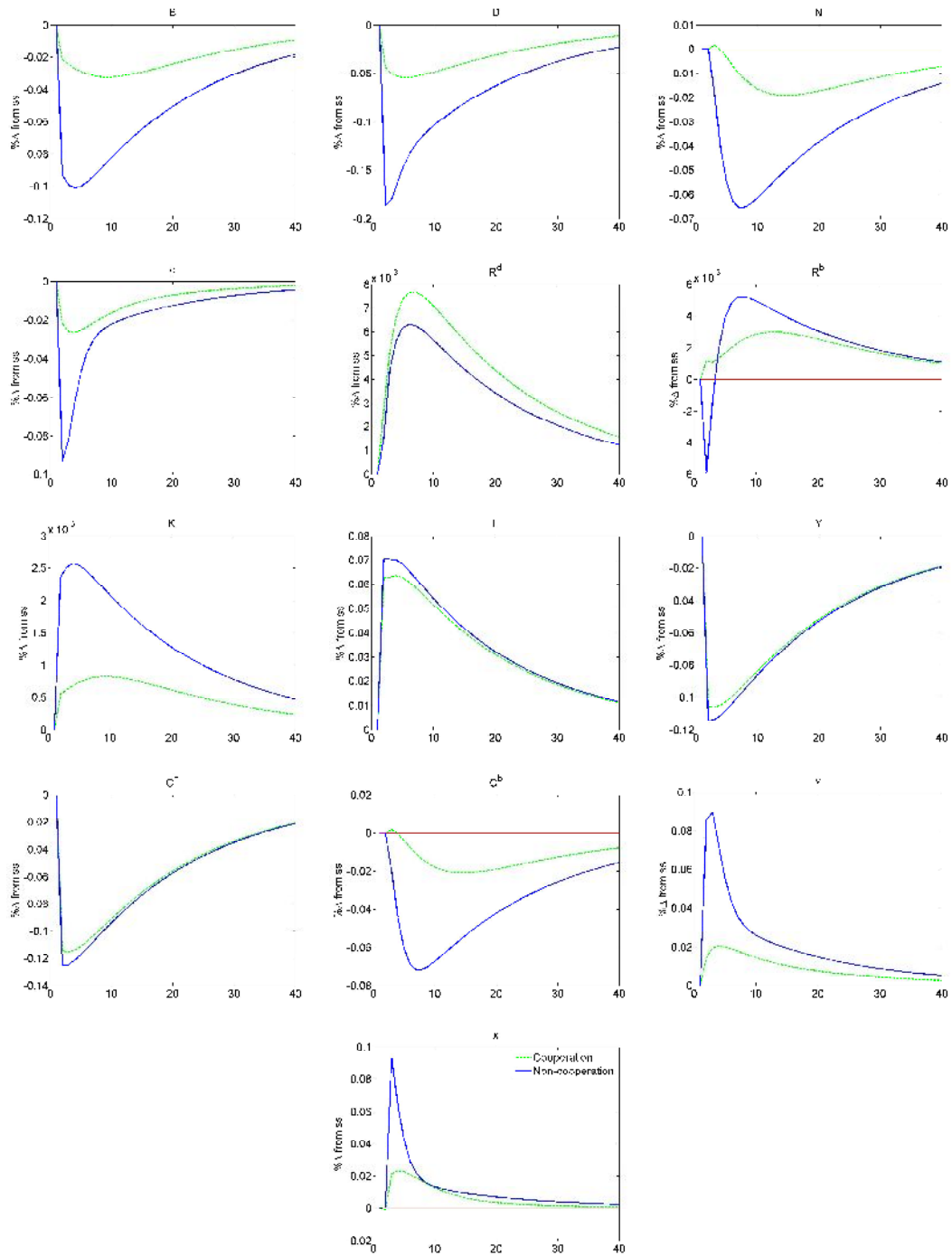
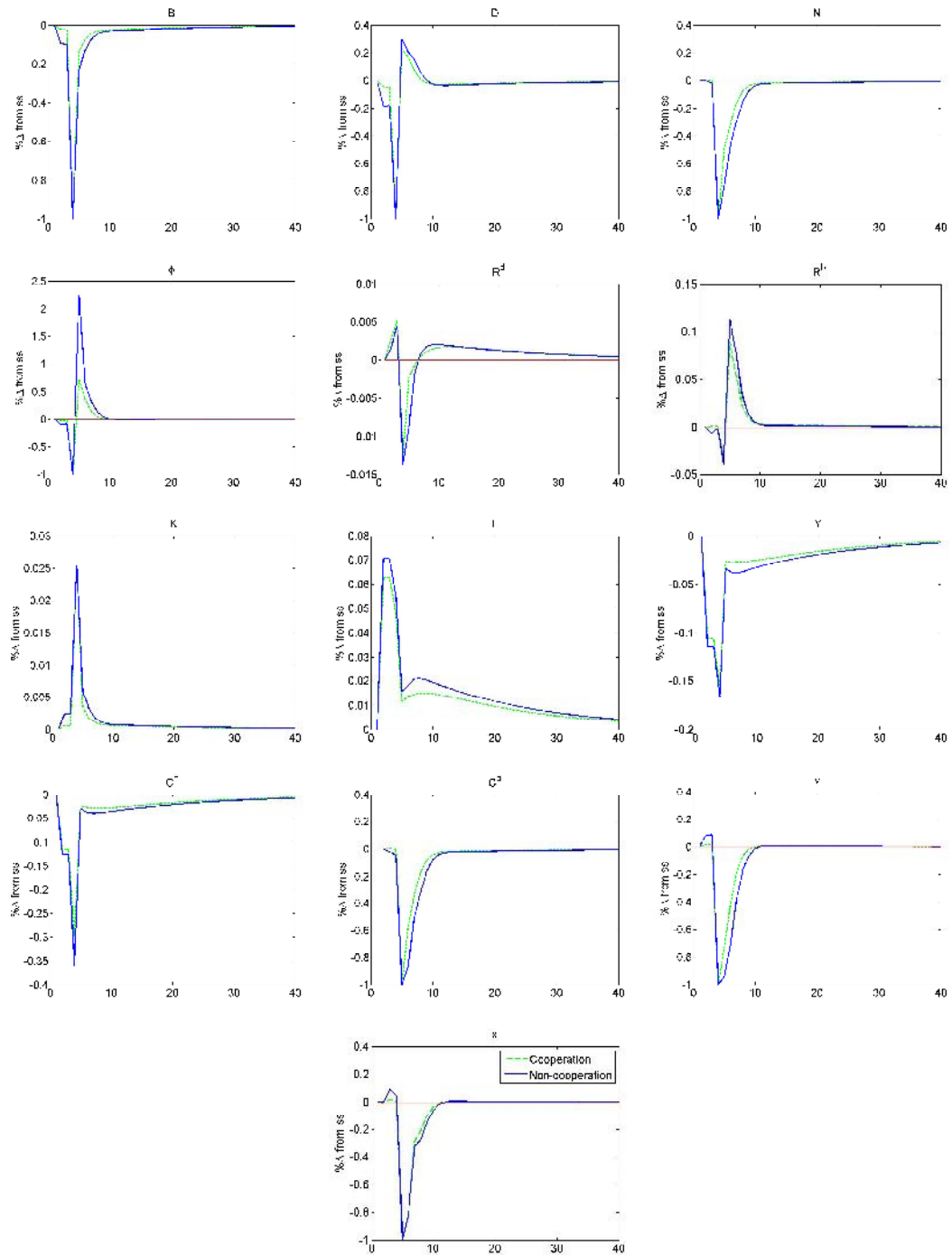Figure