Complementaries and Tensions between Monetary and Macroprudential Policies in an Estimated DSGE Model (Application to Slovenia)

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Abstract

Recent financial crisis has shown that the prior belief that the active monetary policy in pursuing price stability may not be sufficient enough to maintain financial stability as well as macroeconomic stability in an economy. Introducing a new economic policy, the macroprudential policy gave space to a complete new sphere of affecting an economy through a policy maker's perspective. Constructing a dynamic stochastic general equilibrium model, which incorporates a banking sector block, enables us to study the effects of financial frictions on the real economy. Taking the case of Slovenia, the simulation results show that taking into account the interplay between the monetary and macroprudential policies in a form of financial shocks matter in the economy.

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1 Introduction

The goal of price stability under the monetary policy mandate was seen as largely complementary with that of the financial stability, but the recent global financial crisis showed that the sole goal of pursuing price stability does not ensure the overall macroeconomic stability. In the shadows of a rapid rise of credit and asset prices the unrecognised distortions led to inefficient compositions of output, accompanied by the excessive real estate investments, excessive consumption and the widening of external imbalances. By the time the systemic risk materialized, the externalities arising from financial market imperfections intensified, which were reflected in volatile macroeconomic outlooks and together with the financial crisis leading to a large drop in outputs and large-scale financial distresses in majority of countries. The recent financial crisis consequently prompted policy makers to reflect on the existing policy frameworks and to think out of new policy instruments to help ensure the financial stability. An additional policy was introduced – the macroprudential policy. As both monetary policy and macroprudential policy measures initially affect the financial sector, the interaction between the two areas seems to be inevitable. From this perspective the macroprudential policy and monetary policy should share some similarities.

The macroprudential policy moderates the pro-cyclicality of the financial system by influencing assets, liabilities and leverage of financial intermediaries while the monetary policy aims at price stability through the transmission channel by influencing the interest rate level or degree of liquidity in the financial system. As the monetary policy pursuing price stability in the medium term does not ensure the prevention of undesired developments in the financial sectors, these negative effects could in turn spill-over into the real economy and ultimately endanger the price and macroeconomic stability. This is even more important in the case of a small open economy operating in a monetary union. From this perspective it is crucial that the corresponding economic policies target financial stability as well. However, at the current juncture of policies, the actual experience and knowledge of the functioning of the macroprudential instruments and their interaction with the monetary policy instruments is still relatively limited.

This paper adds to the gap of estimating quantitative macroprudential-monetary policy models, taking into account the case of a Slovenia by taking the monetary policy parameters as exogenous, thus simulating a small open economy model operating in a monetary union. Following the works of Iacoviello (2005), Iacoviello and Neri (2010), Gerali et al. (2010), Quint and Rabanal (2014), and Bokan et al. (2018) we construct a DSGE model with banking sector, making it possible to take into account financial frictions, introduce financial shocks to the model and examine their effects on the real economy. After the construction of the theoretical framework of the model, the calibration and the estimation of the model is needed. Some of the model parameters, for which the set of observable variables from data do not provide information to estimate them, are calibrated according to known empirical facts of the modelled economy and are fixed throughout the estimation process. The other parameters are estimated by applying the standard Bayesian methods.

The results suggest that financial shocks matter in the economy. The dynamics of the main real economy variables not only reflect the real economy contraction and expansion, but show the negative influence of the financial variables *via* financial frictions during the financial crisis and their complementary effect during the good times. Implementing macroprudential policy measures would therefore have to be carefully planned and implemented as their effect could easily undermine the efforts of the monetary policy. In the primer DSGE modelling exercise several exogenous shocks that could simulate the implementation of macroprudential instruments are presented and studied. Based on the estimation the persistence parameters of macroprudential shocks have relatively high values, implying that implementing macroprudential measures could have long-lasting effect that resonate through the economy. Restrictive macroprudential instruments, such as the implementation of additional capital buffers and lowering LTV ratios mostly undermine the effects of expansionary monetary policy, but not to the extent that would annul the effects of the latter. If restrictive macroprudential instruments undermine accommodative monetary policy, they on the other hand complement restrictive monetary policy. But not all macroprudential measures are restrictive. The measure of limiting deposit rates for instance complemented the expansionary monetary policy stance by additionally lowering banking rates.

The rest of the paper is organized as follows. Section 2 provides the motivation of the paper, while section 3 offers a quick literature review. Section 4 describes the theoretical structure of the model, while the section 5 offers the explanation of the calibrated parameters that are key in simulating the model but at the same time are not of interest in the estimation process. Section 6 presents the estimation results of the model. Lastly, section 7 presents the concluding remarks.

2 Motivation

Against this backdrop, the aim of the paper is to construct a theoretical model that could, based on the legal setting of the macroprudential policy, try to assess the possible effects of implementing these macroprudential instruments on the real economy, since most of the above measures are yet to be actively taken into effect. From the policy perspective it is important to take into consideration the effects of both, the monetary policy and the macroprudential policy.

During financial crises the aim of a more accommodative or expansionary monetary policy is to in general lower the interest rates, supply the economy with sufficient liquidity and consequently positively influence private consumption and investments in order to restore consumer and business confidence, fix the impaired transmission mechanism and kick-start inflation and output. But as we have witnessed in the latest financial crisis only pursuing the primary goal of inflation close to 2 percent was not sufficient enough to preserve financial stability at the same time. A new approach was needed in a form of macroprudential policy. The primary goal of the macroprudential policy is therefore to secure financial stability of an economy with different macroprudential instruments. Introduction of these instruments are, however, not without an effect on the economy, especially in the banking sector. Policy makers have to be aware of the size of the effects of the macroprudential instruments, and even more importantly the direction of these effects. Combining the two policies means careful planning as the policy maker wants to implement such measures and instrument that complement each other.

In the period before the beginning of the global financial crisis, a combination of a loose monetary policy alongside loosened regulatory regimes provided an incentive for excessive credit growth and a housing boom throughout the world. Based on these issues that have arisen from the onset of the financial crisis the most recent theoretical work[1] was done on identifying the sources of externalities (e.g. excessive credit growth) in the financial sector. These externalities provide a rationale to conduct macroprudential policy and compels the monetary policy to take into account the financial stability in its mandate. With respect to current legislation (such as the CRR/CRD IV legislation[2]) and macroprudential policy guidelines a legal framework was set-up for the conduct of macroprudential policy and the supervision of the Slovene banking system in order to prevent future misalignments and distortions on the financial market. Additionally a coordination mechanisms with relevant authorities at the national and EU level have been introduced as well.

Several macroprudential instruments and recommendations were already legally put in place by Bank of Slovenia, but most of them are still inactive. The following list is in chronological order:

1. In 2012 ceilings to deposit rates were introduced. The purpose of this measure was to complement the internal capital adequacy assessment process and defines a premium on capital requirements for new deposits

[1]Claessens et al. (2008) and Crowe et al. (2013) show that the combination of credit and housing boom amplify the business cycle in both directions: the amplitude and duration.

[2]Capital Requirements Regulation aims to decrease the financial sector distortions and subsequently reflects the Basel III rules on capital measurement and capital standards. This EU-wide legislation was introduced into national legislation by all the EU member countries.

by the private non-banking sector where the realised deposit interest rate exceeds the ceiling set by the instrument. It aims to mitigate income risk in the context of an excessive increase in deposit interest rates by the non-banking sector. It should encourage banks to exercise even greater caution in the management of levels of deposit interest rates, which should have a positive impact on lending rates.

2. In 2014 Bank of Slovenia introduced a macroprudential instrument defining minimum requirements for changes in loans to the non-banking sector relative to changes in non-banking sector deposits, where the ratio is calculated on changes in stocks before considering impairments GLTDF[3]. The GLTDF instrument aims at slowing down the decline in the loan-to-deposit ratio, stabilizing the banking system funding structure and mitigating systemic risk.

3. In 2015, the Bank of Slovenia legally introduced a new macroprudential measure, i.e. a countercyclical capital buffer (CCB). The purpose of the CCB instrument is to protect the banking system against potential losses insofar as these are related to an increase in risks in the system as a result of excessive growth in lending. Currently, the buffer rate is inactive and has been kept at 0 percent of the total risk exposure amount.

4. A macroprudential measure of a capital buffer for other systemically important institutions (O-SII) was legally introduced at the same time as the CCB instrument. It has been inactive and set to 0 percent as well.

5. In 2016 non-binding recommendation measures were implemented, which set the maximum level of the LTV[4] and DSTI[5] ratios. These two measures aim to pursue the intermediate objective of macroprudential policy of mitigating and preventing excessive credit growth and excessive leverage.

3 Literature Review

There is a growing literature implementing financial frictions and later on defining macroprudential policy in monetary models - namely in dynamic stochastic general equilibrium models. Kiyotaki and Moore (1997) allowed financial frictions to affect the real economy *via* quantities through collateral constraints.

[3]Gross loans-to-deposits flows. More on the GLTDF instrument in Šuler Štavt (2014).
[4]Loan-to-value ratio.
[5]Debt service-to-income ratio.

They construct a dynamic economy model in which the lender cannot force borrowers to repay their debts unless the debts are secured. This friction between credit and assets enables the amplification and spillovers of different shocks via new transmission mechanism to other sectors. Bernanke and Gertler (1989) paper introduces financial frictions that affect the real economy *via* price of loans. They developed a mechanism in which the condition of borrower's balance sheets is a source of output dynamics by inversely relating the agency costs of underlying physical investments and borrower's net worth. Based on these seminal contributions[6], Iacoviello (2005) introduced a housing sector loan-to-value rule interacting with monetary policy. He finds that collateral constraints improve the response of aggregate demand to housing price shocks, while nominal debt improves the sluggishness of the response of output to inflation shocks.

Several papers try to follow the Iacoviello strand of research that would emphasize the complementary role of the macroprudential policy to the monetary policy by introducing credit and collateral requirements into quantitative general equilibrium models. Borio and Shim (2007), and N'Diaye (2009) for instance, show that the monetary policy can be supported by the built-in and countercyclical stabilizers. Kannan et al. (2009), Angeloni and Faia (2009) and Angelini et al. (2012) introduce capital ratios as a macroprudential policy tool into a DSGE model. Many other papers such as Galati and Moessner (2010), Beau et al. (2014) and Rubio and Carrasco-Gallego (2014) follow the work already done on financial frictions in DSGE models. Christiano et al. (2008) and Goodfriend and McCallum (2007) continue by introducing financial intermediaries into the models, but only emphasize the demand side of the economy. Recently, Bokan et al. (2018) upgraded a large scale DSGE model of Gomes et al. (2012) with the inclusion of the banking sector introduced by Gerali et al. (2010). They add a stylized banking sector that is characterized by the supply side of the credit markets and thus extend the existing literature.

The second strand of research focuses on empirical evidence. Blundell-Wignall and Roulet (2013) for instance explore the macroprudential issues by determining the determinants of bank systemic risk and the effectiveness of capital controls. Maddaloni and Peydró (2013) analyse the impact on lending standards of both policies by using the Bank Lending Survey data. Looking at the conclusions from the empirical evidence as well as from the theoretical models cautiousness in giving strong policy advice is appropriate with regards to the complexity and interdependency of economies and the implementation of macroprudential instruments and their interaction with monetary policy.

