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FACULTY OF SOCIAL SCIENCES

Institute of Economic Studies

Master's Thesis

Investigation of the dynamics between monetary and macroprudential policies

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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, May 13, 2016

Signature

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Abstract

This thesis studies the interaction between monetary and macroprudential policy using a DSGE model with real and financial frictions under government and financial shock scenarios. Countercyclical capital requirements are used as a macroprudential policy tool combined with a Taylor rule for monetary policy. In the case of the government shock, our findings indicate that policies' coordination reduces the volatility of the output vis-à-vis a "monetary policy only" regime. Analysis of financial shocks indicates that monetary policy alone can suffice to ensure financial stability. Lastly, welfare analysis suggests there is no optimal policy combination for all agents and highlights a redistributive effect of both shocks, showing that policy that is beneficial for one group of agents can decrease welfare for another.

JEL Classification	E44, E52, E61
Keywords	monetary policy, macroprudential policy, capital requirements, financial stability

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Abstrakt

Tato práce se zabývá interakcí mezi měnovou a makroprudenční politikami s využitím DSGE modelu s reálnou a finanční frikcí v rámci scénářů vládních a finanční šoků. Proticyklické kapitálové požadavky se používají jako nástroj makroprudenční politiky v kombinaci s Taylorovým pravidlem jako nástrojem pro měnovou politiku. Výsledky této práce naznačují, že v případě vládního šoku snižuje koordinace politik volatilitu výstupu vzhledem k režimu využívajícím pouze monetární politiku. Na druhou stranu analýza finančního šoku naznačuje, že monetární politika je sama o sobě postačující k zajištění finanční stability. Analýza blahobytu dále ukazuje, že neexistuje optimální kombinace politik pro všechny agenty a upozorňuje na přerozdělovací účinek obou šoků, který naznačuje, že politika, která je prospěšná pro jednu skupinu agentů může snížit blahobyt pro jinou.

Klasifikace	E44, E52, E61
Klíčová slova	měnová politika, makroprudenční politika, kapitálové požadavky, finanční stabilita

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Acronyms

AR(1) – Autoregressive process

BCBS – Basel Committee on Banking Supervision

BIS – Bank for International Settlements

BLS – Bank Lending Survey

CAR – Capital requirement

CGFS – Committee on the Global Financial System

DSGE – Dynamic Stochastic General Equilibrium

ECB – European Central Bank

EMU – European Monetary Union

ESRB – European Systemic Risk Board

EU – European Union

GDP – Gross domestic product

IMF – International Monetary Fund

LTV – Loan-to-value ratio

PIIGS – Portugal, Italy, Ireland, Greece, Spain

SGP – Stability and Growth Pact

Master's Thesis Proposal

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Proposed Topic:

Investigation of the dynamics between monetary and macroprudential policies

Motivation:

The recent financial crisis has shown that the price stability does not always guarantee the economic and financial stability of the country. The main objective of monetary policy is to ensure stable and low inflation and the output growth. When financial market imperfections (such as an excessive leverage and an exposure to risky assets) are presented the financial stability becomes more important. The key goal of macroprudential policy is to ensure the financial stability and limit the systemic risk. Since the monetary policy is not enough to provide the financial stability and price stability at the same time, both policies should coordinate.

Nowadays the cooperation between monetary and macroprudential becomes an important topic for investigation. There is a very recent stream of literature concerning this field. In the paper of Borio and Shim (2007) the authors analyse the contribution made during recent years in the study of both policies' interaction. They conclude that during the build-up phase of financial distress the monetary policy is not able to fight against it without the macroprudential policy support. The authors insist that it's important to implement macroprudential policy tools before the distress in order to make macroprudential policy work countercyclicaly. Angelini et al. (2012) and Maddaloni and Peydro (2013) discovered different effects of this combination for "normal" times and a period when economy is affected by financial shock. The impact of policies' coordination on economic agents' welfare during two time periods is different. Quint and Rabanal (2013) have found out that the welfare of savers and borrowers is improved if macroprudential policy reacts to the nominal credit growth. But this reaction is not homogenous within the agents. De Paoli and Paustian (2013) investigated the optimal policies combination based on reduction of costs of fluctuations. They conclude that the introduction of additional macroprudential tool improves the welfare in case of coordination and that a leadership of macroprudential authority brings lower losses.

In this area there is still a lot of work to be done. So this thesis is to contribute in a search of optimal policies' combination for Eurozone countries responding to government and financial frictions.

Hypotheses:

1. Hypothesis #1: *The coordination of policies will increase the welfare of borrowers if government shock is present*
2. Hypothesis #2: *Macroprudential policy (taking monetary is a baseline) will decrease the welfare of savers in case of financial shock*
3. Hypothesis #3: *The welfare gains in coordination are larger for borrowers than for savers*

Methodology:

For the estimation I will use the DSGE model including the banking sector with nominal and real frictions following Angelini et al. (2012). This model allows to estimate monetary and macroprudential policies separately and combining them together. The monetary policy is modelled by Taylor rule. For macroprudential policy I will use a loan-to-value ratio and capital requirements as countercyclical instruments. It's important to choose such a macroprudential tool to be different from monetary policy instrument in order to avoid the coordination problem (De Paoli, Paustian, 2013). The idea is to estimate the effect of different policy's combinations on agents' welfare using different types of shock. The agents included in the model are patient households (savers), impatient households (borrowers), entrepreneurs and banks. Each shock will be modelled by the autoregressive process and implemented into DSGE model (Rubio M., Carrasco-Gallego J.A., 2013). First of all I will consider the situation when the monetary policy only is present, then the macroprudential policy will be introduced into the model in cooperative way and alone having monetary policy as a baseline. The aim of each policy is to minimize its own loss function (taken by second-order approximation of utility function). Using model calibration I can address my hypotheses. In such a way I can also estimate the volatility of key monetary and macroeconomic parameters and construct the impulse response function (Angelini et al., 2012; Rubio M., Carrasco-Gallego J.A., 2013).

Expected Contribution:

I will estimate the effect of the interaction of monetary and macroprudential policies on financial stability of Eurozone countries. I will try to find the optimal policies‘ combination that improves the welfare of different groups of agents and decreases the volatility of economic variables when the different types of shock are present. In contrast to previous studies of this topic I will consider the government shock instead of the technology shock. I decided to choose this type of supply shock because it affects key macroeconomic variables such as GDP and wages which is important for welfare analysis of agents. I expect to obtain different results of optimal policies‘ combinations following supply and financial frictions.

Outline:

1. Introduction
2. Some stylized facts about macroprudential policy: instruments, interactions with other policies, countries‘ statistics
3. Literature review: briefly review of the recent literature of macroprudential and monetary policy modelling
4. Model specification: DSGE model description, modelling of macroprudential and monetary policies separately, interactions between two policies
5. Results: description of results with different types of shock, welfare analysis for different agents
6. Conclusion: a summary of achieved results

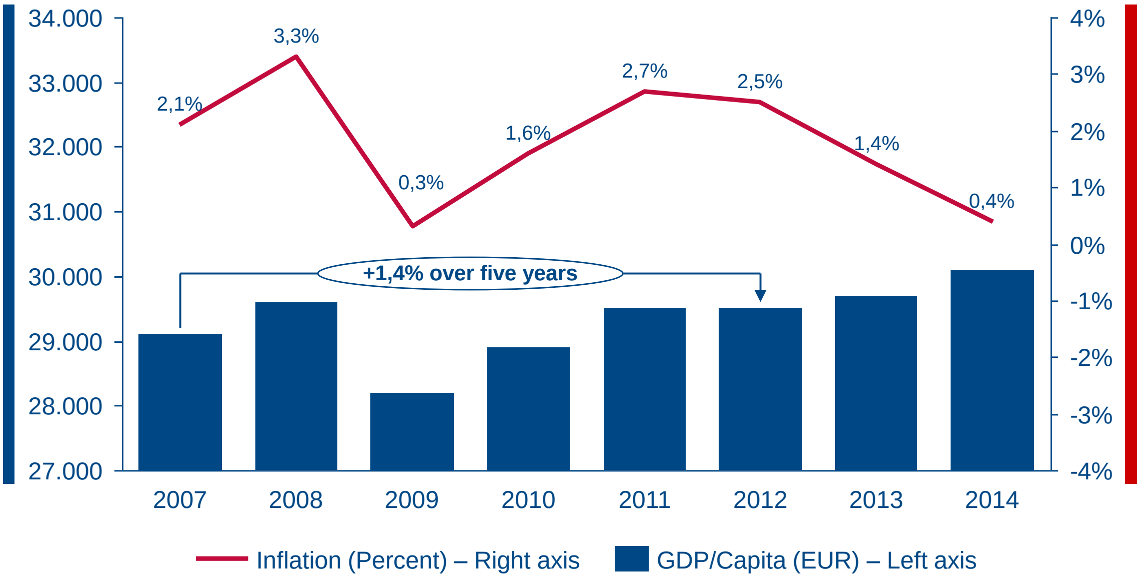
Core Bibliography:

1. Angelini P., Neri S., Panetta F., 2012. Monetary and macroprudential policies. ECB working paper №1449.
2. Borio C., Shim I., 2007. What can (macro-)prudential policy do to support monetary policy? BIS working paper №242.
3. De Paoli B., Paustian M., 2013. Coordinating monetary and macroprudential policies. FRBNY staff report №653.
4. IMF executive summary. The interaction of monetary and macroprudential policies. 2013.
5. Maddaloni A., Peydro J-L., 2013. Monetary policy, macroprudential policy and banking stability. Evidence from the Euro area. ECB working paper №1560..
6. Quint D., Rabanal P., 2013. Monetary and macroprudential policy in an estimated DSGE model of the Euro area. IMF working paper
7. Rubio M., Carrasco-Gallego J.A., 2013. Macroprudential and monetary policies: Implications for financial stability and welfare.

1. Introduction

Following the global crisis of 2007 – 2008, economists argued[1] that monetary policy offers little protection from systemic risk, and therefore different instruments need to be employed in order to secure the overall stability of the financial system, irrespective of inflation. Indeed, the crisis has shown that price stability does not always imply neither the overall financial stability nor the economic growth – while the inflation rate in the Eurozone between 2007 and 2012 averaged at 2.1 percent, economic growth was stagnant (as can be seen in Figure 1) and the year 2009 marked the beginning of the European sovereign debt crisis.

Figure 1 – GDP and inflation in the Eurozone[2]



Borio and Shim (2007) show that the economic environment has changed significantly over the past quarter century. Due to globalization, the markets for the factors of production have become more integrated, triggering financial imbalances in the form of, for instance, asset bubbles, maintaining a low level of inflation. While such imbalances do not automatically imply financial distress, when they occur in a system that is over-leveraged or overexposed, they have the potential to put a liquidity squeeze or perhaps even affect solvency of banking institutions exposed to them. Furthermore, there is also a potential for this shock to spread throughout the financial system in a domino-like fashion, each asset crash triggering further solvency issues.

[1] Smets (2013); Brzoza-Brzezina (2013)
[2] Source: Eurostat

Due to these dynamics – which indicates that our financial system may be prone to more imbalances – other approaches that could address systemic risk have emerged, one of which are macroprudential policy measures. The Basel III framework is a specific example of the use of macroprudential policies.

As the topic of macroprudential regulation has started receiving increased attention only recently, we do not have much experience regarding dynamics of the interactions of polices, and thus we lack the knowledge on how to most efficiently coordinate their use. Recent literature suggests that an introduction of an additional macroprudential tool can be costly[3] or that if the interaction is uncoordinated the reaction to macroprudential policy can be procyclical[4]. Suh (2012) and Angelini *et al.* (2012) also observe that the effect, in general, depends on the type of shock and the macroprudential tool employed.

The aim of this paper is to investigate the interaction dynamics between monetary and macroprudential policy in the context of the financial crisis and the subsequent European sovereign debt crisis. We will model a scenario that would reflect the main features of the sovereign debt crisis while attempting to capture the effect of different policies' combination on the economy and compare these results for government and financial shocks. Our objective is to ascertain which policy combination improves agents' welfare in case of different shocks to the economy.

The main contribution of this thesis to the study of the interaction of policies is the analysis of impact of macroprudential policy on agents' welfare in the context of government and financial shocks.

In order to investigate our hypotheses, we will use a dynamic stochastic general equilibrium (DSGE) model in line with Gerali *et al.* (2009) and Angelini *et al.* (2012). We believe this specification is appropriate for our welfare dynamics estimation because it can capture the effect of macroprudential policy on real and financial variables independently from monetary policy.

This thesis is organized as follows: Chapter 2 summarizes the literature and provides stylized facts about macroprudential policy and government shock, Chapter 3 presents hypotheses, Chapter 4 describes the DSGE model, Chapter 5 briefly summarizes our findings, Chapter 6 shows the results from the model estimation, and Chapter 7 concludes.

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[3] Angelini *et al.*, (2012)
[4] Carvalho and Castro (2015)

2. Literature review

2.1. Stylized facts about policies interaction

The term “macroprudential” has been mentioned for the first time at the meeting of the Cooke Committee in 1978 (the Cooke Committee later became the current Basel Committee on Banking Supervision) in connection to macroeconomic and financial stability and methods to facilitate increased lending in developing countries. Nevertheless, the modern history of macroprudential policy started in 2000 at the International Conference of Banking Supervisors where it was highlighted that macroprudential policy should complementary to the microprudential[5] policy in order to ensure financial stability. This new approach significantly changed the view that had been widely accepted just a decade before, claiming that the monetary policy alone can ensure both price and financial stability.

The main argument against using solely monetary policy is that sometimes, in pursuit of financial stability, a central bank may deviate from the inflation target by increasing interest rates. Over time, it became clear that the monetary policy does not possess necessary instruments to effectively achieve both targets (Chiriacescu, 2013). Papademos (2010) defined financial stability as “a condition in which the financial system – comprising financial intermediaries, markets and market infrastructures – is capable of withstanding shocks and the unravelling of financial imbalances, thereby mitigating the likelihood of disruptions in the financial intermediation process which are severe enough to significantly impair the allocation of savings to profitable investment opportunities”[6]. The paper also pointed at several problems that emerged from the recent financial crisis experience in Europe. First, the nature and consequences of systemic risk have been underappreciated by understating the impact of large banking groups. Second, the problem of financial authorities was that they focused on stability of individual institutions and not on the system as a whole.