A.1: Baseline model - recession without a bank run

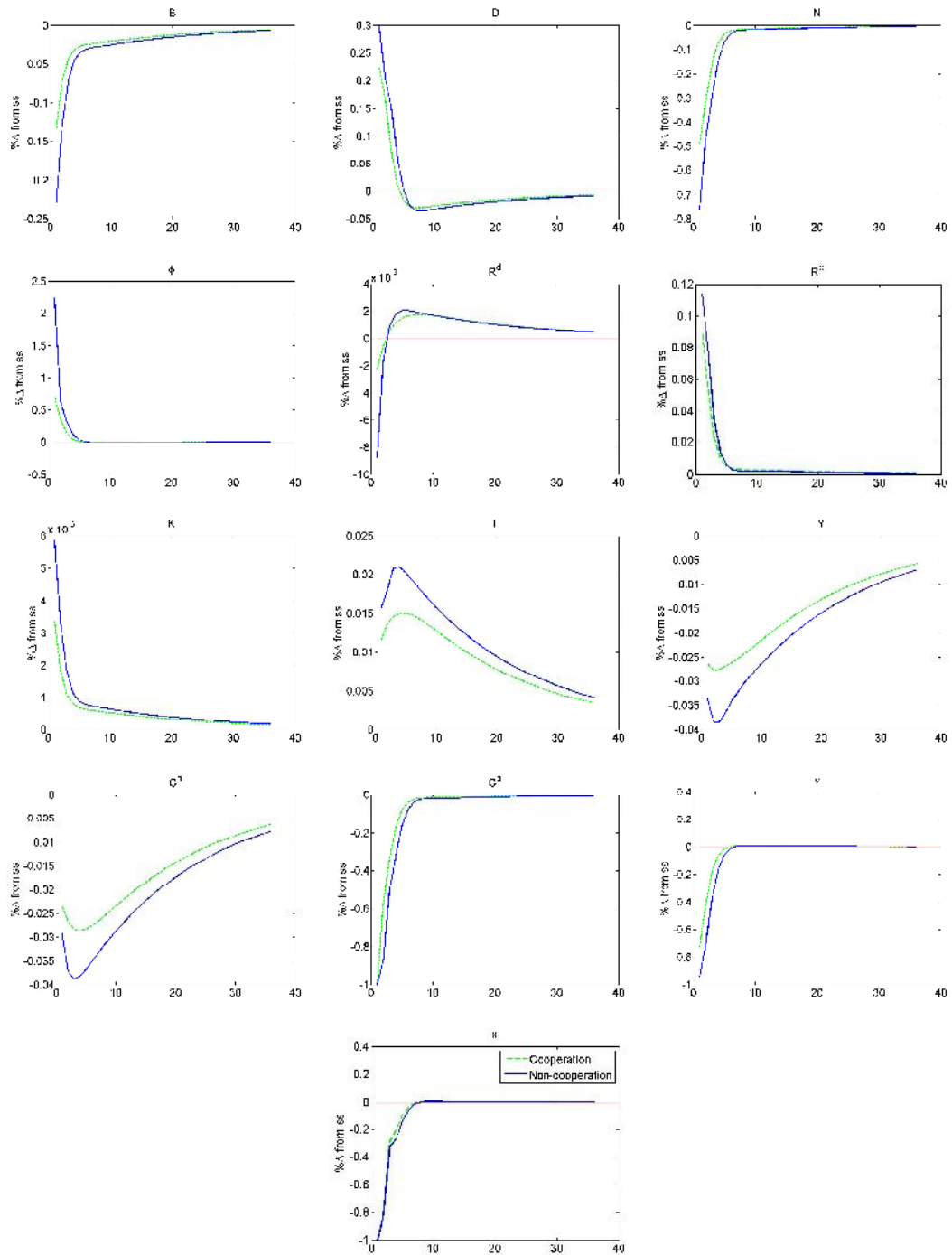