Despite the fruitful start of research on the issue it is still not completely clear how monetary and macroprudential policies interact. Imperfect func-

[6]Relevant papers regarding this subject are Carlstrom and Fuerst (1997) and Bernanke et al. (1999), as well.

tioning macroprudential and monetary policies together with institutional and other economy constraints could deviate substantially from the frictionless world in models described thus far. Consequently, the effects of macroprudential instruments on financial stability are difficult to quantify and design a well-targeted macroprudential policy optimally intertwined with monetary policy (Claessens et al., 2013). Some of the recent work therefore focuses on modelling macroprudential policy without the interaction of the monetary policy. Clerc et al. (2015) developed a DSGE model in order to analyse exclusively the effects of the macroprudential policies. In the so-called 3D model financial intermediaries allocate their net worth together with funds raised from saving households across *via* mortgages and corporate lending. External financing of all borrowers takes the form of debt and is subject to default risk. These frictions cause financial amplification and distortions due to deposit insurance.

We follow the first strand of work by constructing a standard DSGE macromodel of a small open economy with a banking sector where several macroprudential instruments can be defined. The banking sector framework follows the Gerali et al. (2010) model setting operating in a single currency area. By differencing agents to savers and borrowers in the model it enables us to create conditions for credit, i.e. to introduce the financial sector which collects deposits from savers and extends credit to borrowers. Credit granted to borrowers is backed up by the value of housing stock which allows us to model the role of collateral in the form of the loan-to-value ratio. The aspect of the macroprudential policy will be further strengthened by the implementation of instruments influencing the liabilities of the financial sector, acting as additional capital requirements. On the other hand the monetary policy is conducted by a central bank that targets a CPI inflation rate and reacts to deviations in the real GDP growth.

4 The model

The model consists of three types of agents: two types of households, savers and borrowers; and entrepreneurs. Both types of households consume, work and invest in housing[7]. The difference between both types of households comes with the assumption, that savers are saving assets in a form of one-period deposits, while borrowers can only borrow from the banking sector and do not save (one-period loans). Additionally, the borrowers are facing a borrowing constraint, which ties the capability of borrowing to the value of housing collateral. Entrepreneurs produce a homogeneous intermediate good by using capital bought from capital producers and labour, which is supplied by both types of households. All three types of agents have different discount factor

[7]Housing supply is fixed as in Gerali et al. (2010) and Bokan (2018).

that they apply to their future utility. This heterogeneity in discount factors determines positive financial flows in the equilibrium.

The production side of the economy is defined by labour services that are differentiated by households through labour unions which set wages in order to maximize the utility subject to adjustment costs. As entrepreneurs produce the intermediate goods, the monopolistically competitive retail sector buys the intermediate goods in a competitive intermediate market, differentiate and price them subject to nominal rigidities accordingly to Calvo pricing (1983). There is a capital good producer sector as well. It is intended to derive a market price for capital, which is used as collateral when entrepreneurs borrow from the banking sector.

The main focus of the paper is the construction of the banking sector. Considering the macroprudential measures taken by the Bank of Slovenia the structure of the banking sector is the following. On one side there is a wholesale banking sector, which operates under perfect competition. These banks choose loans and deposits. Retail banking sector operates in a monopolistic competition. The idea behind the monopolistic competition in the banking sector is to model the market power and sluggishness of interest rates that banks have when they charge mark-ups and mark-downs on loan rates and deposits[8]. Based on this the degree of market power is simulated by controlling for the value of elasticities of loan and deposit demands. The lower the elasticities higher the monopoly power in the banking sector. Secondly, the sluggishness of the interest rates is resolved by applying the Calvo pricing mechanism.

Retail banks take loans from wholesale bank at a homogeneous interest rate and then provide differentiated loans to households and entrepreneurs, thus exploit the market power against their customers with applying mark-ups to loans and mark-downs to deposits with respect to the official policy rate. Additionally the retail banks face retail-rate adjustment costs when changes in financing conditions appear. Due to the financial intermediation based on differentiated interest-rate setting the transmission mechanism no longer depends on perfect pass-through and effectiveness. These financial imperfections (mark-ups and mark-downs) rather amplify changes in borrowing and deposit rates, which make the financial side of the modelled economy more realistic. Since banks are accumulating bank capital through reinvested profits by tying their capital-to-assets ratio to the target Basel III capital requirement ratio, the model offers a study of capital adequacy shocks as well.

[8] Several studies highlighted and confirmed the existence of market power in the banking sector by using different methods, but mostly empiric surveys, and the construction of market-power indexes. We will mention a few: De Bandt and Davis (2000), Berger et al. (2004), Claessens and Laeven (2004), Demirguc-Kunt et al. (2004), Fernández de Guevara (2005), Mandelman (2006), Degryse and Ongena (2008), Řepková (2012), Brissimis et al. (2014), Delis et al. (2017).

4.1 Households

There is a continuum of two groups of representative households in the model, savers and borrowers[9]. While the savers hold deposits, the borrowers' consumption is financed by wage income and borrowing.

4.1.1 Savers

The representative saving household maximizes the present value of the expected utility:

$$E_0 \sum_{t=0}^{\infty} \beta_S^t \left[\varepsilon_t^c \log \left(C_t^S(i) - \omega_S C_{t-1}^S(i) \right) + \varepsilon_t^h \log H_t^S(i) - \frac{N_t^S(i)^{1+\varphi}}{1+\varphi} \right] \quad (1)$$

where β_S^t is the discount rate and ε_t^c represents a consumption preference shock[10]. Consumption of a saving household, $C_t^S(i)$, is subject to the habit formation, ω_S. The ε_t^h is an exogenous demand shock in housing. Variable H_t^S are the housing services, while N_t^S represents the hours worked by the household. The parameter φ is the disutility of work effort.

A saving household is subject to a budget constraint, depicted in real terms:

$$C_t^S(i) + Q_t^h \Delta H_t^S(i) + D_t^S(i) = W_t^S N_t^S(i) + \left(1 + R_{t-1}^d\right) \frac{D_{t-1}^S(i)}{\pi_t} + T_t^S(i) \quad (2)$$

The expenses of the savers are divided between consumption $C_t^S(i)$, accumulation of housing services at real price Q_t^h and deposits made at D_t^S time t. The expenses are financed by the wage income $W_t^S N_t^S(i)$, gross interest income on deposits $\left(1 + R_{t-1}^d\right) \frac{D_{t-1}^S(i)}{\pi_t}$ in time $t-1$ and a lump-sum transfers $T_t^S(i)$ originating labour unions membership net fee and firms' and banks' dividends.

[9]Gerali et al. (2010) and Bokan et al. (2018) use the notion of patient and impatient households.

[10]All the shocks considered in the model with the exception of the monetary policy shock follow an $AR(1)$ process with *i.i.d.* normal innovations, generally denoted as $\varepsilon_t = (1-\rho_\varepsilon)\overline{\varepsilon} + \rho_\varepsilon \varepsilon_{t-1} + \eta_t^\varepsilon$. The parameter ρ_ε is the autoregressive coefficient, the $\overline{\varepsilon}$ is the steady-state value and η_t^ε is an *i.i.d.* zero mean normal random variable with standard deviation equal to σ_ε.

4.1.2 Borrowers

Analogous to the saving households, a representative borrowing household maximizes the present value of the expected utility:

$$E_0 \sum_{t=0}^{\infty} \beta_B^t \left[\varepsilon_t^c \log \left(C_t^B (i) - \omega_B C_{t-1}^B (i) \right) + \varepsilon_t^h \log H_t^B (i) - \frac{N_t^B (i)^{1+\varphi}}{1+\varphi} \right] \quad (3)$$

where β_B^t is the discount rate and ε_t^c represents a consumption preference shock. Consumption of a borrowing household, $C_t^B (i)$, is subject to the habit formation, ω_B. The ε_t^h is an exogenous demand shock in housing. Variable H_t^B are the housing services, while N_t^B represents the hours worked by the household. The parameter φ is the disutility of work effort.

In contrast to savers, a borrowing household does not collect deposits. It has to finance its whole consumption through wage income and borrowing. The budget constraint of a borrowing household is:

$$C_t^B (i) + Q_t^h \Delta H_t^B (i) + \left(1 + R_{t-1}^{hh}\right) \frac{B_{t-1}^B (i)}{\pi_t} = W_t^B N_t^B (i) + B_t^B (i) + T_t^B (i) \quad (4)$$

The expenses side of the budget constraint of a borrowing household includes consumption $C_t^B (i)$, housing services $Q_t^h \Delta H_t^B (i)$ and reimbursement of previous borrowing $\left(1 + R_{t-1}^{hh}\right) \frac{B_{t-1}^B(i)}{\pi_t}$. The expenses of the borrowing household are financed by wage income $W_t^B N_t^B (i)$, new loans $B_t^B (i)$ and net labour union membership fees $T_t^B (i)$.

Further on, the borrowing households are facing a borrowing constraint, as introduced by Iacoviello (2005) and followed by Gerali et al. (2010) and Bokan et al. (2018). The expected value of their collateralizable housing stock at period t must be high enough to guarantee lenders of debt repayment:

$$\left(1 + R_t^{hh}\right) B_t^B (i) \leqslant \varepsilon_t^{hh,ltv} E_t \left[Q_{t+1}^h H_{t+1}^B (i) \, \pi_{t+1} \right] \quad (5)$$

where $\varepsilon_t^{hh,ltv}$ stands for stochastic loan-to-value (LTV) ratio for household mortgages. The assumption is that the LTV ratio variations are modelled as exogenous stochastic processes and do not depend on individual bank choices. This characteristic allows to study the effects of credit-supply restrictions on the real side of the economy. However, there is an issue that can arise from the latter equation. For the size of the LTV shocks we have to assume that they are small enough, so that the borrowing constraint remains binding for the borrowers in the neighbourhood of the steady state and prevents of savers becoming borrowers[11].