The evidence from the recent financial crisis raised the question about the monetary policy’s ability to deal with distress. As described above, the price stability and the safety of particular institutions cannot guarantee the essential financial stability of the system as a whole. It made the macroprudential policy to emerge as a policy that can ensure the stability of the whole financial system. Macroprudential policy is used to

[5] Policies applicable to individual institutions on a standalone basis
[6] p. 460

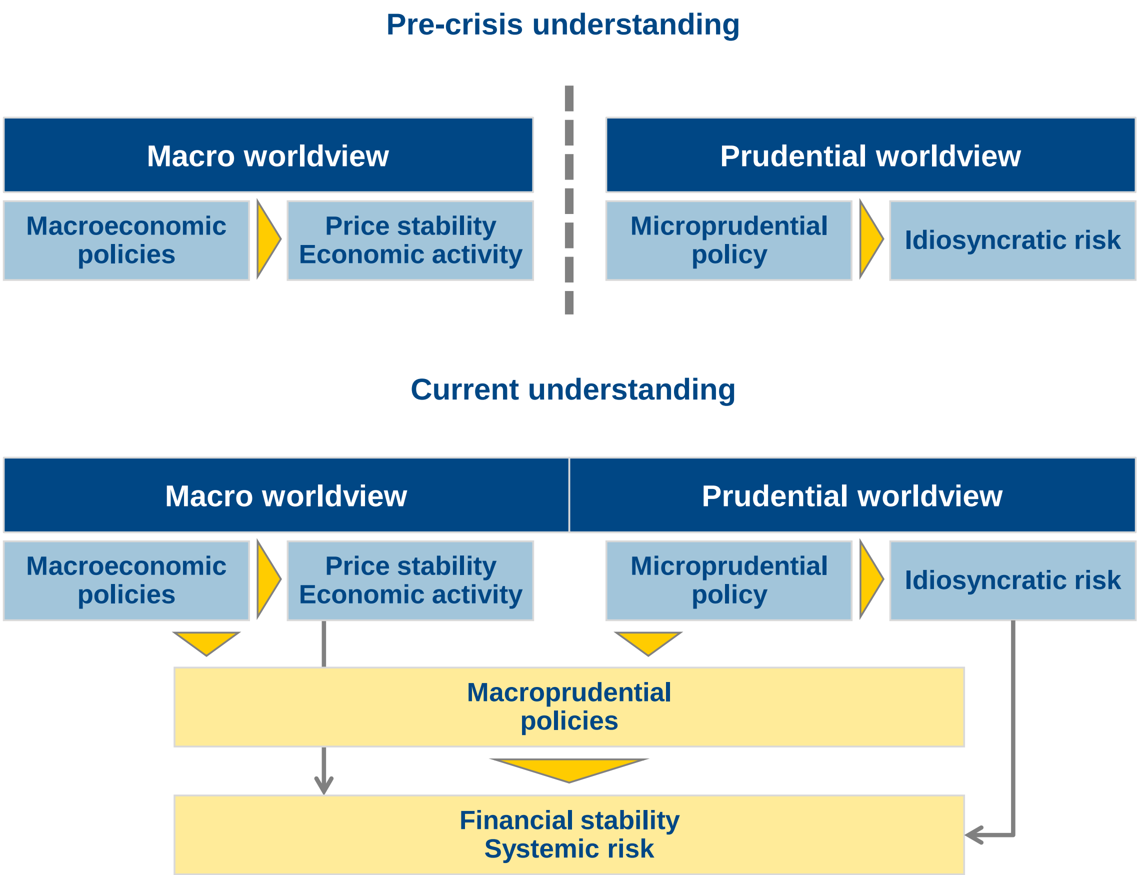
prevent the development of financial imbalances in its build-up phase and make the financial system more resilient to shocks (Smets, 2013). As macroprudential and monetary policies pursue different objectives they should utilize different tools. According to Tinbergen's effective assignment principle, "there should be as many instruments as objectives needed and that the instrument should be assigned to those objectives that they can most efficiently achieve[7]" (Tinbergen, 1952). One reason why the monetary policy is not able to achieve financial stability is that distortions are not always related to the degree of liquidity in the system which monetary policy can affect. Additionally, if the impact of financial distortion is not homogenous among economic sectors, monetary policy is ineffective. In this case, the conflict between policies' objectives arises and an additional macroprudential tool can increase agents' welfare (IMF, 2013).

The introduction of macroprudential policy increases the monetary policy trade-off. Moreover, if the monetary policy is constrained by zero lower bound, price stability conflict with financial stability. Agents do not internalize their contribution to the systemic risk as a result they take excessive leverage and liquidity risk rises. By constraining financial market participants' behaviour, macroprudential policy forces them to internalize their contribution to systemic risk and reduce it. Macroprudential tools can also provide buffers against unexpected shocks. Policies complement each other by supporting the transmission (IMF 2013).

Figure 2 shows the view of policies' objectives before and after financial crisis (IMF 2013).

[7] See Smets (2013) p. 2

Figure 2 – Policies and their objectives



Yet the interaction between two policies may have side effects when one policy pursues a certain goal while the other has a different primary goal, which essentially means that policymakers act in an uncoordinated fashion. For instance, the change in policy rates affects agents' behaviour of taking excessive leverage that can be also a macroprudential concern. This dynamic may be partly counteracted using an appropriate macroprudential instrument may, thus giving monetary policy more space for movement. For example, when monetary policy increases the asset price by reducing the policy rate it leads to leverage growth and asset price boom, in this case limits on loan-to-value (LTV) ratios or higher capital requirements can reduce the volatility. On the other hand, if macroprudential policy affects output, an effective monetary policy can reduce it, if necessary. For example, increasing of capital buffers makes banks quickly issue new equity, which might not be possible due to limited access to financial markets. This effect can be offset by more accommodative monetary policy as long as it is effective[8].

According to Smets (2013), there are three different views on policy interaction:

[8] IMF (2013)

i. A “modified Jackson Hole consensus”
ii. “Leaning against the wind vindicated”
iii. “Financial stability is price stability”

Below is a brief overview of all three views.

A “modified Jackson Hole consensus” argues with the popular pre-crisis view called Jackson Hole consensus which states that the financial stability is taken into account by the monetary authority as a complementarity to price stability. By the Jackson Hole consensus, the Central bank should not target asset prices and should not deal with bubbles (Issing, 2008). In contrast, a modified Jackson Hole consensus argues that the monetary policy should be responsible only for price stability and that macroprudential policy should pursue financial stability with a unique set of instruments. Moreover, this view aims to emphasize that the interaction between two policies is limited and thus the instruments, objectives and transmission mechanisms of two policies can be easily separated.

“Leaning against the wind vindicated” supports the “leaning against the wind” strategy. According to this view, action done by monetary policy can affect risk taking by financial intermediaries and at the same time, weak financial intermediaries may negatively affect price stability. It states that central banks’ short-term inflation targeting is a weak instrument against financial distortions. This view stresses that financial stability is considered as a part of monetary policy secondary objectives leading to a widening of the policy horizon.

“Financial stability is price stability” insists on a strong connection between two policies. This view argues that price stability and financial stability are strongly interconnected so it is impossible to differentiate them. Under this approach, the coordination between monetary policy and macroprudential policy is crucial because it solves the problem of time inconsistency that arises due to the fact that the financial cycle is longer than the business cycle (Smets, 2013).

There are several arguments supporting the third view; i.e. monetary and macroprudential policies should exist under one roof. First, the coordination can be better achieved if one institution controls both financial and the price stability. Second, if macroprudential tool is inefficient, it might be more appropriate for monetary policy to also pursue financial stability. Lastly, some of non-standard monetary policies, as for example reserve requirement, can be also seen as macroprudential tools. On the other hand, the main reason why policies should act separately is that pursuing both objectives decreases central bank's credibility as it may increase political pressure (Smets, 2013).

2.2. Country experience from using macroprudential instruments

Macroprudential policy is a relatively new way to address systemic risk. The Macroprudential policy became widely used in Asia after the crisis in 1990s, and it has also become more popular in recent years in Europe. With regards to policies' interactions and country specifics, an important factor is whether the country can control exchange rate or not (as is the case of Eurozone member states). For the latter group of countries, macroprudential policy becomes an efficient tool to compensate the possible loss of independent monetary policy. In this section, we would like to briefly discuss some examples of macroprudential tools implementation in Europe (based on Grace *et al.* (2015)).

As a response to the global crisis, the European Union established the European Systemic Risk Board (ESRB) under the purview of the European Central Bank (ECB), with its main role being macroprudential oversight. However, the ESRB currently does not have a direct enforcement power and it is represented only as an advisory organ while the ECB and the national authorities still plays a decisive role.

Since 2003, Austria has adopted measures to reduce the amount of foreign currency denominated loans in order to address the risk created by foreign currency lending. The risk awareness of foreign currency borrowers was increased and the granting of foreign currency loans has been suspended. However, these measures are non-binding and serve mainly as recommendations.

In order to reduce the risk in mortgage market in 2010, the Netherlands announced the gradual reduction of LTV cap of 100 percent by 2018.

Motivated by high household debt Norway reduced LTV cap to 90 percent of housing loans and to 75 percent for home equity loans. These measures were efficient in credit growth reduction. Furthermore, in 2015 Norway implemented a 1 percent countercyclical capital buffers. Sweden had a similar problem with high household indebtedness. In order to protect consumers the government has introduced LTV cap of 85 percent for mortgages. This measure is to reduce the amount of new mortgages with loans higher than 85 percent of market value. Similarly to Norway, Sweden took 1 percent countercyclical capital buffers.

In order to strengthen the resilience of the financial system in 2013 Switzerland has introduced sectoral countercyclical capital buffer[9].

2.3. The effects of government shocks on the economy

Kirchner *et al.* (2010) report that the level of government debt significantly affects government spending in the long-term period. In other words, higher debt-to-GDP ratio affected by government spending shock may increase uncertainty about sustainability of public finance, which would lead to lower consumption. They also explained several transmission channels through which government shock affects the economy. In particular, "after long deficit cut consumption increases because an (larger) expected increase in taxation tomorrow causes a (larger) decline in wealth and a (larger) fall in consumption today. A significant and sustained reduction of government spending may then lead consumers to expect a permanent future tax cut and an increase in permanent income, resulting in a rise in private consumption" (Kirchner *et al.* 2010). Furthermore, the presence of a credit constraint decreases private consumption because agents expect higher taxes in future so they start to consume less and save more. Another transmission channel is wages, as more than half of government spending in EMU consists of wage payments in the government sector. In this case, government shock has a negative wealth effect on consumption and labour supply.

When we talk about the recent Eurozone crisis, we consider a sovereign debt crisis as the crisis that persisted for several years in certain Eurozone countries. The key feature of this crisis is that countries were unable to repay their government debt or to bail themselves out by essentially 'printing money,' as they were constrained by having one common monetary policy controlled by the European Central Bank. Government actions had profound effects of economic dynamics of the countries, as the states had a huge government debt and deficit three to four times higher than what would be in line with the Stability and Growth Pact. According to Brown and Chambers (2005) this problem occurred because some countries were hiding their true indebtedness by using inconsistent accounting and off-balance-sheet transactions and thereby ignoring the international standards on national accounting of liabilities. In 2009 this problem

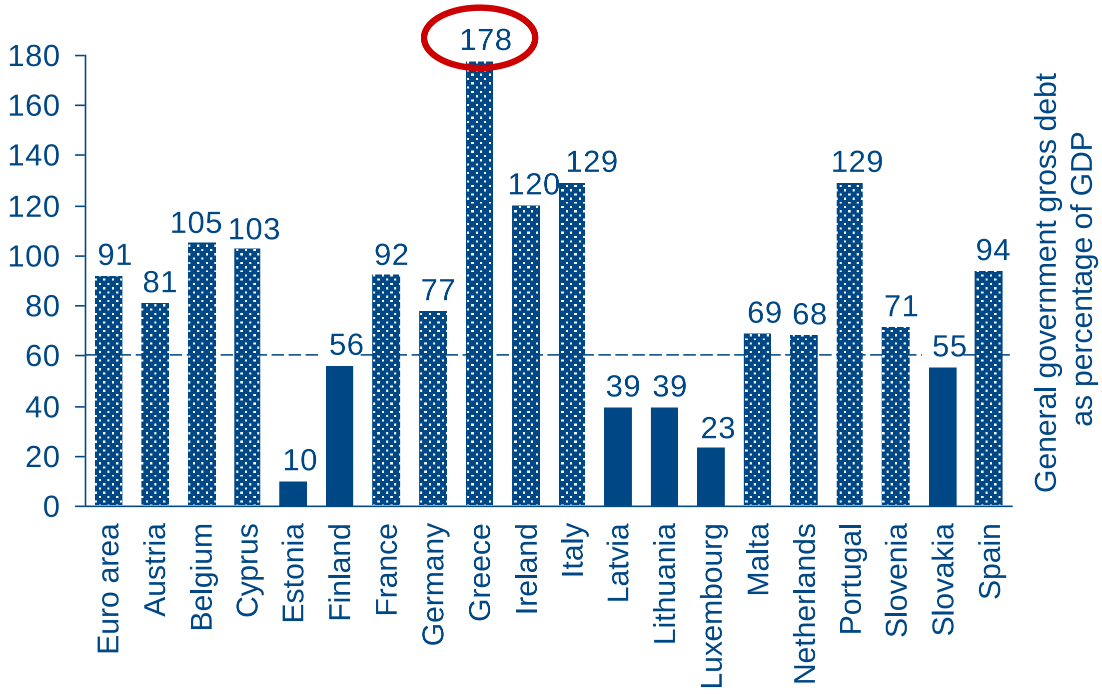
[9] See Grace *et al.* (2015), Lim *et al.* (2011)

became public and gave rise to further uncertainty with regards to the PIIGS[10] countries' long term solvency. In particular, the reason behind the significant government debt in Greece was a size of government sector in the economy and enormously high wages in this sector (Matsaganis, 2011). This is an example of a government spending shock that became a starting point for the economic distress of the aforementioned countries. In numbers, the government debt of Ireland has increased by 61.1 percent of GDP from 2009 to 2013, the government debt of Portugal raised by 44.4 percent in a corresponding period, and Greece – by 48.1 percent which along with the fall in GDP made the total government debt-to-GDP ratio reach 174 percent in 2013 (Eurostat). Unfortunately, monetary policy alone cannot ensure the reduction of such an accumulation of long-term debt because it doesn't dispose with instruments that work in a countercyclical manner. Currently, apart from fiscal measures, macroprudential policy is seen as a good solution of this problem. According to Smets (2013), taking in to account the specifics of the EMU, monetary policy cannot longer exist alone, and macroprudential policy is crucial in avoiding cross-border externalities in supervision and contagion of systemic risk. Boz *et al.* (2015) examines the link between sovereign risk and banking sector stress. This link is not obvious but it was proven from the previous sovereign default experiences that sovereign crises bring further distortions in the financial system[11]. The specific case of the Eurozone shows that the EMU sovereign bonds are assigned a risk-free rate, not taking into account a credit rating of the issuer sovereign. The results from this paper suggest that macroprudential policy, acting through the leverage ratio and capital requirements on risk weighted assets, is welfare improving even if the risk weight of sovereign bonds is zero.

In Figure 3 illustrates the percentage of government debt to GDP in Euro area in 2013. In most of EMU countries government debt exceeded the maximum threshold of 60 percent GDP as defined in the Stability and Growth Pact (SGP).

[10] Portugal, Italy, Ireland, Greece and Spain
[11] See Boz *et al.* (2015).

Figure 3 – Government debt as a percentage of GDP in 2013[12]



Taking into account the experience from the recent financial crisis 2007-2008, the European Commission has decided to give a key role of macroprudential supervision to the European Systemic Risk Board (ESRB) that has been created at the end of 2010. According to its mandate, the ESRB is "responsible for the macroprudential oversight of the financial system within the monetary union in order to contribute to the prevention or mitigation of systemic risks to financial stability" (Gerba and Macchiarelli[13], 2015). It is important to understand that this organ doesn't have a legal binding authority, but it can give warnings and recommendations to the European Union and its individual members.