Figure A.2: Baseline model - bank run
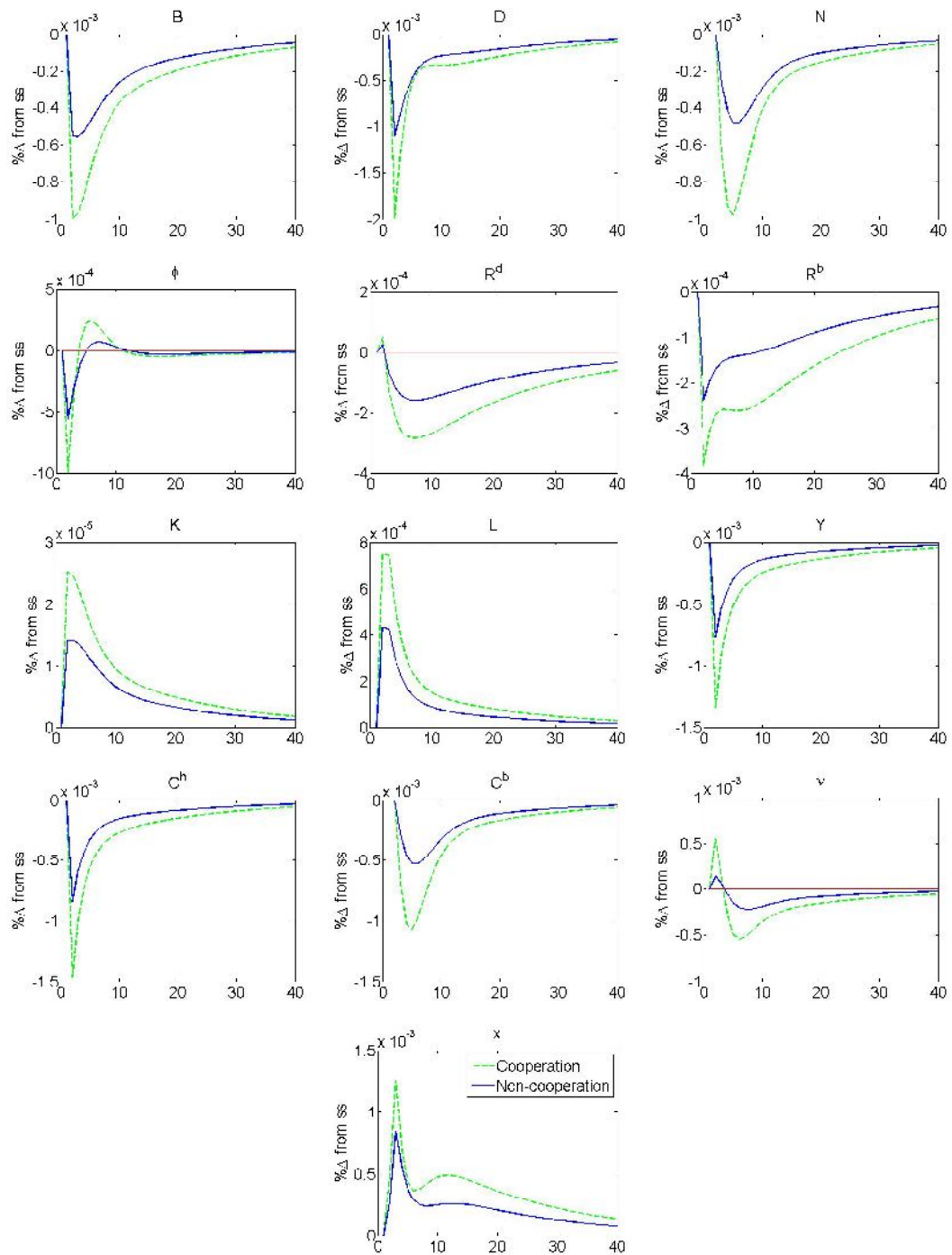