4.1.3 Wage dynamics

Savers and borrowers indexed by $n \in (S, B))$ offer differentiated labour. The labour supply is sold by unions to perfectly competitive labour aggregating firms which assembles the labour supply accordingly to a CES aggregator and sells the homogeneous labour input to entrepreneurs. Based on two types of households, we assume that there are two unions. Each union sets nominal wages for its members (saving and borrowing households) by maximizing their utility subject to a downward sloping demand and quadratic adjustment costs:

$$E_0 \sum_{t=0}^{\infty} \beta_n^t \left(U_{C_t^n(i)} \left[\frac{W_t^n(i)}{P_t} N_t^n - \frac{\kappa_w}{2} \left(\frac{W_t^n(i)}{W_{t-1}^n(i)} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right)^2 \frac{W_t^n}{P_t} \right] - \frac{(N_t^n)^{1+\varphi}}{1+\varphi} \right) \tag{6}$$

which is subject to:

$$N_t^n(i) = \left(\frac{W_t^n(i)}{W_t^n} \right)^{-\varepsilon_t^w} N_t^n \tag{7}$$

ι_w is an indexation parameter of lagged and steady-state inflation. Parameter κ_w controls/measures for the effect of the quadratic adjustment costs, while ε_t^w is the wage-elasticity shock. The wage Phillips curve can then be written as:

$$\kappa_w \left(\pi_t^{w^n} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right) \pi_t^{w^n} = \beta_n E_t \left[\frac{\lambda_{t+1}^n}{\lambda_t^n} \kappa_w \left(\pi_t^{w^n} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right) \frac{\left(\pi_{t+1}^n\right)^2}{\pi_{t+1}} \right] - (1-\varepsilon_t^w) N_t^n + \frac{\varepsilon_t^w (N_t^n)^{1+\varphi}}{W_t^n \lambda_t^n} \tag{8}$$

[11] This issue is discussed in more detail by Iacoviello (2005) by simulating when does the collateral constraint bind. The conclusion is that the borrowing constraints might become looser in an economic upswing. Thus, when the demand increases, the collateral price increases as well, consequently implying two effects. First, the price effect reduces the asset demand. And second, the collateral effect drives asset demand up, leading to further relaxation of the borrowing constraint. If the second effect dominates, the collateral capacity for each unit of the asset pledged becomes procyclical, rising in good times, and falling in bad times. This offers potential for more buffer-stock behaviour in good times, and for less in bad times. If so, borrowing constraints might be less binding in good states of the world. The asymmetric response of the collateral constraints in confirmed by the Guerrieri and Iacoviello (2017) paper.

4.2 Entrepreneurs

In order to model borrowing in the production side as well, there is a continuum of borrowing entrepreneurs that maximize the utility function, given by:

$$E_0 \sum_{t=0}^{\infty} \beta_{ent}^t \left[\log \left(C_t^{ent}(i) - \omega_{ent} C_{t-1}^{ent}(i) \right) \right] \tag{9}$$

where $C_t^{ent}(i)$ represents consumption, and is subject to habit formation, ω_{ent}. An entrepreneur chooses consumption, physical capital, $K_t^{ent}(i)$, loans from banks, B_t^{ent}, the degree of capacity utilization, u_t, and labour input, N_t^{ent}. The decisions of an entrepreneur are therefore subject to a budget constraint:

$$\begin{aligned} C_t^{ent}(i) + W_t^S N_t^{Sd}(i) + W_t^B N_t^{Bd}(i) + \left(1 + R_{t-1}^{ent}\right) \frac{B_{t-1}^{ent}(i)}{\pi_t} \\ + Q_t^k \Delta K_t^{ent}(i) + \psi\left(u_t(i)\right) K_{t-1}^{ent}(i) = \frac{Y_t^{ent}}{X_t} + B_t^{ent}(i) + Q_t^k (1-\delta) K_{t-1}^{ent}(i) \end{aligned} \tag{10}$$

where δ is the depreciation rate, Q_t^k is the price of physical capital in terms of consumption, while the expression $\psi\left(u_t(i)\right) K_{t-1}^{ent}(i)$ represents the real cost of setting a level u_t of utilization rate.

The relative competitive price of the wholesale good is defined as $\frac{P_t^{ret}}{P_t} = \frac{1}{X_t}$, and is produced by each entrepreneur based on the technology equation:

$$Y_t^{ent}(i) = \varepsilon_t^A \left[K_{t-1}^{ent}(i) u_t(i) \right]^{\alpha} N_t^{ent}(i)^{1-\alpha} \tag{11}$$

where α is the share of capital utilization in the production function and ε_t^A is a stochastic process for total factor productivity. The aggregate labour is defined as $N_t^{ent} = \left(N_t^{Sd}\right)^{\mu} \left(N_t^{Bd}\right)^{1-\mu}$, where μ is the share of savers in total labour supply.

Banks are willing to lend to entrepreneurs but only against collateral. This implies that entrepreneurs are constrained by the value of the collateral in the form of physical capital, which follows the assumption of Gerali et al. (2010). The borrowing constraint of the entrepreneur is:

$$\left(1 + R_t^{ent}\right) B_t^{ent}(i) \leqslant \varepsilon_t^{ent,ltv} E_t \left[Q_{t+1}^k K_{t+1}^{ent}(i) (1-\delta) \pi_{t+1} \right] \tag{12}$$

where $\varepsilon_t^{ent,ltv}$ stands for stochastic loan-to-value (LTV) ratio for entrepreneurs mortgages. As was discussed in the borrowing households section, the assumption for the size of the LTV shocks is that they are small enough, so that the borrowing constraint remains binding for the borrowers in the neighbourhood of the steady state.

4.2.1 Capital goods producers and goods retailers

Following Smets and Wouters (2003) and Christiano et al. (2005), at time t zero-profit perfectly competitive firms buy last period capital, $(1-\delta)K_{t-1}$, at price P_t^k from entrepreneurs in the capital goods market. Capital goods producers are owned by entrepreneurs. At the same time the firms buy an amount x_t of final goods from retailers at price P_t. The purchasing activity in the capital goods market increases the stock of effective capital, $\overline{K}_t$, and at the end of the period is sold back to entrepreneurs. The last period capital is thus converted into new capital, while the transformation of the final good is subject to quadratic adjustment costs. Both constitute a maximization problem for the capital goods producers:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{ent} \left(q_t^k \Delta \overline{K}_t - x_t \right) \tag{13}$$

subject to:

$$\overline{K}_t = \overline{K}_{t-1} \left[1 - \frac{\kappa_i}{2} \left(\frac{x_t \varepsilon_t^{qk}}{x_{t-1}} - 1 \right)^2 \right] x_t \tag{14}$$

The expression $\Delta \overline{K}_t = K_t - (1-\delta)K_{t-1}$ is the capital flow output. The parameter κ_i measures the adjusting cost of investment, while ε_t^{qk} represents the productivity shock of investment goods.

In order to provide the price stickiness in the model, the retailers operate in a monopolistically competitive market. They buy the intermediate good from entrepreneurs at the price P_t^{ret}, re-brand and differentiate the good at no cost. Each retail good firm then sells his differentiated good, applying a mark-up over the wholesale price P_t^{ret}. The pricing mechanism of the retailers follows Calvo (1983) and are indexed to a combination of past and steady-state inflation, with relative weights parametrized by ι_p. The retailers, if they want to change their price they face a quadratic adjustment cost parametrized by κ_p as well. They maximize profits according to the following equation:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{ret} \left[P_t(j) Y_t(j) - P_t^{ret} Y_t(j) - \frac{\kappa_p}{2} \left(\frac{P_t(j)}{P_t} - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} \right)^2 P_t Y_t \right] \quad (15)$$

subject to a downward sloping demand from the consumers maximization of the consumption aggregator:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon_t^y} Y_t \quad (16)$$

where demand faces a stochastic price-elasticity shock ε_t^y.

4.3 Banking sector

The banking sector acts as an intermediary for all financial transactions in the model, which in turn allows for financial frictions to occur. Consequently, banks can assert a relatively high loan rate to the borrowing entrepreneurs and households, and a low deposit rate to the saving households. Banks are owned by households and follow a balance sheet identity:

$$B_t = D_t + K_t^b \quad (17)$$

Banks can finance loans, B_t, by using D_t or bank capital, K_t^b. Banks in the model serve as a feedback loop between the real and the financial sector in the economy. The bank capital is accumulated out of retained earnings, and plays a key role in determining the conditions of credit supply, both for quantities and for prices. A further assumption is that a representative chooses optimal capital-to-assets (i.e. leverage) ratio from which it is costly to deviate. Therefore, as the macroeconomic conditions deteriorate, the profitability of banks and bank capital might be negatively hit. Banks might respond to the ensuing weakening of their financial position (i.e. increasing leverage) by reducing the amount of loans they are willing to extend to the private sector. The model might thus potentially account for the type of the credit cycle typically observed in recent recession episodes, with a weakening real economy, a reduction of bank profits, a weakening of banks' capital positions and the ensuing credit restriction.

4.3.1 Wholesale banking

The wholesale banking sector is modelled under perfect competition. It combines bank capital, K_t^b with wholesale deposits, D_t, and loans B_t, as depicted in equation (17). A wholesale activity cost is related to the capital position of the bank. The bank pays a quadratic cost (parametrized by a coefficient κ_K^b and proportional to outstanding bank capital) whenever the capital-to-assets ratio $\frac{K_t^b}{B_t}$ moves away from an optimal or target value $\overline{cap}_b$.

Bank capital follows a typical capital dynamics equation:

$$K_t^b = (1 - \delta_b) K_{t-1}^b + \theta_b \Pi_{t-1}^b \tag{18}$$

where Π_{t-1}^b are overall profits of each bank, while $(1 - \theta_b)$ captures the dividend policy of the banks and is exogenously determined. The parameter δ_b measures resources used in the managing bank capital.

A wholesale bank chooses loans and deposits so it maximizes a discounted sum of cash flows and chooses:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(1 + R_t^b\right) B_t - B_{t+1} + D_{t+1} - \left(1 + R_t^d\right) D_t + \Delta K_{t+1}^b - \frac{\kappa_{K^b}}{2} \left(\frac{K_t^b}{B_t} - \overline{cap}_b \right)^2 K_t^b \right] \tag{19}$$

while the bank's decision is subject to a balance sheet constraint:

$$B_t = D_t + K_t^b \tag{20}$$

The variable R_t^b is the net wholesale loan rate and R_t^d is the net wholesale deposit rate. Both rates are taken as given. By using the balance sheet constraint twice (19) the wholesale bank's maximization problem can be simplified into:

$$\max_{\{B_t, D_t\}} \left[R_t^b B_t - R_t^d D_t - \frac{\kappa_{K^b}}{2} \left(\frac{K_t^b}{B_t} - \overline{cap}_b \right)^2 K_t^b \right] \tag{21}$$

The first order conditions of the maximization problems provide a condition that links the spread between wholesale rates on loans and on deposits to the degree of leverage:

$$R_t^b = R_t^d - \frac{\kappa_{K^b}}{2}\left(\frac{K_t^b}{B_t} - \overline{cap}_b\right)^2 \left(\frac{K_t^b}{B_t}\right)^2 \quad (22)$$

Further on, in order to close the model, the assumption is that banks have access to unlimited finance at the monetary policy rate R_t from a lending facility at the central bank: hence, $R_t^d \equiv R_t$. Simple algebra of the above equation yields the following equation for wholesale loan-deposit rate spread:

$$S_t^{b,W} = R_t^b - R_t = -\frac{\kappa_{K^b}}{2}\left(\frac{K_t^b}{B_t} - \overline{cap}_b\right)^2 \left(\frac{K_t^b}{B_t}\right)^2 \quad (23)$$

The wholesale spread is inversely related to the overall capital-to-assets ratio of banks, $\frac{B_t}{K_t^b}$. To put in perspective, when banks' capital level are low the leverage increases and margins become wider. The higher the leverage, the wider the spread between the wholesale loan rate and the monetary policy rate, the more the banks want to lend, thus increasing profits per unit of capital (or return on equity). And *vice versa*.