The specific feature of a monetary union is that it has a single monetary policy but at the same time there is certain heterogeneity among the countries. The task of the macroprudential policy is to address side effects of monetary policy on financial stability, suggesting that macroprudential policy should be also complemented by fiscal and structural policies on different government levels. In this particular case, Gerba and Macchiarelli (2015) argue that ECB or SSM and ESRB should establish a balance between micro- and macroprudential policies' actions and ensure their communication on European and national levels.

[12] Source: Eurostat
[13] p.8

2.4. Modelling policies

The study of macroprudential and monetary policies is presently gaining more and more traction. One of the papers published before the recent financial is an article by Borio and Shim (2007) in which the authors analyse the contribution made in this field during recent years. They concluded that much progress has not been made because of analytical and institutional obstacles. The authors suggest how to remove these obstacles emphasizing the importance of creating a set of macroprudential measures in good times in order to implement them efficiently during distress. It is better to think that the risk rises in booms not in recessions, and measures against it should be high enough to limit it in time of imbalances.

2.4.1. DSGE model for the Euro Area

From the technical point of view, most papers about the interaction between monetary and macroprudential policies are based on DSGE models. For instance, Rubio and Carrasco-Gallego (2013) analyse the effect of coordination and non-coordination between macroprudential and monetary policies for welfare and financial stability. They use the loan-to-value ratio as a macroprudential instrument and they conclude that acting together, policies improve the welfare of agents especially in non-coordinated game.

Similarly Angelini *et al.* (2012) discuss the interaction between macroprudential and monetary policies based on a DSGE model with banks and credit market frictions for Eurozone. Their model is based on the previous study of Gerali *et al.* (2009) including banking sector modelled by Angelini *et al.* (2011). They find different effects of the policy combination for "normal" times and a period when economy is affected by a financial shock. The authors use LTV and capital requirements as macroprudential policy instruments. Findings include the fact that when economy is driven by supply shock, non-cooperative policies may increase the volatility of policy instruments because they have different objectives, and cooperation brings just a slightly positive effect compare to using a monetary policy only. The authors suggest using only the monetary policy in this case. But when the economy is hit by financial shock, the coordination of monetary and macroprudential policies has a positive effect on economy stabilization. Monetary policy only is not enough for reducing the harmful effect of financial shock. For the further investigation, the authors offer to find some proxy for systemic risk to improve the model.

Brzoza-Brzezina *et al.* (2013) investigate whether the introduction of macroprudential policy in peripheral Eurozone has a significant effect on its price stability. The authors simulate a DSGE model with household and banking sector, their analysis based on calibrated parameters. The paper assumes different types of asymmetric shocks hitting the core and periphery. This could, for instance, be a productivity shock, housing preference shock or a monetary shock. The main findings are as follows: macroprudential policy can substantially reduce the volatility of output as well as other key macroeconomic variables (except mortgage loans in case of LTV policy). This policy is efficient in case of monetary policy, investment specific and housing preference shocks. LTV and CAR turn out to be inefficient when economy is hit by productivity shock. As opposite to Suh (2012) this paper concludes that the effect from using LTV ratio as a macroprudential instrument is higher than capital requirements.

De Paoli and Paustian (2013) study the implementation of new policy instruments, in particular the coordination of monetary and macroprudential policy that can guarantee the financial stability. The authors analyse macroprudential policy as a cyclical tax on the borrowing of firms. The model considers cooperation between authorities in a non-cooperative Nash game. The authors' analysis focuses on a reduction of costs of fluctuations using a model in which these costs are driven by nominal rigidities and credit constraints. The paper finds that if the cost-push shock is present the policies should cooperate. If the policies are set up independently one policy should be leading in order to reduce coordination problems. The authors also suggest using alternative tools for modelling macroprudential policy, for example LTV or taxes on deposit rates.

Beau, Clerc, Mojon (2012) analyse the interdependencies between monetary and macroprudential policies based on DSGE model for the Euro area. Their main goal is to find the circumstances under which both policies affect the price stability on positive, neutral or negative manner. The authors try to ascertain whether there is a risk of conflict arising from the interaction between monetary and macroprudential policies. Lastly, they compare the dynamic stability for four different policy regimes and they conclude that the response of inflation to technology, monetary and cost-push shocks is almost identical among the four regimes. Macroprudential policy or its combination with an augmented Taylor rule policy would have a better effect on parameters in case of a financial shock.

Quint and Rabanal (2013) study the optimal combination of monetary and macroprudential policies based on two-country model for Eurozone. This model includes real, nominal and financial frictions to find out the optimal responds of both policies. The authors discovered that implementing of macroprudential policy rules may have a positive effect on volatility and welfare. The introduction of macroprudential policy leads to welfare growth of savers, but its effect on borrowers' depends on the type of shock. The authors used the DSGE model, specified as follows:

1) Two countries (all countries are split in two groups: a core and a periphery)
2) Two sectors (durables, non-durables) non-durables are traded across countries, durable goods are non-tradable
3) Two types of agents (savers and borrowers). Monetary policy is estimated by the extended Taylor rule.

The macroprudential instrument that influences credit market conditions is then introduced. This instrument is ether additional capital requirements, liquidity ratios, reserve requirements or loan-loss provisions. The paper has a range of differences comparing to the rest of literature investigated the joint effect of monetary and macroprudential policies. Real Eurozone data is used for estimation (not calibrated parameters). The aim of the policies is to maximize welfare, and unlike other papers this one studies the intranational and international redistribution effects. The main results are that the welfare gain after introducing the macroprudential policy is relatively small, and the optimal policy combination has a large redistribution effect within countries.

The model similar to Angelini *et al.* (2012) is used by Darracq Pariès *et al.* (2010). The closed economy DSGE model encompasses financially constrained households, entrepreneurs and oligopolistic banks. The paper provides interesting analysis of different types of distortions into the model. For instance, the estimation shows that a positive shock to housing preferences, which increases the amount of loans, leads to the restrictive monetary policy and a negative spill-over effect on corporate sector. In this case, GDP growth and inflation is compensated by the negative effect on investment. There is an evidence of a positive impact of technology, labour supply and investment shocks on investment activity. To model the interaction between macroprudential and monetary policies, the capital requirement and the interest rate rules are used. The authors construct a joint loss function similar to Angelini *et al.* (2012). They found that the optimized monetary policy rule is significantly affected by an introduction of countercyclical capital requirement. This specification allows the decrease of the volatility of key macroeconomic variables significantly. However, despite the reduction of the values of the joint loss function almost to zero, this result leads the cost of increasing the volatility of bank lending rate, which is difficult to implement in practice. Therefore, the authors insist that the macroprudential policy rule should be calibrated very carefully. For future analysis and estimation, they suggest improving the specification of banking sector in this model by, for example, taking into account the liquidity position of banks.

Another contribution in studying the jointly optimal effect of monetary and macroprudential policy was made by Collard *et al.* (2012). The authors assume that the source of financial friction is connected with the excessive risk-taking by banks. Furthermore, the paper sets up an equilibrium conditions under which locally optimal (Ramsey) policies introduce a macroprudential policy instrument (in this case, capital requirements) to prevent an excessive risk-taking by banks. The model proposed allows for illustrating the changing in capital requirements in time with respect to shocks which affects the attractiveness of risky and safe projects.

2.4.2. DSGE for different countries

Suh (2012) considers the banking sector in the DSGE model with financial frictions applying calibrated parameters based on US data. Within this model, the task of monetary policy is only to stabilize inflation, and the task of macroprudential policy is to stabilize credit. It focuses on efficient interactions between the two policies such that financial, inflation and output gap stability can be achieved. Suh (2012) assumes that monetary policy follows an extended Taylor rule in log-linearized form. Next, the author uses the capital requirement ratio and target LTV as macroprudential policy instruments, implementing shocks to productivity, housing preferences and government spending that follow stationary AR(1) processes. For welfare analysis, the paper splits the economic cycle into three groups: “stable” – no shocks, “normal” – basic calibration for the standard deviation of shocks, and “volatile” – two times higher volatility. The conclusion is that the macroprudential policy is a welfare-improving. Welfare gains are higher for countercyclical capital requirements, and much lover for LTV ratio. Macroprudential policy helps facilitate more lending and capital accumulation by reducing the uncertainty related with lending activity. Optimal policy separates macroprudential from monetary policy objectives. The reason is that these instruments are used to stabilize different target variables.

The theoretical concept of optimal macroprudential policy was introduced in by Munakata *et al.* (2012) The paper works with the DSGE with financial frictions and it constructs the second order approximation function of agent's welfare such that the optimal policy should respond to change in credit. Furthermore, Munakata *et al.* (2012) assume that monetary policy controls the nominal interest rate on deposits and macroprudential policy controls the loan interest rate. The outcome of the optimal policy depends on the type of macroprudential policy. This paper is interesting in the context future possible studies. For example, assuming that monetary and macroprudential policies act in a non-cooperative way instead of cooperation.

Brzoza-Brzezina *et al.* (2014) investigate the effect of foreign currency loans on economic policy and agents' welfare. Authors construct a DSGE model for a small open economy where housing loans can be denominated in domestic or foreign currency, a model which was meant to emulate the Polish economy. The paper splits the economy into two sectors: households and banks and introduces different types of shocks to the model (productivity shock, government spending shock, risk premium shock, monetary policy shock and shock to share of domestic currency loans).. Based on series of simulations, the authors conclude that a large number of foreign currency loans negatively affect monetary policy transmission. The paper also found that foreign currency loans do not affect the effectiveness of macroprudential policy. The second finding is that the welfare of agents holding foreign currency loans increases in domestic interest rate shock and decreases in persistence of exchange rate shock. Finally, they show that the policy which is responsible for the amount of foreign currency loans may decrease the economic growth.

Lima *et al.* (2012) examines two types of DSGE model: the core model with product frictions and the model with banking sector and financial frictions. The authors assume only one monetary policy instrument. They investigate the difference in the optimized rules with and without financial frictions, assuming that monetary policy responds only to non-financial variables. Next, the paper looks at the effects of monetary policy on spreads, leverage and Tobin Q. They use a tax on loans as macroprudential instrument. The authors also examine whether both policies should jointly target financial and non-financial variables. The main findings are follows: stabilization gains from macroprudential policy are small; monetary policy is beneficial in welfare cost reduction of imposing a zero lower bound constraint under discretion; the benefit of jointly targeting financial and non-financial variables is insignificant. Finally, the authors derive the optimal tax policy in a countercyclical manner.

Harmanta *et al.* (2014) research optimal policy mix using DSGE model with banking sector for the open economy of Indonesia. The paper applies collateral constraints to households and financial accelerator to entrepreneurs. This model is based on simulation of monetary policy (interest rate) exchange rate and macroprudential policy (capital requirements and LTV). The authors discovered transmission channels of monetary and macroprudential policies. For example, higher LTV ratio increases consumption and purchasing of housing assets, which will lead to increasing of output and inflation. Introducing the capital requirement will lead to reduction of credit allocation in both sectors of economy. Such shocks negatively affect production and output. The paper found a positive effect of using the policy mix on GDP, inflation, consumption, export and import.

Carvalho and Castro (2015) discuss the effect of interaction of monetary and macroprudential policies on the Brazilian economy and the measures that could have been taken in order to mitigate the consequences of the recent financial crisis. The authors estimated a DSGE model with banking sector using different subsets of policy instruments, such as a countercyclical capital buffer, reserve requirement and risk weight factors combining them with monetary policy. They found that the combination of risk weights factors and reserve requirements can have similar positive effect during build-up phase of the crises as their combination together with capital requirements. This paper also contributes to the study of effect of recent macroprudential policy announcements on inflation targeting. Macroprudential policy announcements that are made in a manner inverse to monetary policy cause the gap between inflation forecasts and inflation targeting to increase. This last finding is important for improving central banks' communication policies.

2.4.3. Different models

Madaloni and Peydro (2013) analyse the impact of short-term interest rates and macroprudential policy instruments on lending standards before and during the recent financial crisis in EU. For their analysis, the authors use data of lending condition from the Bank Lending Survey for Eurozone countries due to the fact that they have the same monetary and prudential policies. The authors focus on capital requirements and restrictions to the LTV for mortgage loans. The main finding are as follows: “in the period before the crisis the monetary policy low interest rates and bank lending conditions unrelated to borrowers’ risk leaded to growth of risky mortgage loans”. This negative impact of low interest rate may be reduced by a stronger macroprudential policy. During the crisis, the low monetary policy rates helped to soften lending conditions especially for banks that borrow long term. All in all, the authors suggest that monetary policy rates combining with central bank provision of long-term liquidity is a good instrument against a possible recession.

Agur and Demetzis (2015) study the effect of monetary policy on macroprudential regulation and financial stability. They modelled the effect of monetary policy on banks’ behaviour through two transmission channels: profit and leverage. This paper argues that the macroprudential policy can efficiently address externalities from monetary policy. The authors found that the macroprudential policy is not able to neutralize the effect from the monetary policy. This effect depends on a stage of financial cycle. In unstable times when financial intermediaries tend to take more leverage and thus the risk increases, macroprudential policy can only partially minimize the effect of low interest rate. However in post-crisis times, lower interest rates combined with macroprudential policy incentives reduces the risk.

Kincaid and Watson (2013) investigate the coordination of the macroprudential policy with macroeconomic and microprudential policies. The authors aimed to gauge the role of macroprudential instruments under fixed and floating exchange rate regimes. They also pose several questions about how macroprudential actions should be coordinated according to inflation targeting and fiscal rules, how it works in a specific country, whether the only one institution is responsible for financial stability or several institutions should cooperate to ensure it. The authors analyse a DSGE model with a financial accelerator, shocks to investments, adjustment costs, changing financial costs for firms reflecting levels of leverage, contract verification, asymmetric information, principal-agent problems, and collateral constraints. Kincaid and Watson (2013) emphasize on coordination between macroprudential policy with microprudential, monetary and fiscal policies. Since “macroprudential policy under both fixed and floating exchange rate regimes is highly vulnerable to leakages through connections with foreign financial institutions and markets” the results suggest that the gains from cross-border coordination should be significant.

Table 1 – Overview of literature review

Paper	Economy	Macroprudential instrument	Housing sector	Financial sector	Nature of results
Angelini, Neri, Panetta (2011)	Closed economy	CAR & LTV	Yes	Yes	Numerical based on a model calibration
Angelini, Neri, Panetta (2012)	Closed economy	CAR & LTV	Yes	Yes	Numerical based on a model calibration
Beau, Clerc, Mojon (2012)	Closed economy	LTV	Yes	No	Numerical based on a model estimation
Brzoza-Brzezina, Kolasa, Makarski, (2013)	Monetary Union	CAR & LTV	Yes	Yes	Numerical based on a model calibration
Brzoza-Brzezina, Kolasa, Makarski, (2014)	Small open economy	LTV	Yes	Yes	Numerical based on a model calibration
Collard, Dellas, Diba, Loisel (2012)	Closed economy	CAR	Yes	No	Analytical, Numerical based on a model calibration
Darracq Pariès, Kok Sørensen, Palenzuela (2010)	Closed economy	CAR	Yes	Yes	Numerical based on a model estimation
De Paoli, Paustian (2013)	Closed economy	LTV, tax on borrowing, tax on deposit	No	Yes	Analytical, Numerical based on a model calibration
Gerali, Neri, Sessa, Signoretti (2009)	Closed economy	CAR & LTV	Yes	Yes	Numerical based on a model calibration
Harmanta, Purwanto, Rachmanto, Oktiyanto (2013)	Small open economy	CAR & LTV	Yes	Yes	Numerical based on a model estimation
Lima, Levine, Pearlman, (2012)	Closed economy	Tax on loans	Yes	Yes	Numerical based on a model calibration
Munakata, Nakamura,	Closed economy	Separation rate	Yes	Yes	Analytical

Teranishi, (2012)					
Quint, Rabanal (2013)	Monetary Union	Short cut	Yes	Yes	Numerical based on a model estimation
Rubio, Carrasco-Gallego (2013)	Closed economy	LTV	Yes	No	Numerical based on a model calibration
Suh (2012)	Closed economy	CAR & LTV	Yes	Yes	Numerical based on a model calibration

3. Background and hypotheses

3.1. Background

Fundamentally, it is a role of governments and central banks to maximize the welfare of their citizens. Monetary, macroprudential and fiscal policies can have significant effects on the welfare of households as well as entrepreneurs (collectively referred to as "economic agents"), especially when applied to combat shocks to the economy. Optimizing welfare in the context of shocks has several aspects to it, including the stabilization of income and consumption levels, as well as inflation. While conventional tools such as monetary policy and fiscal spending have been studied relatively heavily, the potential use of macroprudential policies along with the more conventional tools has been less looked into.