Figure A.3: Baseline model - periods after the run

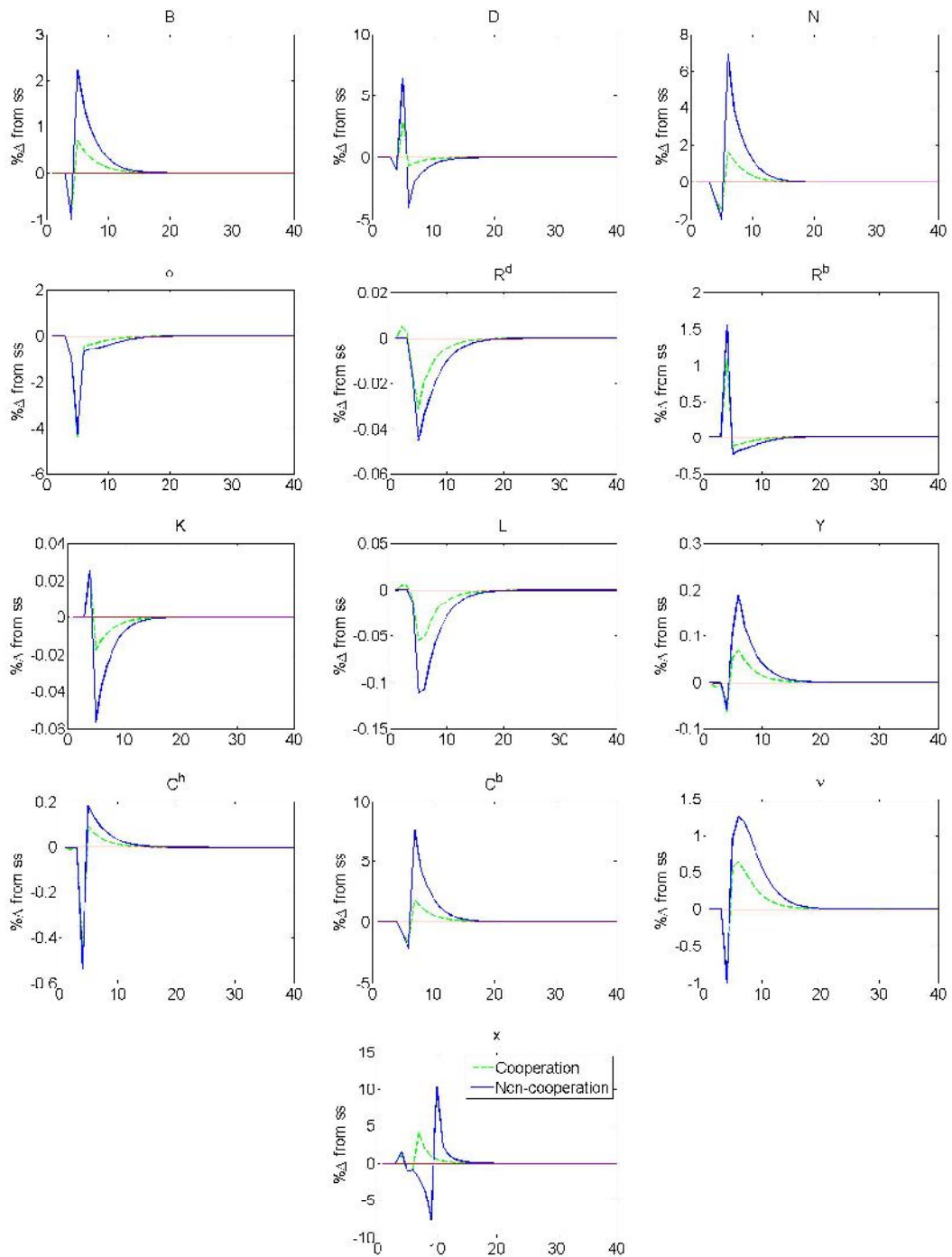Figure