4.3.2 Retail banking

In order to construct the retail banking sector, the loan and deposit demand Dixit-Stiglitz aggregation framework has to be defined first. The assumption is that deposits and loans aggregated by households and entrepreneurs are a composite CES basket of slightly differentiated products each supplied by a branch of a bank j with elasticities of substitution equal to ε_t^d, ε_t^{hh} and ε_t^{ent}. These elasticities of substitution are stochastic. This choice arises from our interest in studying how exogenous shocks hitting the banking sector are transmitted to the real economy. ε_t^d, ε_t^{hh}, ε_t^{ent} affect the value of the mark-ups and mark-downs that banks charge when setting interest rates and, consequently, the value of the spreads between the policy rate and the retail loan (deposit) rates. Innovations to the loan (deposit) mark-up (mark-down) can thus be interpreted as innovations to bank spreads arising independently of monetary policy and we can take account of their effects on the real economy.

The demands for loans to households, loans to entrepreneurs and deposits at bank j depend on overall volumes and on the interest rates charged by bank j relative to the average rates in the economy and are given by the loans functions:

$$B_t^B(i) = \left(\frac{R_t^{hh}(i)}{R_t^{hh}}\right)^{-\varepsilon_t^{hh}} B_t^B \quad (24)$$

$$B_t^{ent}(i) = \left(\frac{R_t^{ent}(i)}{R_t^{ent}}\right)^{-\varepsilon_t^{ent}} B_t^{ent} \tag{25}$$

and the deposit function:

$$D_t^S(i) = \left(\frac{R_t^d(i)}{R_t^d}\right)^{-\varepsilon_t^d} D_t^S \tag{26}$$

The retail banking sector works in a monopolistic competition. On one side, the retail bank j acquires wholesale loans $B_t(j)$ from the wholesale bank at rate R_t^b, differentiates them at no cost and resells them to households and entrepreneurs applying two different mark-ups. In order to introduce stickiness and to study the implication of an imperfect bank pass-through, the assumption is that each retail bank faces quadratic adjustment costs for changing the rates it charges on loans. These costs are parametrized by κ_{hh} and κ_{ent} and are proportional to aggregate returns on loans. The retail bank therefore maximizes:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} [R_t^{hh}(i) B_t^B(i) + R_t^{ent}(i) B_t^{ent}(i) - R_t^b B_t(i) \\ - \frac{\kappa_{hh}}{2}\left(\frac{R_t^{hh}(i)}{R_{t-1}^{hh}(i)} - 1\right)^2 R_t^{hh} B_t^B - \frac{\kappa_{ent}}{2}\left(\frac{R_t^{ent}(i)}{R_{t-1}^{ent}(i)} - 1\right)^2 R_t^{ent} B_t^{ent}] \tag{27}$$

and the condition $B_t(j) = B_t^B(j) = B_t^{ent}(j)$ holds. After imposing a symmetric equilibrium, the first order condition for households yields:

$$1 - \varepsilon_t^{hh} + \varepsilon_t^{hh} \frac{R_t^b}{R_t^{hh}} - \kappa_{hh}\left(\frac{R_t^{hh}}{R_{t-1}^{hh}} - 1\right)\frac{R_t^{hh}}{R_{t-1}^{hh}} \\ + \beta_S E_t\left[\frac{\lambda_t}{\lambda_{t-1}} \kappa_{hh}\left(\frac{R_{t+1}^{hh}}{R_t^{hh}} - 1\right)\left(\frac{R_{t+1}^{hh}}{R_t^{hh}}\right)^2 \frac{B_{t+1}^B}{B_t^B}\right] = 0 \tag{28}$$

and for entrepreneurs

$$1-\varepsilon_t^{ent}+\varepsilon_t^{ent}\frac{R_t^b}{R_t^{ent}}-\kappa_{ent}\left(\frac{R_t^{ent}}{R_{t-1}^{ent}}-1\right)\frac{R_t^{ent}}{R_{t-1}^{ent}}$$
$$+\beta_{ent}E_t\left[\frac{\lambda_t}{\lambda_{t-1}}\kappa_{ent}\left(\frac{R_{t+1}^{ent}}{R_t^{ent}}-1\right)\left(\frac{R_{t+1}^{ent}}{R_t^{ent}}\right)^2\frac{B_{t+1}^{ent}}{B_t^{ent}}\right]=0 \quad (29)$$

where λ_t denotes the Lagrange multiplier for budget constraints of households and entrepreneurs. Loan rates are set by banks based on current and expected future values of the wholesale bank rate, which is the relevant marginal cost for this type of bank and which depends on the monetary policy rate as well as on the capital position of the bank. The adjustment to changes in the wholesale rate depends inversely on the intensity of the adjustment costs (as measured by κ_{hh} and κ_{ent}) and positively on the degree of competition in the bank loans sector (as measured by the inverse of ε_t^{hh} and ε_t^{ent}).

Under perfectly flexible interest rates the equations (28) and (29) is simplified to:

$$R_t^{hh}=\frac{\varepsilon_t^{hh}}{\varepsilon_t^{hh}-1}R_t^b \quad (30)$$

and

$$R_t^{ent}=\frac{\varepsilon_t^{ent}}{\varepsilon_t^{ent}-1}R_t^b \quad (31)$$

The interest rates on loans are therefore set as a simple mark-up over marginal cost. The spread between the loans and the monetary policy rate under flexible rates is given by:

$$S_t^{hh}\equiv R_t^{hh}-R_t=\frac{\varepsilon_t^{hh}}{\varepsilon_t^{hh}-1}S_t^{wh}+\frac{1}{\varepsilon_t^{hh}-1}R_t \quad (32)$$

and

$$S_t^{ent}\equiv R_t^{ent}-R_t=\frac{\varepsilon_t^{ent}}{\varepsilon_t^{ent}-1}S_t^{wh}+\frac{1}{\varepsilon_t^{ent}-1}R_t \quad (33)$$

The intuition behind it is that the spread on retail loans is increasing with the monetary policy rate, and is proportional to the wholesale spread S_t^{wh}, which is determined by the bank's capital position. In addition, the degree of monopolistic competition also plays a role by an increase in market power.

These relations between the elasticity and the loan spreads allows to interpret shocks to (ε_t^{hh} and ε_t^{ent}), and are modelled as stochastic processes.

On the other side, a deposit bank j collects deposits $D_t^S(j)$ from saving households and then uses deposits at the renumeration rate R_t. The maximization problem of a deposit bank is:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[R_t D_t^S(i) - R_t^d(i) D_t(i) - \frac{\kappa_d}{2} \left(\frac{R_t^d(i)}{R_{t-1}^d(i)} - 1 \right)^2 R_t^d D_t^S \right] \quad (34)$$

Quadratic adjustment costs for changing the deposit rate are parametrized by the coefficient κ_d and are proportional to aggregate interest paid on deposits. After imposing a symmetric equilibrium, the first order condition for optimal deposit interest rate setting is given by:

$$1 - \varepsilon_t^d + \varepsilon_t^d \frac{R_t^b}{R_t^d} - \kappa_d \left(\frac{R_t^d}{R_{t-1}^d} - 1 \right) \frac{R_t^d}{R_{t-1}^d} + \beta_d E_t \left[\frac{\lambda_t}{\lambda_{t-1}} \kappa_d \left(\frac{R_{t+1}^d}{R_t^d} - 1 \right) \left(\frac{R_{t+1}^d}{R_t^d} \right)^2 \frac{D_{t+1}^S}{D_t^S} \right] = 0 \quad (35)$$

Again, under perfectly flexible interest rates the equation (28) is simplified to:

$$R_t^d = \frac{\varepsilon_t^d}{\varepsilon_t^d - 1} R_t \quad (36)$$

The overall real profits of a bank are the sum of net earnings (intermediation margins minus other costs) from wholesale banks and the retail banks:

$$\Pi_t^b = R_t^{hh} B_t^{hh} + R_t^{ent} B_t^{ent} - R_t^d D_t^S - \frac{\kappa_{K^b}}{2} \left(\frac{K_t^b}{B_t} - \overline{cap}_b \right)^2 K_t^b - \Upsilon_t^b \quad (37)$$

where Υ_t^b represents adjustment costs for changing interest rates on loans and deposits.

4.4 Monetary Policy

The monetary policy follows a Taylor-type rule:

$$(1+R_t) = (1+R)^{1-\phi_r}(1+R_{t-1})^{\varrho_r}\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\phi_r)}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y(1-\phi_r)}\varepsilon_t^r \tag{38}$$

where ϕ_π and ϕ_y are weights assigned to inflation and output stabilization, respectively. R is the steady-state nominal interest rate, while $Y_t = \gamma^{ent}Y_t^{ent}(i)$ is the aggregate output and ε_t^r is an *i.i.d.* shock to monetary policy with normal distribution and standard deviation σ_r.

4.5 Market Clearing

In order to close the model market clearing has to occur. In the final goods market the equilibrium condition is given by the resource constraint:

$$Y_t = C_t + Q_t^k\left[K_t - (1-\delta)K_{t-1}\right] + \psi(u_t)K_{t-1} + \delta^b K_{t-1}^b + \Upsilon_t \tag{39}$$

where $C_t = C_t^S + C_t^B + C_t^{ent}$ is aggregate consumption, $K_t = \gamma^{ent}K_t^{ent}(i)$ is the aggregate stock of physical capital, $I_t = K_t - (1-\delta)K_{t-1}$ is investment, and K_t^b is the aggregate bank capital. The variable Υ_t includes real adjustment costs for the prices, wages and interest rates.

At the same time an equilibrium in the housing market has to be achieved as well:

$$\overline{H} = \gamma^S H_t^S(i) + \gamma^B H_t^B(i) \tag{40}$$

where $\overline{H}$ denotes the exogenous fixed housing supply stock, while the parameters γ^S and γ^B determine the share of household types.

5 Calibration

The key calibrated parameters are set with the intention of suiting the model as close as possible to the economy characteristics of interest - Slovenia. The saving household discount factor, β_S, is set at 0.9943, which implies a steady-state interest rate on deposits around 2 percent annually. The discount factors of the borrowing households, β_B, and the entrepreneurs, β_{ent}, are set to 0.975.

These values are set according to the papers of Iacoviello (2005), Iacoviello and Neri (2009), and Gerali et al. (2010). The inverse of the Frisch elasticity of labour supply or the disutility of work effort, φ, follows the the Clancy et al. (2014) paper and is set to 1.0. The steady-state of the LTV ratios for household and entrepreneur loans are set to 0.74 and 0.56, respectively (Bank of Slovenia, 2015). The target value of the capital-to-assets ratio ($\overline{cap}_b$) is set to 0.08, following the Basel III criteria, despite . The depreciation rate of capital δ is set to a typically set-up value at 0.025. The steady state elasticity parameter in the labour market ε_w is set to 5 (implying a 15 percent wage mark-up), while for the steady state elasticity parameter in the goods market ε_p is set to 6 (implying a 20 percent price mark-up). The share of unconstrained households μ follows the value of 0.8 set by Gerali et al. (2010). The steady state elasticity parameters ε_d, ε_{ent} and ε_{hh} are set to -1.3, 3.0 and 3.0, respectively. Since Slovenia is a small open economy, the Taylor rule parameters are calibrated close Taylor rule parameters in Clancy et al. (2014) paper for Slovenia. ϕ_π and ϕ_y are set to 2.0 and 0.1, respectively. This means that GDP dynamics of Slovenia does not influence the endogenous setting of the monetary policy interest rate. On the other side we let the inflation gap set the monetary policy interest rate, accordingly to the literature with respect to the modelling of the ECB's monetary policy.