The golden standard for examining aggregate effects on the broader economy and its dynamics is the dynamic stochastic general equilibrium model (DSGE). Our aim is to use the DSGE model to investigate the effects of macroprudential policies as responses to economic shocks, both alone and in the context of monetary policy interventions.

The two types of shocks our analysis will aim to consider are financial and government shocks. One of the causes of the recent economic and financial crisis in EMU was the overleveraging of individual governments. This debt burden and consequent economic crisis can have effects on government spending and hence can be a contributing factor to government shocks. In light of the recent financial crisis, we consider it critical to understand this dynamic in more detail. For this reason, our proposed model deals not only with financial shocks but also with government shock as well. Our model will build on foundations laid out in Suh (2012), which includes government spending shock. Suh (2012) conclude that the macroprudential policy is welfare improving and capital requirement has bigger impact than LTV.

The main aim of this paper is to investigate the effects of a combined and separate implementation of monetary and macroprudential policies on agents' welfare. A DSGE model with nominal and financial frictions is a good method for this kind of estimation. Somewhat similar analysis has been applied in Angelini *et al.* (2012) in order to estimate the volatility of macroeconomic variables, and potential welfare gains of three groups of agents. The paper found that there is no policy regime that would be optimal for all agents. Another paper that served as inspiration for our model was Rubio and

Carrasco-Gallego (2013), which estimated the effect of increasing LTV on welfare of savers and borrowers. The underlying theme that shaped our hypotheses is the idea that macroprudential policy may be welfare improving for all economic actors if it responds to nominal credit growth.

The motivation to include government spending shocks in our model stems from the dynamics of the recent European sovereign debt crisis. Government actions and spending profiles can significantly influence the perception of financial markets of their respective countries. This was very much the case during the recent crisis, when the continuously evolving fiscal policy in the highly indebted PIIGS countries dictated how the future economic performance, as well as solvency, was perceived. Given these continuous pieces of news about the direction of fiscal policy had on the markets, we consider it a pivotal component in our broader model.

The standard method of modelling financial frictions in a DSGE framework, (Angelini *et al.* (2012), Darracq Pariès *et al.* (2010), Gerali *et al.* (2009)) is to include a financial shock and a housing shock following the notion that one of the main reasons of the recent financial crisis was a property bubble. In our model, we want to introduce a government spending shock in order to show the specific features of monetary union crisis. We assume that the government shock negatively affects consumption of households. For modelling the shock, we use the government expenditure data for Eurozone countries and calibrated parameters such as an autocorrelation and a standard deviation that was used in Suh (2012).

The main contribution of this paper to study of the interaction of policies is the analysis of impact of macroprudential policy on agents' welfare, taking into account government and financial shocks.

3.2. Hypotheses

The hypotheses in this research are as follows:

1. *Hypothesis #1: The coordination of policies will increase the welfare of borrowers if government shock is present*
2. *Hypothesis #2: The macroprudential policy will decrease the welfare of savers in case of financial shock*
3. *Hypothesis #3: The welfare gains in coordination are larger for borrowers than for savers*

4. Methodology and model

4.1. High-level overview of our analysis

This section introduces the specifics of our DSGE model in detail. The model is broadly based on Angelini *et al.* (2012) with several exceptions and additions. We assume that there are three groups of agents in the model: savers, borrowers and entrepreneurs. Following Gerali *et al.* (2009), we include in our model capital good producers who determine the market value of entrepreneurs' collateral. Furthermore, we set up interest and deposit rates as a mark-up and markdown of the policy rate respectively.

As mentioned above, the policies we want to investigate are monetary and macroprudential, as well as their interaction. There are two policy rules in this model in order to capture the effect of policies' implementation separately. Monetary policy is modelled by the Taylor rule; and macroprudential policy is represented by countercyclical capital requirement. Under each policy, the policymaker minimizes its own loss function. Monetary policy's aim is to minimize the volatility of the interest rate, output and inflation; macroprudential policy minimizes the volatility of the output and capital requirement. When policies coordinate, there is one common loss function to minimize.

Our model assumes two types of shock: a government spending shock and a financial shock. Negative government spending shock can be characterized by increasing GDP deficit and government debt, which can be offset in the future by higher taxes (as a result lower consumption) or lower government spending. Financial shock is defined as a shock to financial system that unexpectedly changes financial conditions (Eickmeier *et al.,* 2011). Both shocks create uncertainty among agents about future consumption. A government shock is modelled in a way that it directly affects consumption of savers and borrowers, while a financial shock decreases bank capital, similarly to Angelini *et al.,* 2012).

The model is run for two shocks and three policy cases separately. All agents in the DSGE model are connected. For example, monetary and macroprudential policies affect the interest and deposit rates for savers and borrowers through the policy rate determination. Also households provide entrepreneurs with the labour force. That's why it's possible to observe the effects of different shocks on agents' welfare. Monetary policy is modelled by the Taylor rule, whereas for macroprudential policy LTV and capital requirements are used as instruments.

In order to gauge the welfare implications, we use the second order approximation of the model in line with Angelini *et al.* (2012) and Carrasco-Gallego (2013). Hypotheses for our model are loosely based on results of Angelini *et al.* (2012), that borrowers are better off in case of cooperation when economy is hit by productivity shock (technology shock in their case), and savers are worse off in case of non-cooperation when financial shock is present. Lastly, we aim to test these hypotheses for in the context of different shocks (government shock) and for different policy combinations (macroprudential policy).

4.2. The DSGE model

The model is represented by three groups of agents: households, entrepreneurs and banks. Patient households (savers) save their money in form of deposits in banks, impatient households (borrowers) and entrepreneurs borrow from banks, subject to borrowing constraint. Firms produce goods using capital and labour force provided by households. Banks give loans to households and firms and accumulate deposits from them.

4.2.1. Households

Households consume, work (provide labour force) and accumulate housing. In our model, we assume two types of households which differ by their discount factor (measurer of patience with regards to future spending). This factor for patient households (savers) is higher than for impatient (borrowers).

4.2.1.1. Patient households (savers)

Patient households maximize their lifetime utility (Rubio and Carrasco-Gallego (2013), Angelini *et al.* (2012)):

$$\max_{C_t^P H_t^P L_t^P} E_0 \sum_{t=0}^{\infty} \beta_t^P \left((1-a^P)\varepsilon_t^G \log(C_t^P - a^P C_{t-1}^P) + log H_t^P - \frac{(L_t^P)^{1+\varphi}}{1+\varphi} \right)$$

by choosing how much to consume (C_t^P), to spend on housing (H_t^P) and how many hours to work (L_t^P). β_t^P is the patient household discount factor, β ϵ (0,1), φ is the labor supply elasticity and a^P is the degree of external habit formation for patient households. ε_t^G denotes as a government shock that affects consumption.

Government spending follows a stationary AR(1) process (Suh 2012, Lima *et al.* 2012)

$$\widehat{G_t} = \rho_G \hat{G}_{t-1} + \varepsilon_t^G$$

where $\widehat{G_t}$ is the log-linear deviation of government spending.

The patient households' utility is maximized subject to the following budget constraint:

$$C_t^P + q_t^H(H_t^P - H_{t-1}^P) + D_t^P = w_t^P L_t^P + \frac{(1 + r_{t-1}^D)D_{t-1}^P}{\pi_t} + T_t^P$$

where q_t^H is a price of housing, D_t^P denotes deposits, w_t^P is the hourly wage, r_{t-1}^D is the interest rate on deposits from the previous period, π_t is an inflation and T_t^P is a lump-sum transfers.

4.2.1.2. Impatient households (borrowers)

Similar to savers borrowers maximize their utility:

$$\max_{C_t^I H_t^I L_t^I} E_0 \sum_{t=0}^{\infty} \beta_t^I \left((1 - a^I)\varepsilon_t^G log(C_t^I - a^I C_{t-1}^I) + log H_t^I - \frac{(L_t^I)^{1+\varphi}}{1 + \varphi} \right)$$

where C_t^I, H_t^I, L_t^I are respectively consumption, housing and hours worked for impatient households, β_t^I is the impatient household discount factor, β ϵ (0,1), φ is the labor supply elasticity and a^I is a degree of external habit formation for impatient households. Similarly to the case of patient households, the consumption of borrowers is affected by the government shock ε_t^G. The utility is maximized subject to the budget constraint:

$$C_t^I + q_t^H(H_t^I - H_{t-1}^I) + \frac{(1 + r_{t-1}^{bH})b_{t-1}^I}{\pi_t} = w_t^I L_t^I + b_t^I + T_t^I$$

Where r_{t-1}^{bH} is the interest rate on loans b_{t-1}^I from a previous period.

The households are also subject to borrowing constraint, where the expected value of collateral should be bigger or equal to the debt repayment:

$$(1 + r_t^{bH})b_t^I \le m^I E_t(q_{t+1}^H H_{t+1}^I \pi_{t+1})$$

where m^I is the LTV ratio and the terms in brackets is the value of the housing stock that can be used as collateral for the loan. This collateral is used to guarantee that the borrower will repay the loan.

4.2.2. Entrepreneurs

Each entrepreneur maximizes its utility:

$$E_0 \sum_{t=0}^{\infty} \beta_t^E \log(C_t^E - a^E C_{t-1}^E)$$

Where β_t^E is entrepreneur's discount factor. This variable is lower than β_t^P assuming that entrepreneurs are net borrowers. a^I is an entrepreneurs' degree of external habit formation. There is no shock in entrepreneurs' utility function because in DSGE model all agents are connected and the government spending shock will affect the entrepreneurs' utility function through households.

Entrepreneurs produce the good y_t^E which is sold at price 1/x (x_t is defined as $\frac{P_t}{P_t^W}$). Furthermore, entrepreneurs take on loans b_t^E from banks, also consume and pay wages to both patient and impatient households. In order to maximize the lifetime utility, entrepreneurs choose the optimal stock of physical capital k_t^E, the utilization rate u_t, the desired amount of labour input L_t^E, which equals to ${L_t^{E,P}}^{\eta} * {L_t^{E,I}}^{(1-\eta)}$, where η is the wage share of patient households. Labour and capital factors are used to produce an intermediate output y_t^E, which is represented in the production function:

$$y_t^E = a_t^E [k_{t-1}^E u_t]^{\alpha} {L_t^E}^{1-\alpha}$$

The entrepreneurs' budget constraint is:

$$C_t^E + w_t^P L_t^{E,P} + w_t^I L_t^{E,I} + \frac{(1 + r_{t-1}^{bE}) b_{t-1}^E}{\pi_t} + q_t^k k_t^E + \varphi(u_t) k_{t-1}^E$$
$$= \frac{y_t^E}{x_t} + b_t^E + q_t^k (1 - \delta) k_{t-1}^E$$

Where δ is depreciation of the capital k_t^E, q_t^k is the price of one unit of physical capital, $\varphi(u_t)$ is the real cost of setting a level of utilization rate u_t, $L_t^{E,P}$, $L_t^{E,I}$ correspond to labour service provided by patient and impatient households.

Similar to borrowers, we assume that the amount of the loan which banks provide to entrepreneurs should be supported by collateral. Borrowing for entrepreneurs' constraint is:

$$(1 + r_t^{bE}) b_t^E \leq m^E E_t (q_{t+1}^k k_t^E \pi_{t+1} (1 - \delta))$$

Where m^E is entrepreneurs' loan-to-value ratio. A term in brackets is the expected value of accumulated capital after depreciation which is the market value of collateral.

We assume that the retailer market is monopolistically competitive and prices are sticky. Retailers buy the intermediate good from entrepreneurs and differentiate it at no cost and then sale it at a mark-up over the wholesale price. We also assume that retailers' prices are indexed to a combination of past and steady-state inflation, with relative weights parametrized by ζ; if they want to change their price beyond what indexation allows, they face a proportional adjustment cost. In a symmetric equilibrium Phillips curve represents the retailers' problem first-order condition:

$$1-\varepsilon^y+\frac{\varepsilon^y}{x_t}-\kappa_p\left(\pi_t-\pi_{t-1}^{\zeta}\pi^{1-\zeta}\right)\pi_t + \beta^P E_t\left[\frac{C_t^P-a^P C_{t-1}^P}{C_{t+1}^P-a^P C_t^P}\kappa_p(\pi_{t+1}-\pi_{t-1}^{\iota P}\pi^{1-\iota P})\pi_{t+1}\frac{y_{t+1}^E}{y_t^E}\right]=0$$

Where $x_t = \frac{P_t}{P_t^W}$ is the gross mark-up earned by retailers.

4.2.3. Capital goods producers

Capital goods producers are introduced to the model in order to derive a market price for capital, which determined the value of entrepreneurs' collateral, against which banks concede loans. We assume that, at the beginning of each period, each capital good producer buys an amount $I_t(j)$ of final good from retailers and the stock of old undepreciated capital $k_t^E(1-\delta)$ from entrepreneurs. The amount of new capital that capital good producers can produce is given:

$$k_t^E(j)=(1-\delta)k_{t-1}^E(j)+\left[1-\frac{\kappa_i}{2}\left(\frac{I_t(j)}{I_{t-1}(j)}-1\right)^2\right]I_t(j)$$

Where κ_i is the parameter measuring the cost for adjustment investment (Gerali, 2009).

4.2.4. Banks

Banks have a monopolistic power to set up the deposit and the interest rates. These rates are sticky as banks need to pay adjustment costs in case they change the deposit or loan rates. Banks need to keep the value of loans equal to value of deposits plus bank capital.

Banks' aim is to keep the capital-asset ratio close to an exogenous target v, which can be interpreted as a capital adequacy ratio of 8 percent in line with the Basel regulations (BCBS, 2006).

The cost of varying the capital-asset ratio is:

$$\frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t}-v\right)^2 K_t^b$$

Where k_{Kb} is the intensity of costs (can be also understood as a first-order derivative of a decreasing and convex function) (Angelini *et al*., 2011), K_t^b is the bank capital and B_t represents total loans, v are capital requirements set by the macroprudential authority.