A.4: Monetary policy shock - no bank run

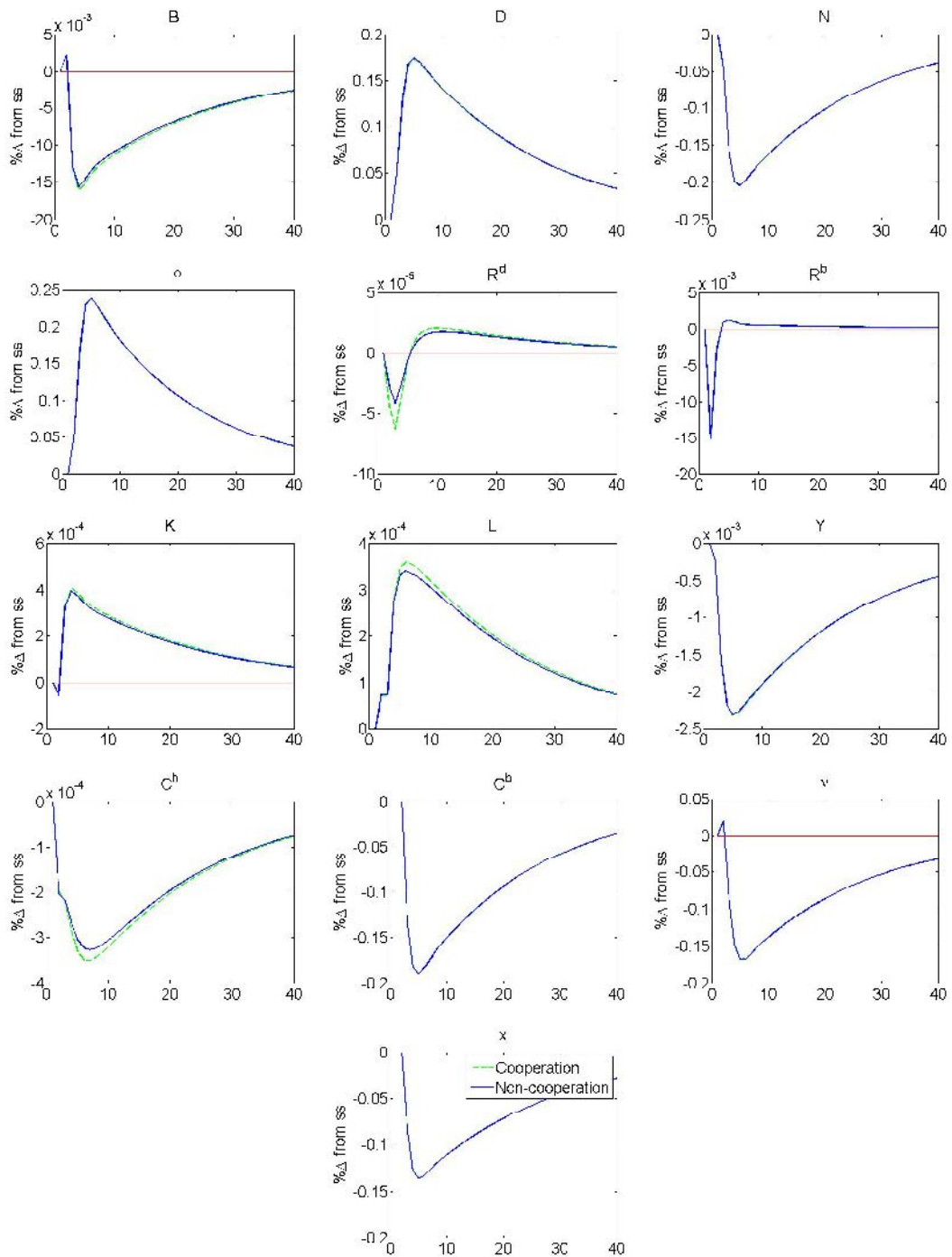