6 Estimation

Other parameters that were not calibrated, and are of our interest, need to be estimated. We apply bayesian methodogy techniques by setting up the prior values of the parameters and observing the actual data. There are 12 observable variables: private consumption, private investment, wages, house price index, loans to households, loans to entrepreneurs, deposits, eonia index, interest rate of household borrowing, interest rate of entrepreneurs borrowing, and the deposit rate. Data is given on a quarterly frequency while the period expands from 2005Q3 till 2017Q1. They enter the model as deviations from the steady state.

The results of the prior and posterior distribution of the estimated variables are shown in Table 1. The estimation process followed the 2.000.000 step Metropolis-Hastings MCMC algorithm with 2 sequential chains and acceptance rate of 36 percent. The converge diagnostics (Brooks and Gelman, 1998), shocks and the prior and posterior distributions are presented in the Appendix B. Looking at the estimation results, all the shocks are quite persistent, especially shocks related to banking sector, such as the LTV shocks ($\varepsilon^{ent,ltv}$ and $\varepsilon^{hh,ltv}$), and are in-line with the existing literature. This would imply that from the policy perspective it is important to take into consideration these "long-lasting" characteristics of shocks when implementing related macroprudential measures and instruments. The interest rate stickiness parameters (the κs) show that the deposit rate value of the parameter is higher than for the loan rates meaning that the deposit rate adjust faster to changes in the official rate of monetary policy rate. These findings could indicate a bigger competition between banks attracting deposits, or put differently less market power and/or a more interest rate elastic demand for deposits[12]. This could be due to the fact that the sample is relatively short and includes a strong boom cycle followed by a very strong protracted recession.

[12] Similar conclusions were made by De Bondt (2002).

Table 1: Prior and posterior distribution of the estimated variables

Parameter and shock	prior mean	posterior mean	90 % interval	HPD	prior distribution	prior std. error
ρ_{ε^c}	0.800	0.6238	0.5139	0.7263	beta	0.1000
ρ_{ε^h}	0.800	0.9958	0.9922	0.9994	beta	0.1000
$\rho_{\varepsilon^{ent,ltv}}$	0.800	0.9910	0.9836	0.9985	beta	0.1000
$\rho_{\varepsilon^{hh,ltv}}$	0.800	0.9624	0.9341	0.9916	beta	0.1000
ρ_{ε^d}	0.800	0.5515	0.4729	0.6350	beta	0.1000
$\rho_{\varepsilon^{hh}}$	0.800	0.8983	0.8369	0.9624	beta	0.1000
$\rho_{\varepsilon^{ent}}$	0.800	0.8161	0.7244	0.9113	beta	0.1000
ρ_{ε^A}	0.800	0.7529	0.7225	0.7766	beta	0.1000
$\rho_{\varepsilon^{Q^k}}$	0.800	0.6112	0.4824	0.7388	beta	0.1000
ρ_{ε^p}	0.800	0.9831	0.9716	0.9953	beta	0.1000
ρ_{ε^w}	0.800	0.9787	0.9652	0.9924	beta	0.1000
$\rho_{\varepsilon^{K^b}}$	0.800	0.7465	0.6631	0.8288	beta	0.1000
ϱ_r	0.500	0.8303	0.7983	0.8630	beta	0.1500
κ_p	50.000	80.9541	53.9801	107.6701	gamma	20.0000
κ_w	50.000	64.4650	45.5446	84.9286	gamma	20.0000
κ_i	2.500	9.7119	7.3136	11.8940	gamma	1.0000
κ_d	10.000	5.4199	3.9014	6.9256	gamma	2.5000
κ_{ent}	3.000	2.2458	0.5650	3.9713	gamma	2.5000
κ_{hh}	6.000	2.0722	1.2860	2.8461	gamma	2.5000
κ_{K^b}	10.000	5.1816	2.1502	8.3412	gamma	5.0000
ι_p	0.500	0.4852	0.2671	0.7213	beta	0.1500
ι_w	0.500	0.3352	0.1523	0.5257	beta	0.1500
$\omega_B = \omega_{ent} = \omega_S$	0.500	0.7729	0.7080	0.8379	beta	0.1000
ε^c	0.010	0.0491	0.0384	0.0591	inv. gamma	0.0500
ε^h	0.010	0.0440	0.0268	0.0610	inv. gamma	0.0500
$\varepsilon^{ent,ltv}$	0.010	0.0189	0.0151	0.0226	inv. gamma	0.0500
$\varepsilon^{hh,ltv}$	0.010	0.0139	0.0110	0.0168	inv. gamma	0.0500
ε^d	0.010	0.5759	0.4913	0.6607	inv. gamma	0.0500
ε^{hh}	0.010	0.4205	0.3400	0.5079	inv. gamma	0.0500
ε^{ent}	0.010	0.9400	0.5662	1.2760	inv. gamma	0.0500
ε^A	0.010	0.0097	0.0025	0.0187	inv. gamma	0.0500
ε^{Q^k}	0.010	0.0362	0.0255	0.0462	inv. gamma	0.0500
ε^r	0.010	0.0082	0.0063	0.0100	inv. gamma	0.0500
ε^p	1.000	1.0220	0.9563	1.0956	inv. gamma	0.0500
ε^w	0.400	1.0022	0.8965	1.1131	inv. gamma	0.0500
ε^{K^b}	0.050	0.1559	0.1289	0.1820	inv. gamma	0.0500

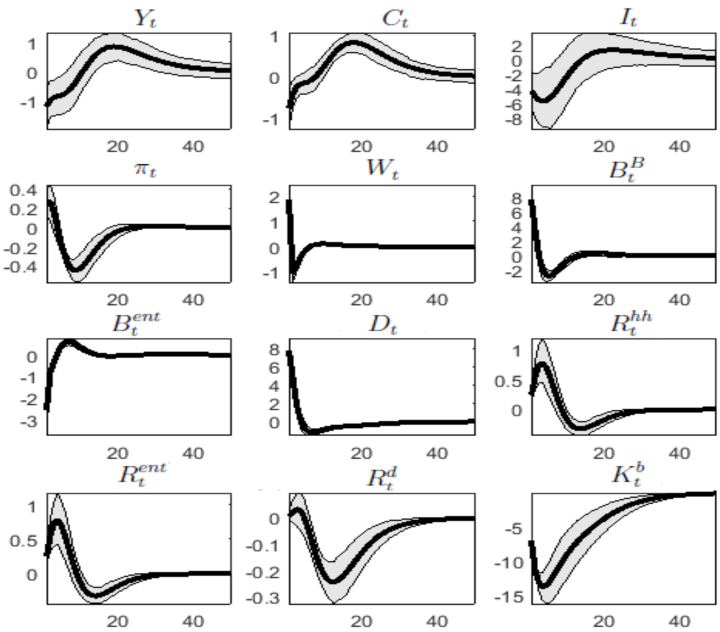
6.1 Impulse responses

This section discusses the results and presents the impulse responses of key variables on separate exogenous banking sector shocks imposed to the modelled economy. In applied work namely, it is often of our interest to study the response of one variable to an exogenous impulse in another variable. Impulse response describes the evolution of the variable of interest along a specified time horizon after a shock in a given moment. The impulse responses of the exogenous shocks in the following figures depict a 50-period horizon.

Following a negative capital shock of 1 p.p. the decline in bank liabilities leaves banks too leveraged with costs relative to their deviation from capital requirements (Figure 1). The negative capital shock is additionally amplified as the model allows for the coefficient on the adjustment costs on the capital-to-assets ratio, κ_{K^b}, estimated at 5.1816 to take an effect. Consequently bank capital decreases more than just 1 p.p. since it is costly for banks to raise new capital in order to quickly comply with the capital/loans (legal) target. Banks try to re-balance assets and liabilities by reducing the aggregate volume loans and increasing the volume of deposits. At the same time they increase the interest rate margin by increasing interest rate on loans and decreasing deposit interest rate. These adjustments in the banking sector does not go unnoticed and transmits into the real economy as well. Investments and consumption decrease, consequently decreasing the aggregate output for 1 p.p.[13]. Based on the results of the impulse responses of the negative capital shock it is crucial to understand, that the increase in capital requirements could invoke similar effects to the economy, therefore the accuracy of the timing of the implementation of a capital buffer (e.g. different than 0 percent) is to be established only in a so-called clear up-cycle period (Langrin and McFarlane, 2014). Otherwise it could have negative implications in terms of banks' financial strength and its perceived confidence or the overall stigma in the banking sector.

[13]However, at this stage it is still difficult to construct a quantitatively realistic scenario based on the conflicting indications following hard and survey evidence on realized and latent bank capital losses and on the tightening of credit standards as discussed by Gerali et al. (2010).

Figure 1: Bank capital shock (deviations from steady state in percentage points)



Further on, another typical macroprudential measure is the ability of macroprudential policy to influence the amount of loans given to the economy (in our case households and entrepreneurs) based on the available collateral value - the so called LTV ratio. On the contrary to the capital shock, a 1 p.p. positive LTV ratio shock has a stimulating effect on the economy (see Figures 2 and 3). Output, consumption, investments, inflation and wages rise. As the collateral (housing) value rises the aggregate loans in the banking sector (can) increase as well. The increase in loans temporarily decreases the bank capital ratio forcing banks to collect more deposits from households by raising deposit rates. Due to the minor inflation increase the loans interest rates follow suit. However, simply putting ceiling or caps on LTV ratio is not a clear-cut measure with respect to instrument's efficiency. Several (micro-founded) studies have found out that limiting LTV ratios can have important policy implications. Capping higher LTV ratio loans on one side can reduce bank risk. But on the other side, a simple cap on LTV ratios may not work well in practice as a macro-prudential policy measure due to the fact that the LTV ratio can exhibit counter-cyclicality. Additionally, in some cases too restrictive LTV ratio caps have prevented higher quality entrepreneurs from borrowing. Findings imply that a simple, or unconditional cap on LTV ratios might not only be ineffective in curbing loan amount in boom periods but may also counter-productively constrain well-performing borrowers (Ono et al., 2013). Consequently, to have LTV ratio caps implemented as an effective macro-prudential policy measure, policy makers should be aware that the efficacy of an LTV ratio cap may depend crucially on how it is conditioned.