The amount of total loans to impatient households and entrepreneurs equals to amount of deposit to patient households plus bank capital:

$$b_t^I + b_t^E = D_t^P + K_t^B$$

Bank capital includes accumulated profit:

$$K_t^b = (1-\delta_b)\frac{K_{t-1}^b}{\varepsilon_t^k} + J_{t-1}^B$$

Where δ_b is a depreciation rate, ε_t^k is a financial shock that affects banks' capital, J_{t-1}^B is a bank profit from previous period.

The bank's profit is the sum of earnings from the wholesale and the retail branches:

$$J_t^B = r_t^{bH} b_t^I + r_t^{bE} b_t^E - r_t^d D_t^P - \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{B_t}-v\right)^2 K_t^b - Adj_t^b$$

The net wholesale loan rate is defined as:

$$R_t^b = R_t - \kappa_{Kb}\left(\frac{K_t^b}{b_t^I + b_t^E} - v_t\right)\left(\frac{K_t^b}{b_t^I + b_t^E}\right)^2$$

where, K_t^b is a bank capital, R_t is a policy rate defined by the Taylor rule, κ_{Kb} is quadratic adjustment costs for changing the bank capital, $b_t^I + b_t^E$ is the sum of total loans for households and entrepreneurs, and v_t is capital requirements.

In this model, we assume that banks face quadratic adjustment costs for changing the rates they charge for loans (κ_{bH} and κ_{bE} for households and entrepreneurs respectively). The problem of banks is to set up the interest rates to maximize:

$$\max_{\{r_t^{bH}(j), r_t^{bE}(j)\}} E_0 \sum_{t=0}^{\infty} \lambda_{0,t}^P \Bigg[r_t^{bH}(j) b_t^H(j) + r_t^{bE}(j) b_t^E(j) - R_t B_t(j) - \frac{\kappa_{bH}}{2}\left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} - 1\right)^2 r_t^{bH} b_t^H - \frac{\kappa_{bE}}{2}\left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} - 1\right)^2 r_t^{bE} b_t^E \Bigg]$$

Subject to demand schedules

$$b_t^H(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}}\right)^{-\varepsilon_t^{bH}} b_t^H, \text{ and } b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_t^{bE}}\right)^{-\varepsilon_t^{bE}} b_t^E$$

With $b_t^H + b_t^E = B_t(j)$

The first order condition:

$$1 - \varepsilon_t^{bi} + \varepsilon_t^{bi} \frac{R_t}{r_t^{bi}} - \kappa_{bi}\left(\frac{r_t^{bi}}{r_{t-1}^{bi}} - 1\right)\frac{r_t^{bi}}{r_{t-1}^{bi}} + \beta_P E_t \left\{ \frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_{bi} \left(\frac{r_t^{bi}}{r_{t-1}^{bi}} - 1\right)\left(\frac{r_t^{bi}}{r_{t-1}^{bi}}\right)^2 \frac{b_{t+1}^E}{b_t^E} \right\} = 0$$

With $i = H, E$

Banks set up loan rates taking into account the expected future path of R_t, which is relevant marginal cost and depends on the policy rate and the capital position of the bank. With perfectly flexible rates, the pricing equation is:

$$r_t^{bi} = \frac{\varepsilon_t^{bi}}{\varepsilon_t^{bi} - 1} R_t$$

In this case the interest rates on loans are set up as mark-up over the marginal cost.

The deposit branch performs similar to the loan branch but in an opposite direction. The problem for the deposit branch is to choose a deposit rate $r_t^d(j)$, applying a monopolistically competitive mark-down to the policy rate, in order to maximize:

$$\max_{\{r_t^d(j)\}} E_0 \sum_{t=0}^{\infty} \lambda_{0,t}^P \left[R_t D_t(j) - r_t^d(j) D_t(j) - \frac{\kappa_d}{2}\left(\frac{r_t^d(j)}{r_{t-1}^d(j)} - 1\right)^2 r_t^d D_t \right]$$

Subject to deposit demand

$$d_t(j) = \left(\frac{r_t^d(j)}{r_t^d}\right)^{\varepsilon_t^d} D_t$$

The first order condition:

$$1 - \varepsilon_t^d + \varepsilon_t^d \frac{R_t}{r_t^d} - \kappa_d \left(\frac{r_t^d}{r_{t-1}^d} - 1\right)\frac{r_t^d}{r_{t-1}^d} + \beta_P E_t \left\{\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_d \left(\frac{r_{t+1}^d}{r_t^d} - 1\right)\left(\frac{r_{t+1}^d}{r_t^d}\right)^2 \frac{d_t}{d_t}\right\} = 0$$

By linearizing the above equation and assuming that ε_t^d is non-stochastic we can see that the deposit interest rate is set taking into account the expected future level of the policy rate. The speed of the adjustment to changes in the policy rate depends inversely on the intensity of the adjustment costs (κ_d). With fully flexible rates, r_t^d is determined by a static mark-down over the policy rate:

$$r_t^d = \frac{\varepsilon_t^d}{\varepsilon_t^d - 1} R_t$$

Our model assumes that policies are acting either separately or simultaneously. The policymaker using monetary policy sets the interest rate R_t and uses it as an instrument, and thus affects both savers and borrowers through the lending and deposit rates. On the other hand, the policymaker employing macroprudential policy uses capital requirements as an instrument and affects only the borrowers' lending rate. This way it is possible to see the effect of each policy on savers and borrowers separately.

4.2.5. Aggregation and equilibrium

Aggregate consumption is described as the sum of particular agents' consumptions:

$$C_t = C_t^P + C_t^I + C_t^E$$

Equilibrium in the housing market is given by:

$$\overline{H} = \gamma^P H_t^P(i) + \gamma^I H_t^I(i)$$

Where $\overline{H}$ denotes the exogenous fixed housing supply stock.

4.3. Monetary policy

The primary objective of monetary policy is to ensure price stability. By firmly anchoring inflation expectations to price stability, the ECB's monetary policy has minimized the risk of deflation. "Stable inflation expectations have enhanced the effectiveness of monetary policy in stabilizing the economy, which is particularly relevant when nominal policy rates are very low and face a zero lower bound" (Papademos, 2011).

Another channel through which monetary policy can affect the financial stability and not only price stability is transmission via the bank risk-taking channel. Through this channel, monetary policy affects the price of credit and prevents excessive leverage (Papademos, 2011). However, monetary policy alone cannot ensure financial stability, because financial distortions are not always caused by the lack of liquidity in the system. Sometimes stabilization of the financial system after an asset bubble requires a large change in the policy rate. When the financial distortion is not homogenous within the economic sectors, price and output stability may create a conflict with the financial stability. Moreover, the central bank's credibility increases when it focuses on its primary objectives and for other purposes may cooperate (IMF, 2013).

The central bank instrument is modelled by a Taylor rule with a following specification:

$$R_t = (1-\rho_R)\bar{R} + (1-\rho_R)\left[\chi_\pi(\pi_t - \bar{\pi}) + \chi_y(y_t - y_{t-1})\right] + \rho_R R_{t-1}$$

Where χ_π is the response to deviations of inflation from the target, χ_y is the response to output growth, ρ_R is the inertia in the adjustment of the policy rate. In this model, the Taylor rule has a specification which differs from its classical formulation. This is the including of variable $\rho_R R_{t-1}$, which corresponds to the interest rate in the previous period. This condition became important[14] during recent financial crisis and shows the central bank's reliability. Changing the interest rate too often worsens the bank's reputation and can thereby lead to lower credibility, which has implications of the expectations of economic actors in the context of future central bank announcements.

Next, the central bank stabilizes inflation and output by selecting the parameters in the monetary policy rule in order to minimize the following loss function:

$$L^{cb} = \sigma_\pi^2 + k_{y,cb}\sigma_y^2 + k_r\sigma_{\Delta r}^2 \quad k_{y,cb} \geq 0, k_r \geq 0$$

Where σ^2 are the asymptotic variances of inflation and output growth and of the changes in the policy instrument (monetary policy rate), k_i corresponds to the policymaker's preferences over these variables.

[14] Quint & Rabanal (2013)

4.4. Macroprudential policy

According to BCBS (2010) macroprudential policy has two complementary objectives: to strengthen the financial system and limit the build-up phase of the systemic risk. The paper of CGFS (2010) determines systemic risk as "a risk of disruption to financial services that is caused by an impairment of all or parts of the financial system and has the potential to have serious negative consequences for the real economy"[15]. Angelini *et al.* (2012) mentioned the problem of systemic risk as there is no proxy for this variable because it arises in different forms.

Capital requirements are set according to the rule:

$$v_t = (1-\rho_v)\bar{v} + (1-\rho_v)\chi_v X_t + \rho_v v_{t-1}$$

Where $\bar{v}$ is the steady-state level of v_t, X_t is a key macroeconomic variable (output growth in this case[16]), and χ_v is a sensitivity parameter. In this model χ_v is chosen to be positive in order to make the capital requirement to work countercyclically. Capital requirements increase in good times and decrease in recessions. This equation is built similarly to countercyclical capital buffer introduced by Basel III. Capital requirement can increase up to 2.5 percent from the steady state value (BCBS, 2010).

According to the definition of systemic risk that has a harmful effect on real economy, Angelini *et al.* (2012) assumed that macroprudential policy focuses on minimizing the volatility of output σ_y^2. And finally the macroprudential authority's aim is to minimize the volatility of its instrument $\sigma_{\Delta v}^2$, since it has to keep it in reasonable bounds. Thus, the loss function that macroprudential policy maximizes is:

$$L^{mp} = k_{y,mp}\sigma_y^2 + k_v\sigma_{\Delta v}^2 \quad k_{y,mp} \geq 0, k_v \geq 0$$

4.5. The interaction between macroprudential and monetary policies

We would like to study the effect of monetary and macroprudential policies on the economy when applied separately and in a coordinated manner. First, we assume that monetary and macroprudential authorities act separately. In this case, policymakers need to minimize their own loss functions as described above. On the other hand, when authorities act in coordination, the central bank can be responsible for both policies or

[15] P. 2
[16] See Angelini *et al.* (2012)

cooperate with macroprudential authority. In the case of cooperation, the joint loss function will have the following form:

$$L = L^{cb} + L^{mp} = \sigma_{\pi}^2 + \left(k_{y,cb} + k_{y,mp}\right)\sigma_y^2 + k_r\sigma_{\Delta r}^2 + k_v\sigma_{\Delta v}^2$$

Where the policymaker minimizes the volatility of inflation σ_{π}^2, of output as a key macroeconomic variable, and volatility of changing policy instruments: interest rate $\sigma_{\Delta r}^2$ and capital requirements $\sigma_{\Delta v}^2$.

4.6. Calibrated parameters

Our model will use several calibrated parameters, which are based on related literature. We chose patient households' discount factor following Gerali *et al.* (2009). This parameter is set up in order to obtain a steady-state interest rate on deposits slightly above 2 percent on annual basis following the tendency of Euro area. Discount factor for impatient households and entrepreneurs is set up at 0.975 (Gerali *et al.*, 2009). In our model LTV ratio as chosen to be a parameter and is set to be 0.7 and 0.25 for impatient households and entrepreneurs respectively (Gerali *et al.*, 2009). The depreciation rate of physical capital is 0.25, for banking capital this parameter is chosen to be 0.0982 in order to ensure that the ratio of bank capital to total loans is 0.08. The mark-up in the goods market is 6. Calibrated markdown on deposits rate is set to be -1.3 in order to have an average monthly spread between banking rate in our model and 3-month EURIBOR as 150 basis points on an annual basis. The same way ε^{bH} and ε^{bH} is set to be 5.1 and 3.5 respectively (Gerali *et al.*, 2009). Steady state value of capital requirements is set as 0.08 following countercyclical capital buffer by Basel III (Angelini *et al.*, 2012). Preference parameters in our model are fixed as follows: $k_{y,cb} = 0.5$, $k_r = 0.1$, $k_{y,mp} = 0.5$, $k_r = 0.1$ by Angelini *et al.* (2012). Sensitivity parametersχ_H, χ_E, ρ_H and ρ_E are set at -10, -15, 0.94 and 0.92 respectively (Angelini *et al.* (2011)). Following Suh (2012)) government shock autocorrelation parameter is fixed as 0.8. Table 2 presents an overview of the calibrated parameters.

Table 2 – Calibrated parameters

Symbol	Description	Value
β_P	Patient households' discount factor	0.9943
β_I	Impatient households' discount factor	0.975

Symbol	Description	Value
β_E	Entrepreneurs' discount factor	0.975
φ	Labour supply elasticity	1.5
δ	Depreciation rate of physical capital	0.025
$\bar{m}^I$	Households' LTV	0.7
$\bar{m}^E$	Entrepreneurs' LTV	0.25
ε^y	The mark-up in the goods market	6
ε^d	Markdown on deposit rate	-1.3
ε^{bH}	Mark-up on loans rate for HHs	5.1
ε^{bE}	Mark-up on loans rate for firms	3.5
$\bar{v}$	Capital/loans ratio in steady state	0.08
δ_b	Depreciation rate of bank capital	0.0982
ρ_G	Autocorrelation G	0.8
χ_H	Sensitivity parameter	-10
χ_E	Sensitivity parameter	-15
ρ_H	Sensitivity parameter	0.94
ρ_E	Sensitivity parameter	0.92
$k_{y,cb}$	Monetary policymaker's preference over output	0.5
k_r	Monetary policymaker's preference over interest rate	0.1
$k_{y,mp}$	Macroprudential policymaker's preference over output	0.5
k_v	Macroprudential policymaker's preference over capital requirement	0.1

5. Hypothesis testing and analysis

We wanted to capture the effect when economy is hit by government and financial shock. Also, we modelled three cases assuming that:

1) There is only a monetary policy modelled by Taylor rule.
2) Two policies coordinate minimizing common loss function.
3) There is a macroprudential policy having monetary policy as a baseline.

In the last case, we minimize the loss function of macroprudential policy taking into account Taylor rule. For the estimation, we will use the steady states of economic variables from Gerali *et al.* (2009) that capture periods before a crisis and after, as well as calibrated parameters that correspond to the Euro area. We estimated welfare loses outside the model by taking a second order approximation of utility function for each agent similar to Angelini *et al.* (2012) and Rubio and Carrasco-Gallego (2013).

Below is a consolidated overview of our findings with regards to each hypothesis.

Table 3 – Overview of key finding

Hypothesis 1.	*The coordination of policies will increase the welfare of borrowers if government shock is present*
Key findings	When a government shock is occurs, borrowers benefit the most from policies' cooperation. Their welfare loses are smaller comparing to the cases where either only macroprudential or monetary policy are applied without coordination, or one of them is applied in isolation. Furthermore, we found that the option that leads to the least welfare gains is the use of monetary policy in isolation. Thus, we can see that macroprudential policy has the potential to bring substantial benefits for borrowers. Our analysis therefore failed to reject the hypothesis that there are potential welfare increases when macroprudential and monetary policies are coordinated.
Hypothesis 2.	*The macroprudential policy will decrease the welfare of savers in case of financial shock*
Key findings	In the context of a financial shock, we observe that none of the agents benefit from macroprudential policy only having monetary policy as a baseline. Borrowers are again better off in case of cooperation. On the

	other hand, savers and entrepreneurs are better off in the case of an isolated monetary policy intervention. Our findings analysis thus fails to reject this hypothesis.
Hypothesis 3.	*The welfare gains in coordination are larger for borrowers than for savers*
Key findings	Our results indicate that savers do not benefit from policy coordination. In case of government shock, macroprudential policy intervention is preferable, while in a financial shock they are better off under monetary policy intervention. On the other hand, borrowers always benefit from policies' coordination. We therefore, again, fail to reject our hypothesis.