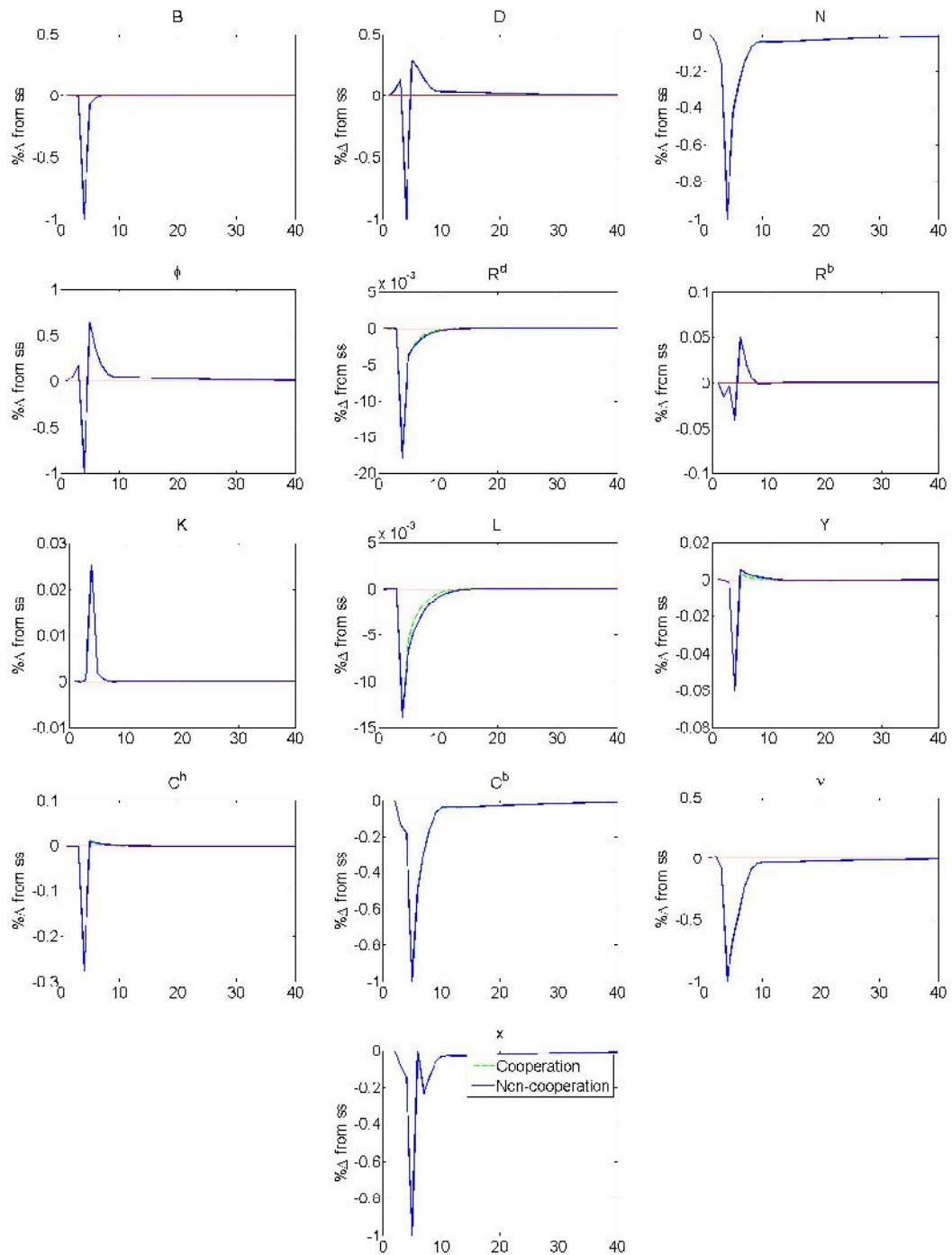Figure A.5: Monetary policy shock - bank run

Figure A.6: Net worth shock - no bank run

Figure A.7: Net worth shock - bank run