Figure 2: LTV ratio for entrepreneurs' mortgages shock (deviations from steady state in percentage points)

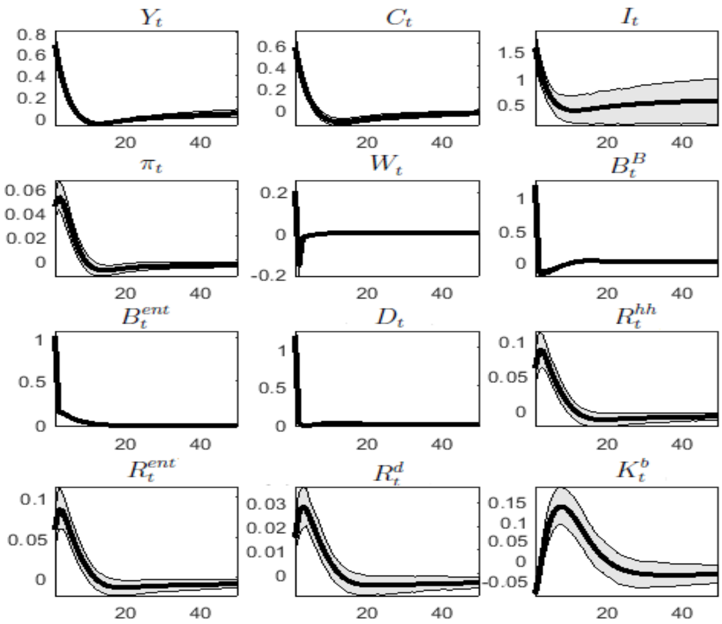
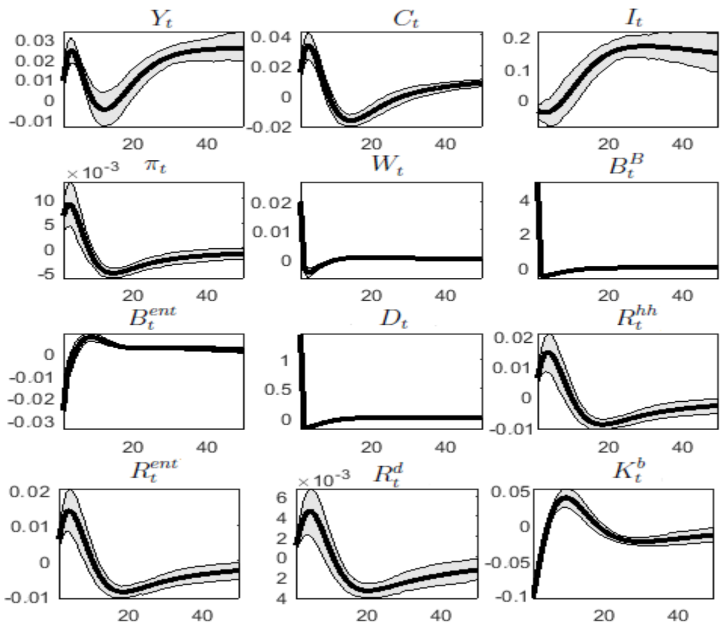


Figure 3: LTV ratio for households' mortgages shock



The model allows us to study other (banking sector) shocks as well. Figure 4, 5 and 6 depict impulse responses of key variables to a mark-up on loans to entrepreneurs and household shocks, and the mark-down shock on deposit rate. The mark-up shock on entrepreneurial loans increases the interest rates for entrepreneurial loans and consequently decreases the incentive for entrepreneurial borrowing, thus decreasing their investment. As the volume of loans decreases, the bank capital relatively increases. The slowdown in the entrepreneurial production affects the aggregate output which decreases alongside the household consumption despite a slight decrease in households loans interest rate due to a fall in inflation rate. The fall in inflation rate decreases the interest rate of deposits which in turn decreases the volume of deposits. The reaction of the economy is slightly different in the case of a mark-up shock on household loans. As the interest rate for household loans increases the volume of loans falls, which relatively increases the bank capital. Consequently the interest rate on deposits slightly increases and volume of deposits decreases. Consumption of saving households increases and pushes entrepreneurs to invest more, while the consumption of borrowing households decrease. Output and inflation slightly increase. The deposit mark-down shock decreases the consumption of households since instantaneous lower volume of deposits relatively decreases bank capital, making banks to decrease household loans. In the absence of consumption, output and inflation decrease. Due to the inflation decrease interest rate for loans decrease. Entrepreneurs take advantage of lower loan rates, borrow and invest more, but cannot offset the fall in output.

Figure 4: Mark-up on loans to entrepreneurs shock (deviations from steady state in percentage points)

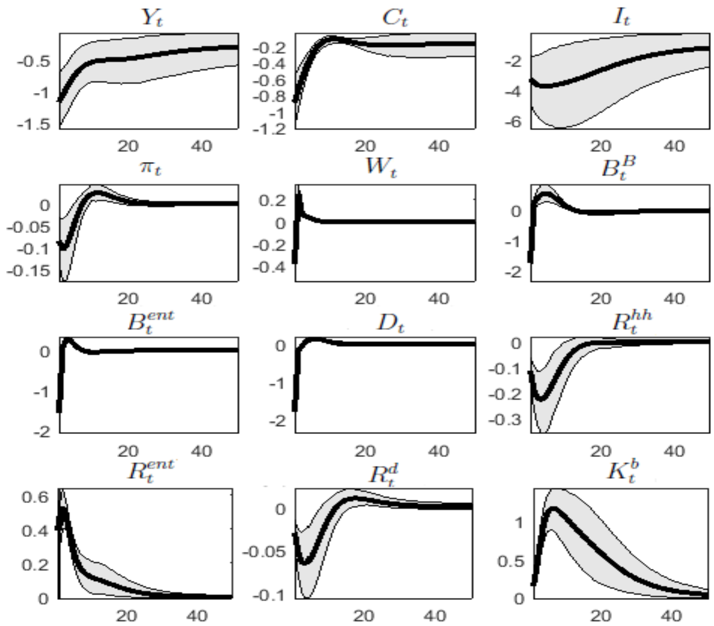


Figure 5: Mark-up on loans to households shock (deviations from steady state in percentage points)

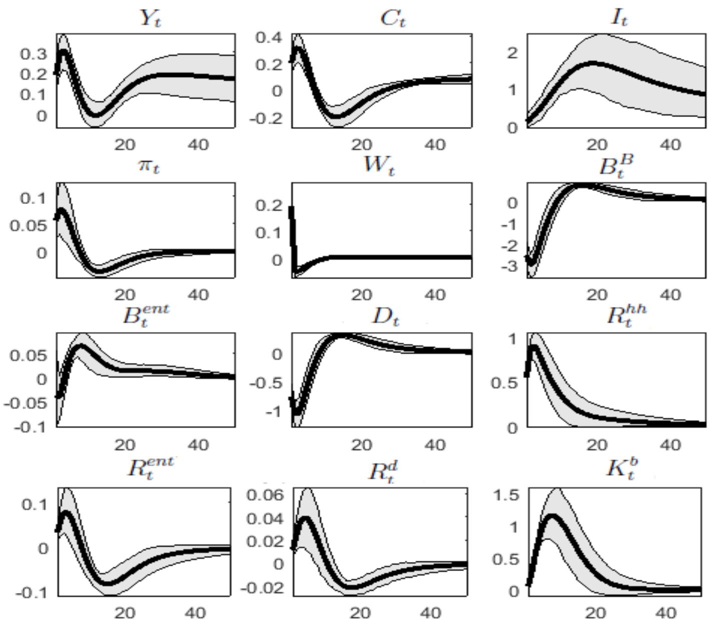
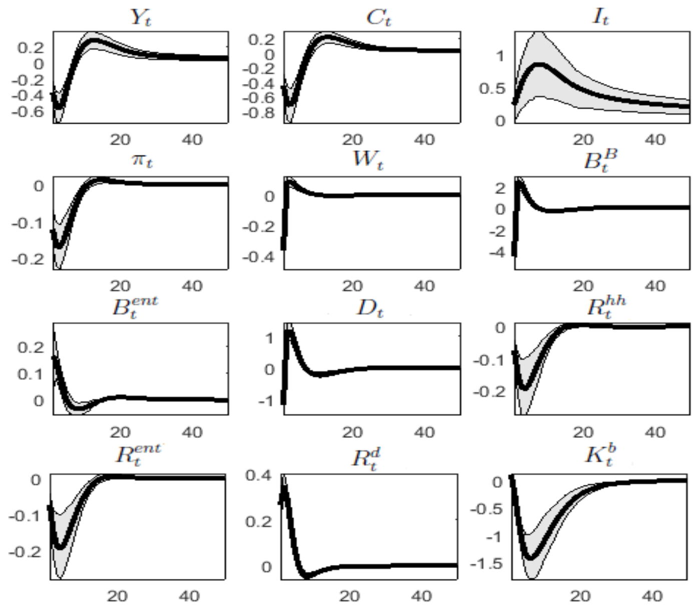


Figure 6: Mark-down on deposit rate shock (deviations from steady state in percentage points)

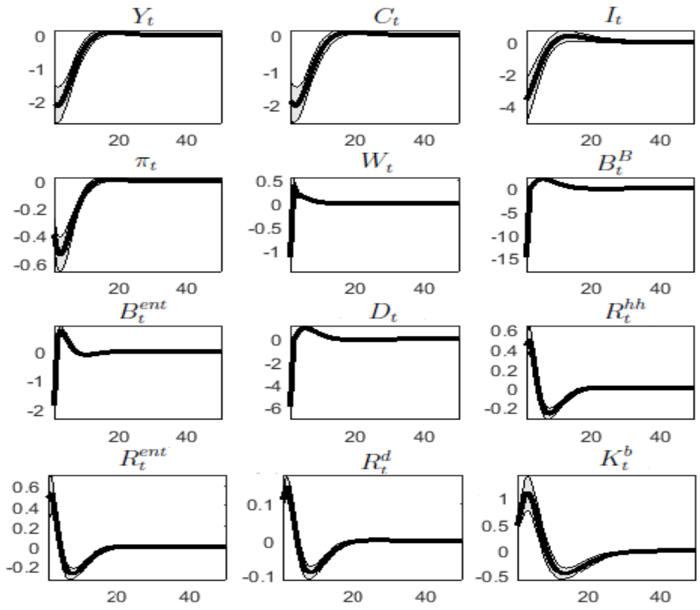


Monetary policy shock is implemented in order to study its effect on the banking sector variables (see Figure 7). As expected the 1 p.p. rise in the key policy rate increases the bank interest rates, both for loans and deposits. As loans rate increases it slows down the consumption and investment due to the decrease in borrowing of households and entrepreneurs. The slowdown in demand is reflected in a decrease in the aggregate output (ca. 2 p.p. from the steady state). Inflation slows down for 0.5 p.p. from the steady state, while wage inflation decreases for 1 p.p. Higher deposit rates, however, cannot attract more deposits to banks as it cannot offset the fall in aggregate demand and wages. The increase in lending rates is higher than the deposit rate increase thus increasing the interest rate margin and providing a bit of compensation for the loss of loans and deposits volume for banks. Additionally, the loss of loans volume increases capital. In short, the real side of the economy reacts substantially to a monetary policy shock[14], while the size of interest rate effects is rather modest and provides a case for the credit channel, not just the interest rate channel[15].

[14]The magnitude of the real economy reaction to a monetary policy rate setting shock is not surprising. In Bokan et al. (2018) paper, the euro area economy reacts to 1 p.p. monetary policy rate increase with a 1.6 p.p. decrease in output.

[15]Bernanke and Gertler (1995) identified three puzzle related to monetary policy shock which point to the existence of other channels than interest rate channel.