6. Discussion

6.1. Summary of key points

Our analysis consists of three main parts. First of all we analyse the effects of a government shock, which impacts agents' consumption in our model, on the economy in terms of the volatility of key macroeconomic variables (such as output, inflation, interest and deposit rates, consumption of the agents, investment etc.) from our model and optimal policies' optimal responses. Next, we replicate this analysis for a financial shock, which is characterized by decrease of bank capital. For all parts of our analysis, we consider the effect of monetary policy alone, coordination of policies and macroprudential policy having monetary policy as a baseline.

Lastly, we analyse the impact of different policies' combination on agents' welfare taking into account government and financial shocks separately.

Key takeaways of our analysis are summarized in Table 4.

Table 4 – Key takeaways from analysis

Government shock	**Financial shock**
Monetary policy alone is good enough to stabilize the volatility of inflation and interest rate	Monetary policy contributes more to variables' stability than macroprudential policy
The **volatility** of the output **is the lowest when policies coordinate**	Macroprudential policy regulation **significantly increases the volatility** of variables
	Savers and entrepreneurs benefit from monetary policy only when economy is hit by financial shock
Both shocks	
Borrowers are better off when policies cooperate	
There is **no policy combination that would be beneficial for all agents**	

This section will be continued with a more detailed discussion of the results and estimation and a robustness analysis. Lastly, the limitations of this study will be explored, as well as possibilities for further research with regards to interaction between monetary and macroprudential policies.

6.2. Discussion of the results

6.2.1. Government shock

The results of the analysis in the context of a government shock are shown in Table 5. The key takeaway from all policy combinations is that their effect is strongly countercyclical (all optimal parameters are positive). All results for government shock are very close to each other.

In case of monetary policy only policymaker's optimal responses to the volatility of inflation and interest rate are, respectively, χ_{π} = 2.00124 and ρ_R = 0.770039. Overall results for monetary policy are significant, as the volatilities of both inflation and interest rate are lower than in case of cooperation. This may lend credence to the conclusion that monetary policy is powerful enough to stabilize key macroeconomic parameters.

When two policies cooperate the volatility of the output is lower compared to other two cases (optimal response is χ_y = 0.321699) because the main objective of two policies is stabilization of output. At the same time the volatility of inflation and interest rate increases comparing to other two cases. This result can be explained by the possible conflict between policies.

In the third case, the response of optimal parameters of macroprudential policies is similar to other policies, but the volatility of inflation and interest rate is lower comparing to monetary policy only. The optimal response to capital requirement volatility is the same as in case of cooperation.

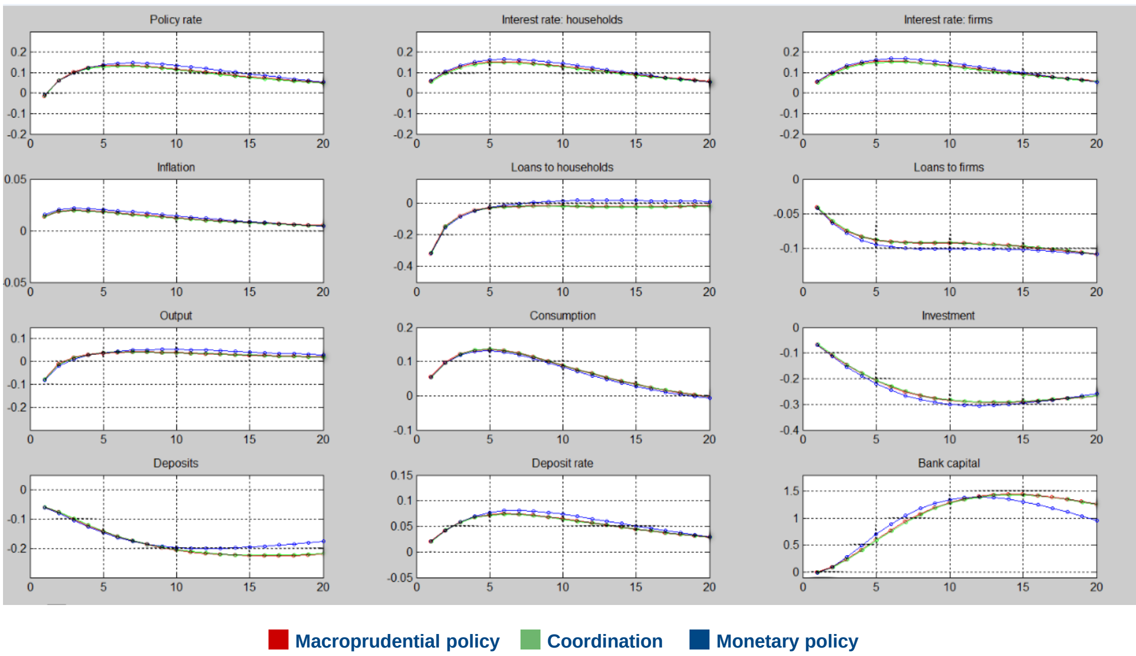
Summing up, the contribution of macroprudential policy is quite modest in the case of a persistent government shock. However, there are still some points proving efficiency of macroprudential policy compare to monetary policy. It is stabilization of the output when two policies cooperate and relatively lower volatility of inflation and policy instruments under macroprudential policy.

Table 5 – Model results under a government shock scenario

Policy	Volatility[17]				Optimal parameters[18]				
	σ_π	σ_y	σ_r	σ_v	ρ_R	χ_π	χ_y	ρ_v	χ_v
Monetary	0.059407	0.188560	0.445061	–	0.770039	2.00124	0.303273	–	–
Coordination	0.093331	0.128564	0.654211	0.012900	0.723674	1.82442	0.321699	0.975176	0.890005
Macroprudential	0.053998	0.151391	0.405858	0.012801	–	–	0.303264	0.975000	0.890000
Policy	Welfare[19]								
	Savers			Borrowers			Entrepreneurs		
Monetary	-442.9972			-292.2901			**-127.3970**		
Coordination	-444.4691			**-290.1042**			-131.8764		
Macroprudential	**-442.8360**			-291.5951			-128.1188		

In Figure 4, we compare[20] the impulse response function in case of monetary and macroprudential policies and their coordination. The impulse response is measured as a percentage change from steady state values of variables. The volatility represents a standard deviation from steady states.

Figure 4 – Impulse response to government shock



In all three cases output, consumption, inflation, bank capital and both deposit and interest rate increases; loans, deposits and investments falls. Central bank reacts to the

[17] Standard deviation in percentage points
[18] Estimated from corresponding loss functions
[19] Computed by second order approximation of the model
[20] A more detailed graph of the impulse responses is available in the appendix of this thesis

shock increasing interest rates that resulted in lower volume of loans for households and firms. At the same moment stabilization of output leads to higher consumption until the fifth period and then it decreases to its initial level because households expect higher taxes in the future. Higher interest rates make investment less attractive, which is shown in its persistent fall on the plot. In all three cases, we can see that reaction of variables is very similar suggesting that all policies' combinations affect economy by the same way.

6.2.2. Financial shock

The financial shock in our model directly affects the bank capital and through this lending and deposit rates. Following Gerali *et al.* (2009) we calibrate the financial shock in a way that it corresponds to 5 percent fall in bank capital with 95 percent persistence. The results of estimations are shown in Table 6.

Table 6 – Model results under a financial shock scenario

<table>
<tr><th>Policy</th><th colspan="4">Volatility[21]</th><th colspan="5">Optimal parameters[22]</th></tr>
<tr><td></td><td>σ_π</td><td>σ_y</td><td>σ_r</td><td>σ_v</td><td>ρ_R</td><td>χ_π</td><td>χ_y</td><td>ρ_v</td><td>χ_v</td></tr>
<tr><td>Monetary</td><td>0.118270</td><td>2.240460</td><td>0.000017</td><td>–</td><td>0.999997</td><td>2.07412</td><td>0.255121</td><td>–</td><td>–</td></tr>
<tr><td>Coordination</td><td>0.177224</td><td>3.235246</td><td>0.000023</td><td>0.275383</td><td>0.999998</td><td>2.18718</td><td>0.269816</td><td>0.975024</td><td>0.89</td></tr>
<tr><td>Macroprudential</td><td>0.177332</td><td>2.791879</td><td>2.394005</td><td>0.217586</td><td>–</td><td>–</td><td>-0.6400</td><td>0.9765</td><td>0.889974</td></tr>
<tr><td rowspan="2">Policy</td><td colspan="9">Welfare[23]</td></tr>
<tr><td colspan="3">Savers</td><td colspan="3">Borrowers</td><td colspan="3">Entrepreneurs</td></tr>
<tr><td>Monetary</td><td colspan="3">-443.2050</td><td colspan="3">-292.3035</td><td colspan="3">-127.4025</td></tr>
<tr><td>Coordination</td><td colspan="3">-443.4871</td><td colspan="3">-291.6966</td><td colspan="3">-128.9062</td></tr>
<tr><td>Macroprudential</td><td colspan="3">-443.2486</td><td colspan="3">-292.1960</td><td colspan="3">-127.8126</td></tr>
</table>

The main difference from the results for government shock is that the output varies much more, suggested that the effect of financial shock is more harmful comparing to a government shock. In case of monetary policy policymaker responds aggressively to inflation growth (χ_π = 2.07412). This reaction is in line with Taylor rule inflation targeting. The responses to output and interest rate growths are much smaller but still countercyclical. The volatility of policy rate is practically negligible. We can say that the monetary policy alone does a reasonably good job stabilizing economy after financial shock. Under policy cooperation the results are similar but the volatility of the

[21] Standard deviation in percentage points
[22] Estimated from corresponding loss functions
[23] Computed by second order approximation of the model

output significantly increases (σ_y = 3.235246). This might be explained by the possible conflict between policies. Such a result is the opposite to the case of government shock. At the same time, the response of central bank and macroprudential authority is countercyclical.

The results of estimation of macroprudential policy are very different from other two policies discussed above. An optimal response to change in capital requirements is positive and its value is similar to the result got for policies' coordination. The interesting finding emerges for the volatility of the output (σ_y=2.791879) and the interest rate (σ_r=2.394005). The volatility of the output is higher than in case of monetary policy due to pro-cyclical response of macroprudential authority. High volatility of the interest rate suggests that macroprudential policy is not a good tool to stabilize it. From our findings suggest that the macroprudential policy's effects on stabilization of the economy may be limited under a financial shock scenario.

Figure 5 - Impulse response to financial shock

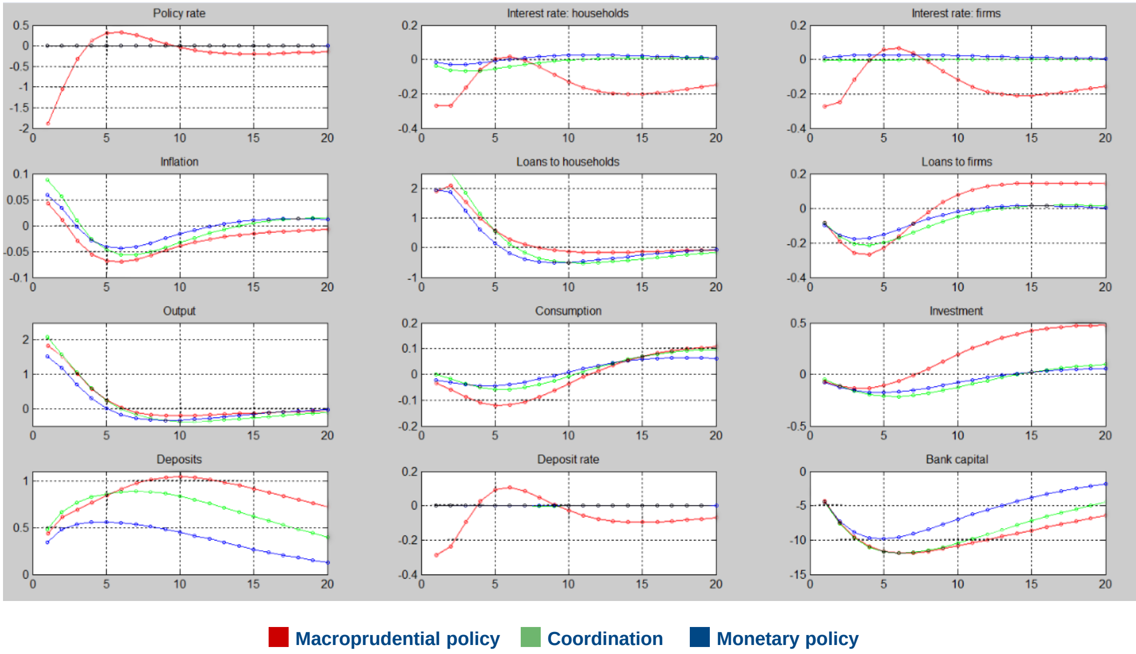


Figure 5 shows[24] the impact of financial shock to key macroeconomic variable in our model. By our assumption financial shocked is modelled in a way that it directly affects the bank capital. Thus we can see on the plot that it decreases. In order to compensate the fall of equity bank increases the deposit rate. The reaction of policy rate in case of monetary policy and cooperation is practically negligible that corresponds to the evidence from to Angelini *et al.* (2012). By the contrast under macroprudential policy it

[24] A more detailed graph of the impulse responses is available in the appendix of this thesis

decreases, then reaches a pick in fifth period and goes back to zero. This magnitude is reflected in short-term growth of the amount of loans (households are affected more) and then it falls. Output, investment and consumption falls and after some time returns to their steady states. Despite the different reaction of macroprudential policy there are still common features in impulse response: in all three cases households are more affected by the shock, bank capital falls significantly in the fifth period, output jumps up at the beginning and then decreases below pre-shock level from period five, investment falls and then goes back to normal. To conclude this section we should say that monetary policy contributes more to variables' stability that macroprudential policy, this is visible from the variables' magnitudes.

6.2.3. Welfare analysis

As a result of our estimation we would like to compare welfare of the three agents (savers, borrowers and entrepreneurs) under different policies regimes. Welfare evaluation is done based on optimal policies' regimes and technically is computed using second order approximation of the model (Angelini et al, 2012).

The results for the case of a government shock are presented Table 5. In the case of a government shock, borrowers are better off under coordinating regime because their welfare loses are the lowest comparing to other two cases. The implication of this is that our model fails to reject our first hypothesis, namely that "*The coordination of policies will increase the welfare of borrowers if government shock is present*". Indeed, our analysis indicates that an efficient coordination of policies will, other things equal, increase the welfare of borrowers. Larger volatility of the output discussed above and the presence of credit constraint in two other regimes makes more difficult for borrowers to repay the debt and accumulate housing thus the utility and welfare decrease more than if policies cooperate. Borrowers are worse off in case of macroprudential policy regime. At the opposite savers' welfare is higher under macroprudential policy regime. The volatility of the policy rate is higher under cooperation. That affects savers' ability to get a repayment rate on deposits and thus consume less. Savers are worse off in case coordinative regime. Large volatility of the interest rate in case of cooperative regime and presence of borrowing constraint affects entrepreneurs' ability to repay the debt thus consume less. Their welfare is also lower. Entrepreneurs benefit in case of monetary policy only regime. The volatility of the policy rate is lower comparing the regime of coordination.