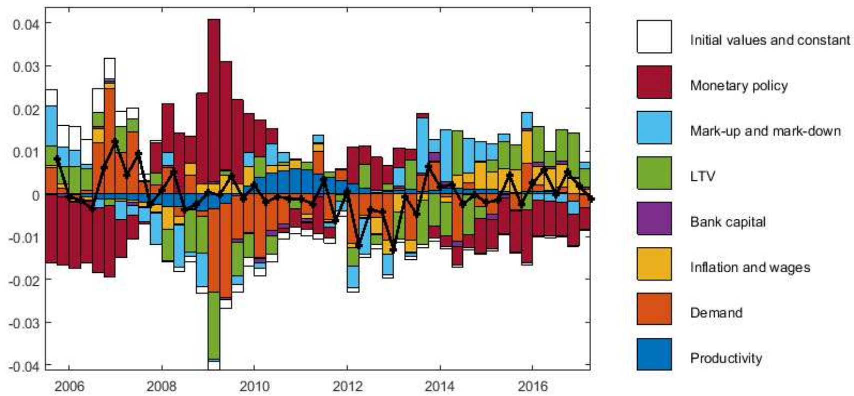
Figure 7: Monetary policy shock (deviations from steady state in percentage points)



6.2 Historical shock decomposition

A more comprehensive story of quantifying financial shocks could be shown with the historical shock decomposition charts. The observation period of the main variables spans from 2005Q3 to 2017Q1. In all of the following figures the acceleration phase of the boom period culminates in large fluctuations of shocks that affect the variable realization. As the Slovene economy started to recover from 2013 on, the negative shocks from the burst period more or less inverted into positive ones. The following Figures 8-12 represent the contribution of shocks on consumption, investment, house price, inflation and wages. In the boom period till 2008 it is evident that demand, productivity and financial shocks had driven consumption and investment growth as well as inflation, house prices and wages. On the other hand the monetary policy acted restrictively. As the financial crisis began in 2008 negative demand and technology shocks as well as financial tightening in loans (negative LTV and loan rate mark-up shocks) contributed in declining investments and low consumption growth in Slovenia. The ECB reacted to the bursting of the bubble by immediately lowering the monetary policy rate (positive contribution of the monetary policy shock), which prevented the consumption and investment to plummet. However, the ECB's decision of lifting key monetary rate early in 2011 due to inflation pressures at that time resulted in a contrary effect to consumption and investment in Slovenia. In the recovery period starting from 2013 on the credit standards eased, wage growth picked up and technology shocks positively contributed to the rising consumption and investments. What is rather surprising is that the monetary policy shocks turned to be negative in the recovery period, suggesting that the ECB's monetary policy may not have been accommodative enough[16]. The negative contribution of the monetary policy shocks on consumption, investment and the inflation possibly reflects the limited room for manoeuvring the monetary policy rates during the recovery period. The existence of an effective lower bound implies that the decline of inflation expectations that accompanied the decrease of inflation caused an unwarranted tightening of monetary conditions in the euro area[17], despite the ECB's implementation of a variety of non-standard measures. One could argue that asset purchase programmes of the ECB did not have as strong direct effect on the Slovene economy as on the other, bigger economies with more developed securities markets, such as Germany, France or Italy. But on the other hand, the recovery of these bigger economies helped Slovene economy to recover *via* increasing foreign demand, while local autonomous factors non-related to the common monetary policy could have played their role as well.

Figure 8: Consumption (deviations from steady state)



[16]A similar pattern is observed by Conti et al. (2017) in the case of the euro area and Jovičić and Kunovac (2017) in the case of Croatia.

[17]Some of the unwarranted tightening of the monetary policy stance was observed by the ECB (2015) too, as this risk rose from the high level and volatility of money market rates which was mitigated by the ECB's policy rate cut, the narrowing of the width of the ECB monetary policy corridor, in trying to restore a symmetric corridor system around the MRO rate, and the announcement of additional measures in 2014.

Figure 9: Investment (deviations from steady state)

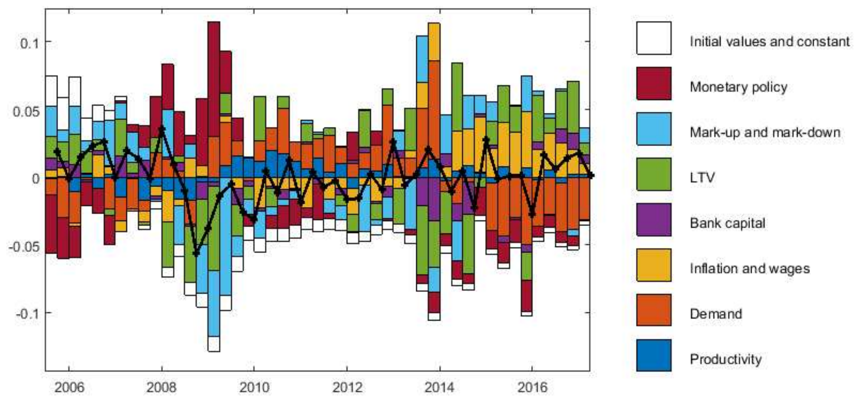


Figure 10: House prices (deviations from steady state)

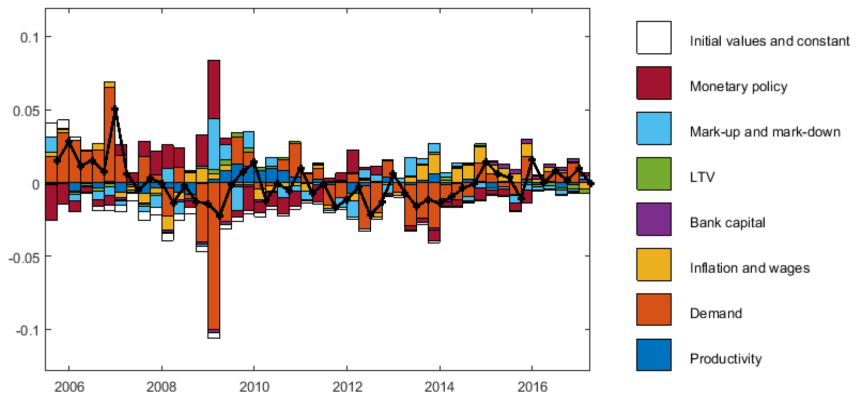


Figure 11: Overall inflation (deviations from steady state)

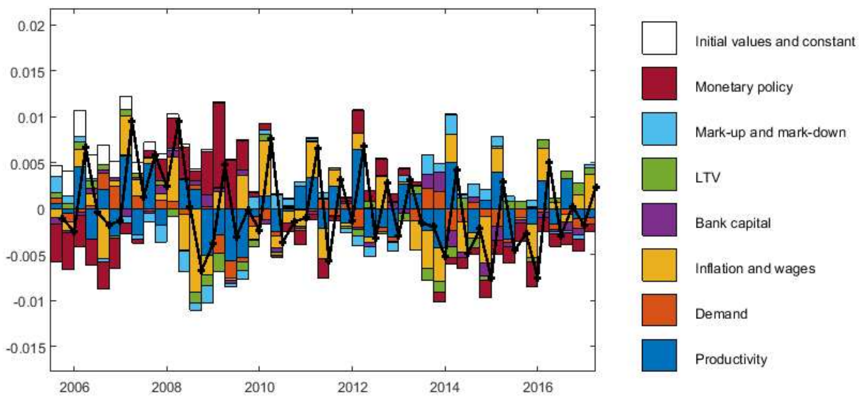
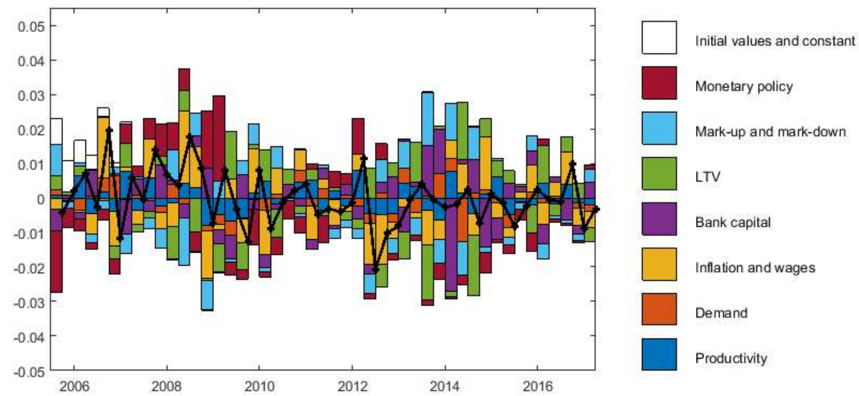


Figure 12: Wages (deviations from steady state)



From the banking sector perspective (Figures 13-15), it is evident that financial factors play a significant role in driving the bank rates alongside the macro condition of the Slovene economy. In the overheating period alongside the restrictive monetary policy shocks, high demand and productivity drove up the deposit and loan interest rates. As the financial crisis began, as expected, the decrease in the monetary policy rate significantly decreased the banking rates. Negative productivity and negative mark-down and mark-up shocks in the loans and deposit rates additionally decreased the banking rates as the financial crisis lingered on. During the recovering period the low inflation and contributed that banking interest rates decreased even further. As was discussed above, the limited room for manoeuvre of monetary policy rates and the consequent unwarranted tightening of monetary conditions in the euro area due to effective lower bound prevented the banking rates to additionally decline. Based on these findings shocks that could simulate the implementation of the macroprudential measures (higher capital requirements, and the LTV ratio caps) can therefore have significant effects on the loans rate dynamics.

Figure 13: Deposit rate (deviations from steady state)

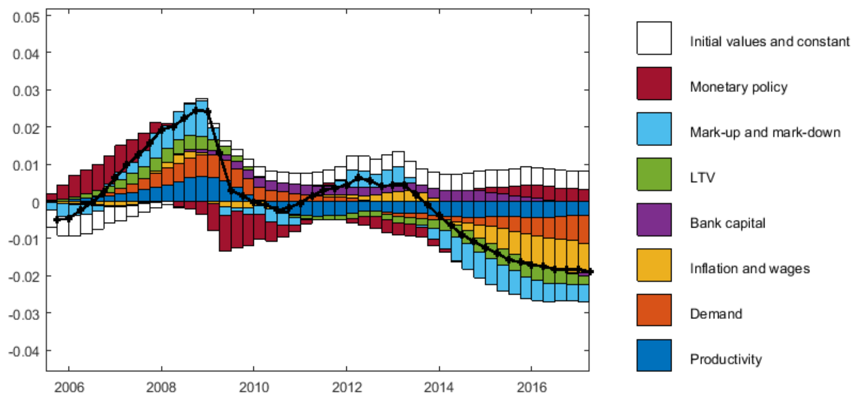


Figure 14: Households' loans rate (deviations from steady state)