We observed similar results for financial shock presented Table 6. There is no policy regime under which all agents are better off in case of financial shock. Welfare of borrowers is again higher under cooperative regime. Agents work less and consume more housing and less nondurable goods. They are worse of under monetary policy only regime. At the opposite savers and entrepreneurs are better off in case of monetary policy only regime. In contrast to the government shock none of the agents benefits under macroprudential policy regime because the volatility of the policy rate is higher than under other policy regimes. Due to high fluctuations of the interest rate it's difficult to adjust expectations, save and repay debts. Thus the consumption and welfare decreases. This finding means we fail to reject our hypothesis number 2.

Summing up our findings for welfare analysis, we have observed that there is no policy regime that is beneficial for all agents. This highlighted an important redistributive effect, showing that one policy combination that is beneficial for one group of agents can be harmful f or another group. The choice of optimal policy depends on the type of agent for which the analysis is performed. Also the result will depend on the type of shock. Our findings in this section are consistent with those in Angelini *et al.* (2012).

6.3. Analysis of model dynamics

This section aims to present the results of a model robustness check that was done by varying the value of parameters of given loss functions. This check is important because the assumption of weight parameters k_y, k_r and k_v is not so strong and based on intuition. For the check we change the parameters of loss functions, in particular putting more weight to policy instruments and less to output. The results are presented in Table 7.

Table 7 – Analysis of model dynamics

Government shock						
Loss function weights	**Baseline** $k_{y,cb}$, $k_{y,mp}$= 0.5, k_r, k_v = 0.1			$k_{y,cb}$, $k_{y,mp}$= 0.25, k_r, k_v = 0.5		
Volatilities[25]	MOP[26]	COOP	MAP	MOP	COOP	MAP
σ_π	0.059407	0.093331	0.053998	0.058842	0.055035	0.054968
σ_y	0.188560	0.128564	0.151391	0.188527	0.151435	0.151321
σ_r	0.445061	0.654211	0.405858	0.437702	0.412375	0.415379
σ_v	–	0.012900	0.012801	–	0.012676	0.012856

[25] Standard deviation in percentage points
[26] Monetary policy; Cooperation; Macroprudential policy

Financial shock						
Loss function weights	**Baseline** $k_{y,cb}$, $k_{y,mp}$=0.5, k_r, k_v = 0.1			$k_{y,cb}$, $k_{y,mp}$=0.25, k_r, k_v = 0.5		
Volatilities	MOP	COOP	MAP	MOP	COOP	MAP
σ_π	0.118270	0.177224	0.177332	0.112128	0.243548	0.298780
σ_y	2.240460	3.235246	2.791879	2.145202	1.545888	3.820779
σ_r	0.000017	0.000023	2.394005	0.000017	0.287973	2.395652
σ_v	–	0.275383	0.217586	–	0.608199	0.009197

From the estimation of government shock we can see that volatilities of all variables are similar to the baseline model in case of the monetary policy. In case of cooperation, both policies respond to fall in output thus its volatility is lower. Interesting results occur for the interest rate volatility. Since we modelled the situation when policymaker puts more weight on instruments' volatility we can see that when two policies cooperate the volatility on interest rate and capital requirement are lower. For macroprudential policy, the results are similar to baseline model: volatilities change insignificantly no matter what weight we put on parameters. Thus, we can conclude that results for government shock are robust.

From the perspective of a financial shock, monetary policy results are similar to baseline model: no volatility of interest rate, low volatility of inflation. In case of cooperation, the volatility of interest rate increases but it is still significantly lower than then in case of macroprudential policy. Comparing to baseline the volatility of output is the lowest when policies cooperate. That is the main difference occurred when parameter changed. Overall, we can see that monetary policy alone is again good enough to stabilize interest rate and inflation, cooperation of policies does not bring substantial effect, and macroprudential policy increases the volatility of output and interest rate. Again, most of our results are robust.

6.4. Limitations of this analysis

Implementation of macroprudential policy still remains relatively unexplored topic. There is a lack of quantitative knowledge regarding effect of policies' interaction on financial stability.

First, modelling of policy interaction using DSGE model is very theoretical and it is impossible to create a model that will fully reflect the reality. Calibration of parameters in a certain manner depends on an economic intuition about the development of the key macroeconomic variables. Modelling is, by definition, based on assumptions. For instance, Rubio (2013) suggests that the analysis of macroprudential policy often relates to distortions if financial system caused by the exceptional event related to non-equilibrium, which cannot be captured by the model[27]. Since the DSGE models have an infinite horizon there is a problem to model financial frictions and intermediations.

Furthermore, IMF (2013) states that the assumption that a macroprudential instrument is well targeted and fully mitigates the effects of a financial shock is too strong and is not likely to work in practice. Also, due to market's imperfection it is hard to determine whether macroprudential policy needs to be restrictive or easing. Therefore, the probability of Type I errors (too little effort; false positive) or Type II errors (too much effort; false negative) increases. Both of these error types are costly and can even accelerate distortion. Moreover, it is still unclear which instrument or a set of instruments is better to use in a pre-crisis period and a period of distress.

However, regardless all the problems, DSGE model has many advantages in evaluating the efficiency of macroprudential policy, such as possibility to choose different types of shocks and policy instruments, different calibration of parameters. The opportunities for further research will be discussed in below section.

6.5. Space of further research

In this section we would like to discuss different approaches to estimate the model.

6.5.1. A different macroprudential instrument

In our model, the main macroprudential tool is capital requirements. An alternative instrument that is used in several research papers is loan-to-value ratio. In particular, Brzoza-Brzezina *et al.* (2013) modelled two macroprudential policy rules: one for capital requirements, another for LTV and stated that either one or another should be used, According to Angelini *et al.* (2011), "LTV ratio is adjusted to response to house prices and represents the actual behaviour of policymaker. The authors found that the contribution of macroprudential policy under technology shock is modest. On the opposite macroprudential policy brings substantial benefits in case of financial shock. Those findings are similar to the results of capital requirement's application. Suh (2012) in particular compares the effect of using LTV and capital requirements on welfare. The paper found that LTV only as a macroprudential tool increases agents' welfare insubstantially comparing to capital requirements.

[27] P. 7

6.5.2. Different specification of macroprudential policy rule

In our model we considered that macroprudential policy responds to the volatility of capital requirements and the output growth as a key macroeconomic variable (Choice of the output growth justified by existing literature[28]). However, there is an alternative specification of macroprudential rule, such as the macroprudential policy should respond to credit growth as a key variable. Quint & Rabanal (2013) applied this to their model for Eurozone and found that the welfare improves if macroprudential policy responds to the nominal credit growth.

6.5.3. Different shocks

Darracq, Pariès *et al.* (2010) studied the effect of different shocks, which they split in four groups. The first group is demand and supply frictions to which belongs housing, technology, labour supply and investment shock and monetary policy is a demand shock. The second group consists of risk shocks on households and entrepreneurs that increase default probabilities of particular agents. The third group represents interest rate mark-up shocks such as the shock on deposit rate and the shock on interest rates for households and entrepreneurs. The last group is the shock on bank capital (financial shock). The most ‘realistic scenario’ of multi-shock has been applied by Gerali *et al.* (2009). In this case, the contribution of macroprudential policy is substantial.

6.5.4. Different loss functions parametrization

The assumption about the loss functions parameters is not so strong and the weights can be specified differently. For example, classical Taylor rule suggests setting up parameters for output and the interest rate as 0.5 each. Angelini *et al.* (2011) tested different loss function specification putting less weight to output volatility and more to the volatility of instruments (interest rate and capital requirements). Their findings are consistent with main model estimation.

6.5.5. Different parameters of the model

Estimation using DSGE model is based on several assumptions. First of all, it is a specification of the model itself, set up of agents’ utility function, monetary and macroprudential policy rules. Then it is a choice of parameters’ values based on different historical evidence. Also, the size of the shock significantly affects the volatility of variables.

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[28] See Angelini *et al.* (2012)

7. Conclusion

The main aim of this thesis was to analyse the effect of different combinations of monetary and macroprudential policies on the economy and, in particular, agents' welfare. This topic has been inspired by the discussion of the adequacy of monetary policy as an instrument used to maintain financial stability. Evidence from the recent global financial crisis 2007–2008 shows[29] that monetary policy alone cannot mitigate systemic risk by pursuing its primary objective – price stability.

This thesis contributes to study of monetary and macroprudential policies' interactions by estimating the effect of a government shock versus that of a financial shock, and the effect different policy combinations have under these scenarios. One of the goals of this thesis was to model a situation that would reflect the main attributes of Eurozone crisis, which was characterized by significant government debt levels in certain counties. Therefore, both the government shock as well as financial shock has been included in our model, analysing three cases: when two policies cooperate minimizing a common loss function, monetary policy alone assuming that macroprudential policy does not exist, and when macroprudential policy minimizes its own loss function having monetary policy as a baseline. We used a countercyclical capital requirement as a macroprudential instrument and a Taylor rule to model monetary policy.

Our findings for the case of the government shock suggest that the application of both monetary and macroprudential policies affects the economy in a similar way. The results of our analysis show that monetary policy alone better stabilizes the volatility of inflation and interest rate. However, the coordination of policies reduces the volatility of output, compared to other two cases. The third case – macroprudential policy – displayed a relatively low volatility of key economic variables.

Results for financial shock differ from those of the government shock. Estimation shows that monetary policy contributes more to variables' stability than macroprudential policy in case of financial shock. Due to the possible conflict of policies, the volatility of variables increases in case of policies' coordination. Macroprudential policy alone also substantially increases the volatility of the interest rate and appears to bring limited benefits in economy stabilization in case of a financial shock.

[29] Smets (2013)

From the welfare perspective, there is no policy combination that would be beneficial for all agents at once. Particularly, borrowers in case of both shocks benefit from policies' coordination, savers are better off in case of macroprudential policy when economy is hit by a government shock, and they are better off in case of monetary policy only when fluctuations are driven by financial shock. Entrepreneurs benefit from monetary policy only no matter what kind of shock affects the economy. That suggests that interaction between policies may have a redistributive effect.

The DSGE model is a good method to estimate the interaction between policies, but it is still grounded in many assumptions. Estimation is contingent on calibrated parameters, specification of loss functions, type of shocks and a choice of macroprudential instrument.

In conclusion, we have shown that there is no optimal policy combination for all agents, highlighting that there is a redistributive effect for both shocks. The contribution of monetary and macroprudential policy has a positive impact on financial stability, even though our model estimated it to be relatively modest.

Bibliography

Agug, I., & Demertzis, M. (2105). Will Macroprudential Policy Counteract Monetary Policy's Effects on Financial Stability? *IMF Working Paper №283*.

Angelini , P., Neri, S., & Panetta, F. (2012). Monetary and macroprudential policies. *ECB working paper №1449*.

Angelini, P., Neri, S., & Panetta, F. (2011). Monetary and macroprudential policies. *Banca d'Italia working paper №801*. .

BCBS. (2006). Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework - Comprehensive Version.

BCBS. (2010). Basel III: A global regulatory framework for more resilient banks and banking systems.

Beau, D., Clerc, L., & Mojon, B. (2012). Macro-Prudential policy and the conduct of monetary policy. *Banque de France*.

Borio, C., & Shim, I. (2007). What can (macro-)prudential policy do to support monetary policy? *BIS working paper №242.*

Boz, E., D'Erasmo, P., & Duru, C. (2015). Sovereign Risk and Bank Balance Sheets: The Role of Macroprudential Policies.

Brown, M., & Chambers, A. (2005). How Europe's governments have enronized their debts. *Euromoney*.

Brzoza-Brzezina, M., Kolasa, M., & Makarski, K. (2013). Macroprudential policy and imbalances in the euro area. *NBP working paper №138*.

Brzoza-Brzezina, M., Kolasa, M., & Makarski, K. (2104). Monetary and macroprudential policy with foreign currency loans. *NBP working paper №184*.

Carvalho, F., & Castro, M. (2015). Macroprudential and Monetary Policy Interaction: a Brazilian perspective. *Banco Central do Brasil working paper №405*.

Chiriacrscu, B. (2013). Macroprudential policy and financial stability. *Theoretical and Applied Economics, Volume XX (2013), No. 2(579), pp. 81-88*.

Collard, F., Dellas, H., Diba, B., & Loisel, O. (2012). Optimal monetary and prudential policies. *Banque de France working paper №413*.

Committee on the Global Financial System. (2010). Macroprudential instruments and frameworks: a stocktaking of issues and experiences. *CGFS papers №38*.

Darracq Pariès, M., Kok Sørensen, C., & Palenzuela , D. (2010). Macroeconomic propagation under different regulatory regimes. Evidence from an estimated DSGE model for the Euro Area. *ECB working paper №1251*.

De Paoli, B., & Paustian, M. (2013). Coordinating monetary and macroprudential policies. *FRBNY staff report №653*.

Eickmeier, S., Lemke, W., & Marcellino, M. (2011). The changing international transmission of financial shocks: evidence from a classical time-varying FAVAR. *Discussion Paper №5 Deutsche Bundesbank*.

EUROSTAT. (2016).

Gerali, A., Neri, S., Sessa, L., & Signoretti, F. (2009). Credit and banking in a DSGE model of the Euro Area.

Gerba, E., & Macchiarelli, C. (2015). Interaction between monetary policy and bank regulation: Theory and European practice. *SRC Special Paper №10*.

Grace , T., Hallissey, N., & Woods, M. (2015). The Instruments of Macro-Prudential Policy. *CBI*, 90-105.

Harmanta, Purwanto, N., Rachmanto, A., & Oktiyanto, F. (2013). Monetary and macroprudential policy mix under financial frictions. Mechanism with DSGE model. *Bank Indonesia*.

IMF. (2013). The interaction of monetary and macroprudential policies. *IMF executive summary*.

Issing, O. (2008). Asset prices and monetary policy. *Contribution to Cato Institute 26th Annual Monetary Conference*.

Kincaid, G., & Watson, C. (2013). The Implications of Macroprudential Policies for International Policy Coordination.

Kirchner, M., Cimadomo, J., & Hauptmeier, S. (2010). Transmission of government spending shocks in the Euro area. Time variation and driving forces. *ECB working paper №1219*.

Lim, C., Columba, F., Costa, A., Kongsamut, P., Otani, A., Saiyid, M., . . . Wu, X. (2011). Macroprudential Policy: What Instruments and How to Use Them? *IMF Working Paper*.

Lima, D., Levine, P., & Pearlman, J. (2012). Optimal macro-prudential and monetary policy.

Maddaloni, A., & Peydro, J.-L. (2013). Monetary policy, macroprudential policy and banking stability. Evidence from the Euro area. *ECB working paper №1560.*

Matsaganis, M. (2011). The welfare state and the crisis: the case of Greece. *Journal of European Social Policy vol. 21*, 501-512 .

Munakata, K., Nakamura, K., & Teranishi, Y. (2012). Optimal macroprudential policy.

Papademos, L. (2011). The role of macro-prudential oversight and monetary policy in preventing financial stability.

Quint, D., & Rabanal, P. (2013). Monetary and macroprudential policy in an estimated DSGE model of the Euro area. *IMF working paper*.

Rubio, M., & Carrasco-Gallego, J. (2013). Macroprudential and monetary policies: Implications for financial stability and welfare.

Smets, F. (2013). Financial stability and monetary policy: How closely interlinked? *Sveriges Riksbank Economic Review.*

Suh, H. (2012). Macroprudential policy: its effect and relationship to monetary policy. *Working paper №12-28*.

Tinbergen, J. (1952). On the theory of economic policy.

Appendix

Derivation

Savers:

Objective – to maximize the utility function:

$$\max_{C_t^P H_t^P L_t^P} E_0 \sum_{t=0}^{\infty} \beta_t^P \left((1 - a^P)\varepsilon_t^G \log(C_t^P - a^P C_{t-1}^P) + logH_t^P - \frac{(L_t^P)^{1+\varphi}}{1+\varphi} \right)$$

Subject to budget constraint:

$$C_t^P + q_t^H (H_t^P - H_{t-1}^P) + D_t^P = w_t^P L_t^P + \frac{(1 + r_{t-1}^D) D_{t-1}^P}{\pi_t} + T_t^P$$

Lagrangean:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_t^P \left((1 - a^P)\varepsilon_t^G \log(C_t^P - a^P C_{t-1}^P) + logH_t^P - \frac{(L_t^P)^{1+\varphi}}{1+\varphi} \right) + \lambda_t \left(C_t^P + q_t^H (H_t^P - H_{t-1}^P) + D_t^P - w_t^P L_t^P - \frac{(1 + r_{t-1}^D) D_{t-1}^P}{\pi_t} - T_t^P \right)$$

FOCs:

$$\frac{\partial L}{\partial C_t} = \frac{(1 - a^P)\varepsilon_t^G}{C_t^P} + \lambda_t = 0$$

$$\lambda_t = -\frac{(1 - a^P)\varepsilon_t^G}{C_t^P}$$

$$\frac{\partial L}{\partial C_{t+1}} = -a^P (1 - a^P) E_t \left[\beta_t^P \frac{\varepsilon_{t+1}^G}{C_{t+1}^P} \right] + \lambda_{t+1} = 0$$

$$\lambda_{t+1} = a^P (1 - a^P) E_t \left[\beta_t^P \frac{\varepsilon_{t+1}^G}{C_{t+1}^P} \right]$$

$$\frac{\partial L}{\partial L_t} = -(L_t^P)^{\varphi} - \lambda_t w_t = 0$$

$$\frac{\partial L}{\partial H_t} = \frac{1}{H_t^P} + \lambda_t q_t^H - E_t[\lambda_{t+1} q_{t+1}^H] = 0$$

$$\frac{\partial L}{\partial D_t} = \lambda_t - E_t\left[\lambda_{t+1}\frac{(1-r_t^D)}{\pi_{t+1}}\right] = 0$$

$$-\frac{(1-a^P)\varepsilon_t^G}{C_t^P} + a^P(1-a^P)E_t\left[\beta_t^P\frac{\varepsilon_{t+1}^G}{C_{t+1}^P}\frac{(1-r_t^D)}{\pi_{t+1}}\right] = 0$$

$$\frac{\varepsilon_t^G}{C_t^P} = a^P E_t\left[\beta_t^P\frac{\varepsilon_{t+1}^G}{C_{t+1}^P}\frac{(1-r_t^D)}{\pi_{t+1}}\right]$$

Euler equation:

$$\frac{\varepsilon_t^G}{C_t^P} = a^P(1-r_t^D)\beta_t^P E_t\left[\frac{\varepsilon_{t+1}^G}{C_{t+1}^P}\frac{1}{\pi_{t+1}}\right]$$

Labour supply condition:

$$w_t = (L_t^P)^{\varphi}\frac{C_t^P}{\varepsilon_t^G(1-a^P)}$$

Intertemporal condition for housing:

$$\frac{1}{H_t^P} = \frac{(1-a^P)\varepsilon_t^G}{C_t^P}q_t^H - a^P(1-a^P)\beta_t^P E_t\left[\frac{\varepsilon_{t+1}^G}{C_{t+1}^P}q_{t+1}^H\right]$$

Borrowers

Utility function:

$$\max_{C_t^I H_t^I L_t^I} E_0\sum_{t=0}^{\infty}\beta_t^I\left((1-a^I)\varepsilon_t^G log(C_t^I - a^I C_{t-1}^I) + logH_t^I - \frac{(L_t^I)^{1+\varphi}}{1+\varphi}\right)$$

Subject to budget constraint:

$$C_t^I + q_t^H(H_t^I - H_{t-1}^I) + \frac{(1+r_{t-1}^{bH})b_{t-1}^I}{\pi_t} = w_t^I L_t^I + b_t^I + T_t^I$$

And borrowing constraint:

$$(1+r_t^{bH})b_t^I \le m^I E_t(q_{t+1}^H H_{t+1}^I \pi_{t+1})$$

Lagrangean:

$$\mathcal{L} =$$

$$E_0 \sum_{t=0}^{\infty} \beta_t^I \left((1-a^I)\varepsilon_t^G log(C_t^I - a^I C_{t-1}^I) + logH_t^I - \frac{(L_t^I)^{1+\varphi}}{1+\varphi} \right)$$
$$+ \lambda_t \left(C_t^I + q_t^H (H_t^I - H_{t-1}^I) + \frac{\left(1 + r_{t-1}^{bH}\right) b_{t-1}^I}{\pi_t} - w_t^I L_t^I - b_t^I - T_t^I \right)$$
$$+ \mu_t (m^I E_t (q_{t+1}^H H_{t+1}^I \pi_{t+1}) - \left(1 + r_t^{bH}\right) b_t^I)$$

FOCs:

$$\frac{\partial L}{\partial C_t} = \frac{(1-a^I)\varepsilon_t^G}{C_t^I} + \lambda_t = 0$$

$$\lambda_t = -\frac{(1-a^I)\varepsilon_t^G}{C_t^I}$$

$$\frac{\partial L}{\partial C_{t+1}} = -a^I (1-a^I) E_t \left[\beta_t^I \frac{\varepsilon_{t+1}^G}{C_{t+1}^I} \right] + \lambda_{t+1} = 0$$

$$\lambda_{t+1} = a^I (1-a^I) E_t \left[\beta_t^I \frac{\varepsilon_{t+1}^G}{C_{t+1}^P} \right]$$

$$\frac{\partial L}{\partial L_t} = -(L_t^I)^{\varphi} - \lambda_t w_t = 0$$

$$\frac{\partial L}{\partial H_t} = \frac{1}{H_t^I} + \lambda_t q_t^H - E_t[\lambda_{t+1} q_{t+1}^H] + \mu_t m^I E_t (q_{t+1}^H \pi_{t+1}) = 0$$

$$\frac{\partial L}{\partial b_t} = -\lambda_t + E_t \left[\lambda_{t+1} \frac{\left(1 + r_t^{bH}\right)}{\pi_{t+1}} \right] - \mu_t \left(1 + r_t^{bH}\right) = 0$$

$$\frac{(1-a^I)\varepsilon_t^G}{C_t^I} + a^I (1-a^I) E_t \left[\beta_t^I \frac{\varepsilon_{t+1}^G}{C_{t+1}^I} \frac{\left(1 + r_t^{bH}\right)}{\pi_{t+1}} \right] - \mu_t \left(1 + r_t^{bH}\right) = 0$$

$$\frac{\varepsilon_t^G}{C_t^I} = E_t \left[\beta_t^I \frac{\varepsilon_{t+1}^G}{C_{t+1}^I} \frac{\left(1 + r_t^{bH}\right)}{\pi_{t+1}} \right] + \mu_t \left(1 + r_t^{bH}\right)$$

Euler equation:

$$\frac{(1-a^I)\varepsilon_t^G}{C_t^I} = -a^I (1-a^I) \left(1 + r_t^{bH}\right) \beta_t^I E_t \left[\frac{\varepsilon_{t+1}^G}{C_{t+1}^I} \frac{1}{\pi_{t+1}} \right] + \mu_t \left(1 + r_t^{bH}\right)$$

Labour supply condition:

$$w_t = (L_t^I)^{\varphi} \frac{C_t^I}{\varepsilon_t^G (1 - a^I)}$$

Intertemporal condition for housing:

$$\frac{1}{H_t^I} = \frac{(1-a^I)\varepsilon_t^G}{C_t^I} q_t^H - a^I(1 - a^I)\beta_t^I E_t \left[\frac{\varepsilon_{t+1}^G}{C_{t+1}^P} q_{t+1}^H\right] - \mu_t m^I E_t(q_{t+1}^H \pi_{t+1})$$

Entrepreneurs:

Utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_t^E \log(C_t^E - a^E C_{t-1}^E)$$

Subject to budget constraint:

$$C_t^E + w_t^P L_t^{E,P} + w_t^I L_t^{E,I} + \frac{\left(1 + r_{t-1}^{bE}\right) b_{t-1}^E}{\pi_t} + q_t^k k_t^E + \varphi(u_t) k_{t-1}^E$$
$$= \frac{y_t^E}{x_t} + b_t^E + q_t^k (1 - \delta) k_{t-1}^E$$

Borrowing constraint:

$$(1 + r_t^{bH}) b_t^E \leq m^E E_t(q_{t+1}^k k_t^E \pi_{t+1}(1 - \delta))$$

Lagrangean:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_t^E \log(C_t^E - a^E C_{t-1}^E)$$

$$+\lambda_t \Bigg(C_t^E + w_t^P L_t^{E,P} + w_t^I L_t^{E,I} + \frac{\left(1 + r_{t-1}^{bE}\right) b_{t-1}^E}{\pi_t} + q_t^k k_t^E + \varphi(u_t) k_{t-1}^E - \frac{y_t^E}{x_t} - b_t^E$$
$$- q_t^k (1 - \delta) k_{t-1}^E\Bigg) + \mu_t (m^E E_t \left(q_{t+1}^k k_t^E \pi_{t+1} (1 - \delta)\right) - \left(1 + r_t^{bE}\right) b_t^E)$$

FOCs:

$$\frac{\partial L}{\partial C_t} = \frac{1}{C_t^E} + \lambda_t = 0$$

$$\lambda_t = -\frac{1}{C_t^I}$$

$$\frac{\partial L}{\partial C_{t+1}} = -a^E E_t \left[\beta_t^E \frac{1}{C_{t+1}^E}\right] + \lambda_{t+1} = 0$$

$$\lambda_{t+1} = -a^E E_t \left[\beta_t^E \frac{1}{C_{t+1}^E}\right]$$

$$\frac{\partial L}{\partial b_t} = -\lambda_t + E_t \left[\lambda_{t+1} \frac{\left(1 + r_t^{bE}\right)}{\pi_{t+1}}\right] - \mu_t\left(1 + r_t^{bE}\right) = 0$$

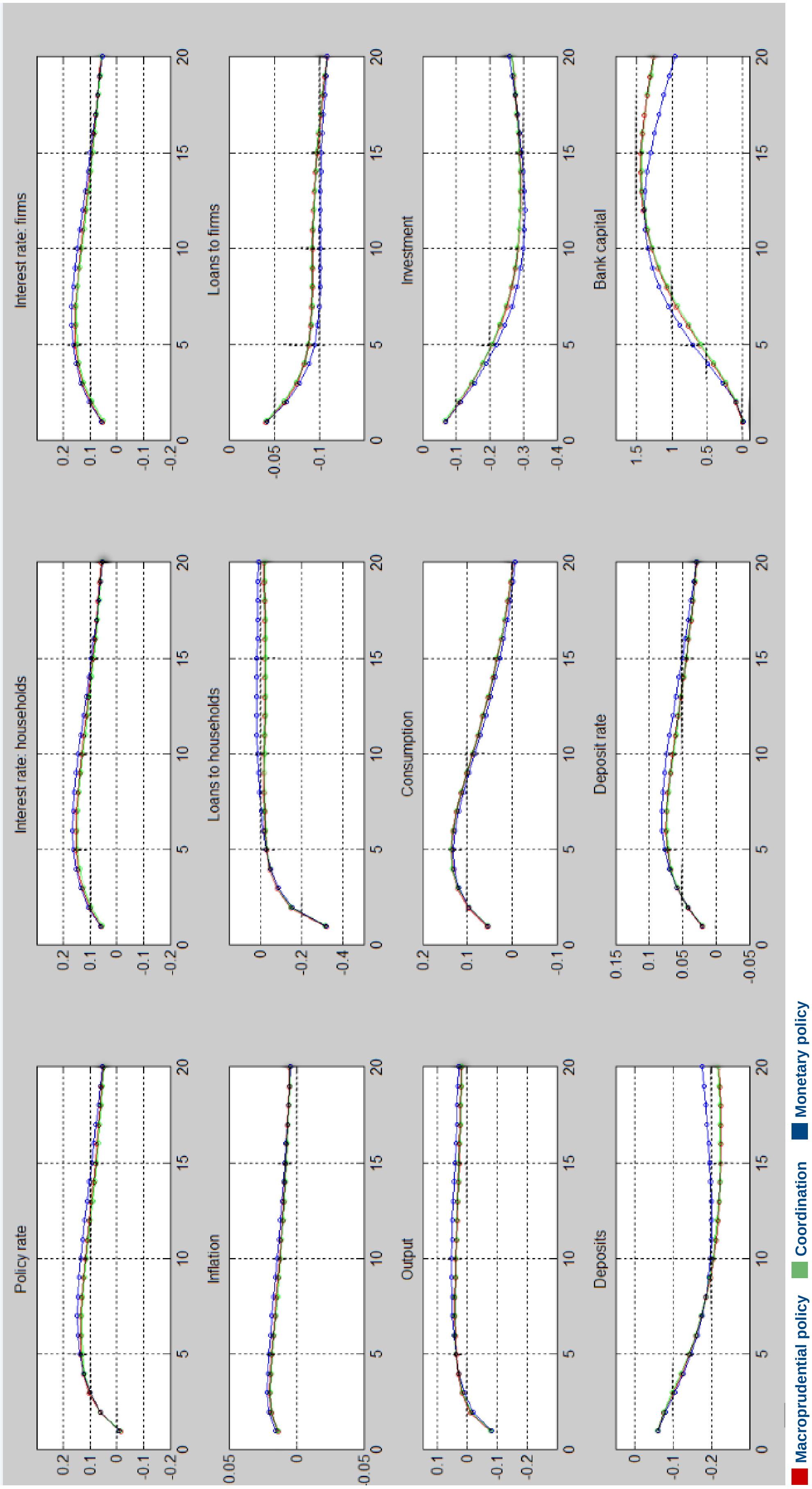
$$\frac{1}{C_t^I} - a^E E_t \left[\beta_t^E \frac{1}{C_{t+1}^E} \frac{\left(1 + r_t^{bE}\right)}{\pi_{t+1}}\right] - \mu_t\left(1 + r_t^{bE}\right) = 0$$

Euler equation:

$$\frac{1}{C_t^I} = a^E\left(1 + r_t^{bE}\right) E_t \left[\beta_t^E \frac{1}{C_{t+1}^E \pi_{t+1}}\right] + \mu_t\left(1 + r_t^{bE}\right)$$

$$\frac{1}{C_t^I} = a^E\left(1 + r_t^{bE}\right)(\mu_t + 1)\beta_t^E E_t \left[\frac{1}{C_{t+1}^E \pi_{t+1}}\right]$$

Government shock impulse response



Financial shock impulse response