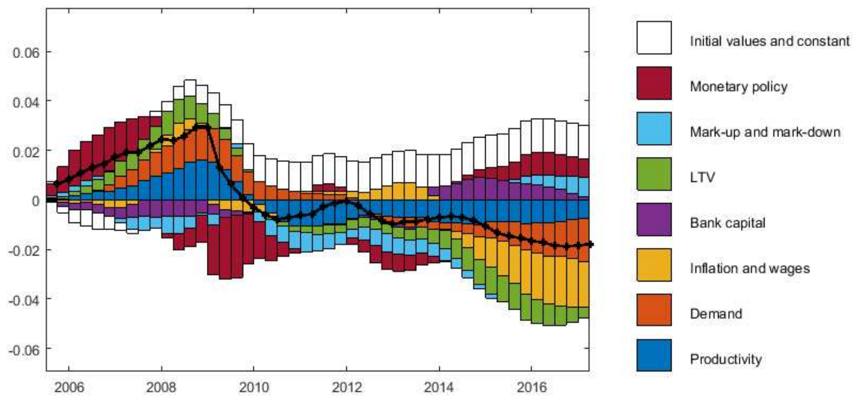
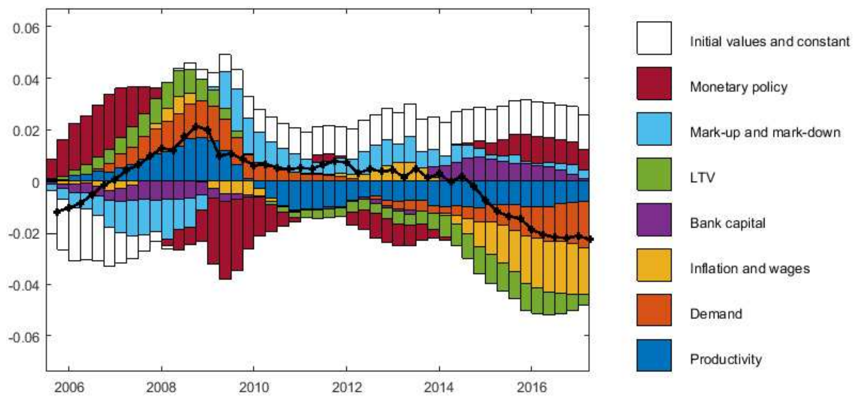


Figure 15: Entrepreneurs' loans rate (deviations from steady state)



Despite the fact that the monetary policy has significant effect on the economy, the ECB's monetary policy is exogenous for the Slovene economy. Said that it cannot prevent distortions of the credit cycle by itself. By having macroprudential policy available at the national level, the policy makers can act counter-cyclically.

We find that:

1. LTV measures can be an effective instrument that can affect any sectoral issues regarding excessive credit growth. That is, these measures can be used to target directly firm or household borrowing, depending on which LTV ratio is changed by the macroprudential authority.

2. Capital increases (such as capital buffers or O-SII measures) have a more general effect, as they affect all sectors. Therefore, if the macroprudential authority believes that the issue is a more general expansion in economic activity that is driven by excessive credit expansion, lender-based measures such as counter-cyclical capital buffer could be used. If the macroprudential authority believes that the issue of excessive credit growth is sector-specific, then borrower-based measures seem to be more effective.

7 Conclusions

The belief that the active monetary policy in pursuing price stability is sufficient enough to maintain financial stability as well as the macroeconomic stability was put to a great challenge during the last financial crisis. Rapid rise of credit and asset prices led to inefficient compositions of output, which was accompanied by excessive real estate investments, excessive consumption and the widening of external imbalances of economies all around the globe. As the systemic risk materialized, the externalities arising from financial market imperfections intensified, reflecting volatile macroeconomic outlooks. Together with the financial crisis lead to a large drop in outputs and large-scale financial distresses in majority of countries. It consequently prompted policy makers to reflect on the existing policy frameworks and to think out of new policy instruments to help ensure the financial stability. Introducing a new economic policy, the macroprudential policy gave space to a complete new sphere of affecting an economy through a policy maker's perspective. Constructing a dynamic stochastic general equilibrium model, which incorporates a banking sector block, enables us to study some of the effects of different macroprudential policy measures.

This paper adds to the gap of estimating macroprudential-monetary policy models, taking the case of Slovenia. The model is estimated on data for Slovenia over the period 2005Q3-2017Q1 based on Bayesian inference methodology. The simulation results show that taking macroprudential policy measures would matter in the economy. Raising additional capital for banks can be costly especially if they find themselves below the binding steady state capital-to-assets ratio. By re-balancing assets and liabilities (volume and price-wise) banks can significantly affect the real economy. Entrepreneurs down-size their investments while households cut down their consumption. Loosening the credit standards (loose LTV ratios) on the other hand can have stimulating effects on the economy, but could undermine banks' risk resistance. Following a monetary policy shock, the real side of the economy reacts substantially, while the size of interest rate effects is rather modest. Future work should investigate more into division of two economies operating in a monetary union and adding alternative banking sector shocks and possibly provide the spillover effects between countries.

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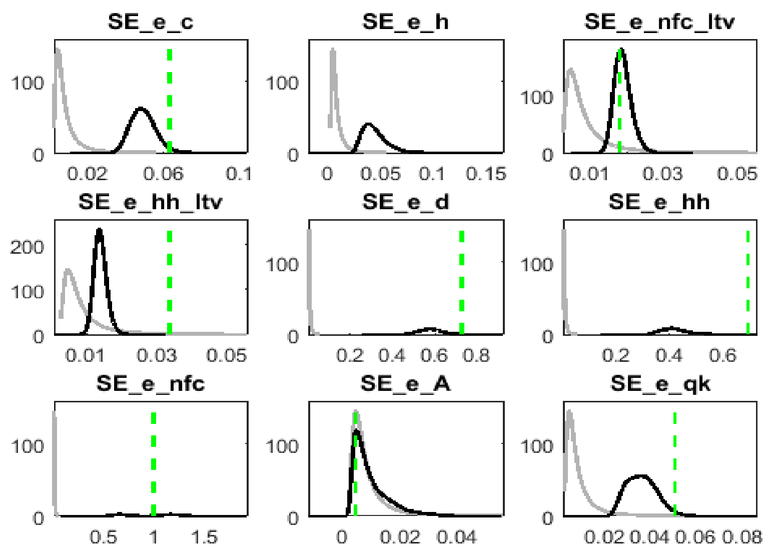
A Calibrated parameters

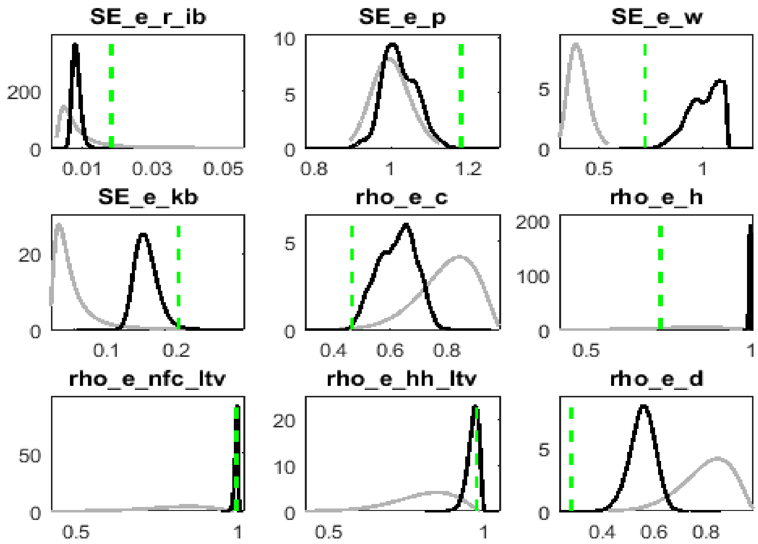
Table 2: Calibrated parameters

Parameter		value
β_S	Saving households' discount factor	0.9943
β_B	Borrowing households' discount factor	0.9750
β_{ent}	Entrepreneurs' discount factor	0.9750
φ	Inverse of the Frisch elasticity	1.0
α	Capital share in the production function	0.25
δ	Depreciation rate of physical capital	0.025
μ	Share of unconstrained households	0.8
$\overline{cap}_b$	Capital adequacy ratio	0.08
$\varepsilon_{hh,ltv}$	Households' LTV ratio	0.74
$\varepsilon_{ent,ltv}$	Entrepreneurs' LTV ratio	0.56
ε_h	Steady state weight of housing in the hh's utility f.	0.2
ε_w	Steady state elasticity parameter in the labour market	5.0
ε_p	Steady state elasticity parameter in the goods market	6.0
ε_d	Steady state mark-down on deposit rate	-1.3
ε_{hh}	Steady state mark-up on loans to households	3.0
ε_{ent}	Steady state mark-up on loans to entrepreneurs	3.0
ϕ_π	Inflation stabilization weight in the Taylor rule	2.0
ϕ_y	Output stabilization weight in the Taylor rule	0.1

B Priors and posteriors

Figure 16: Priors and posteriors of the estimated parameters

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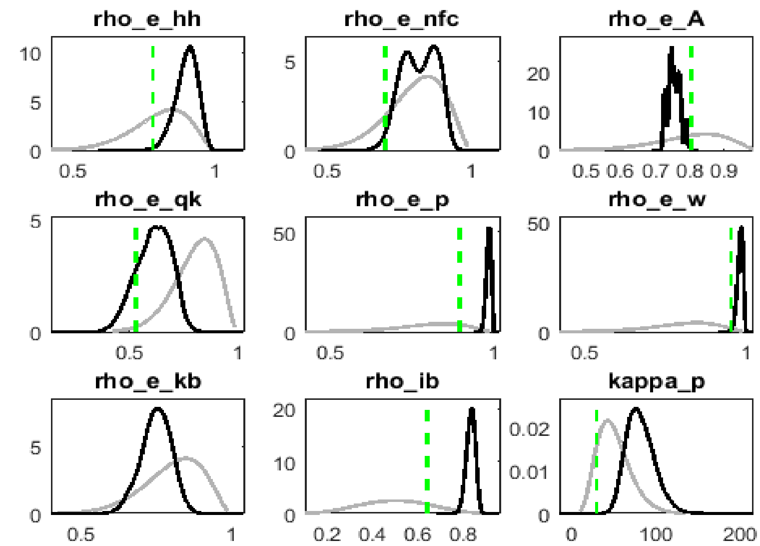
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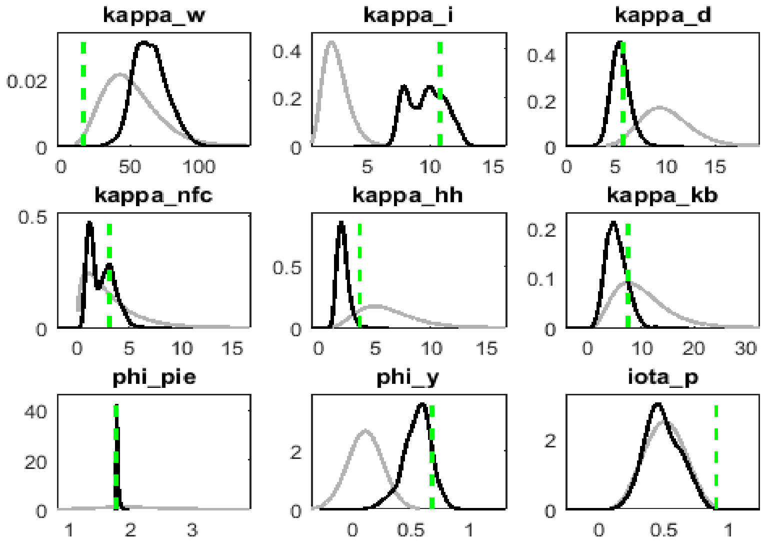
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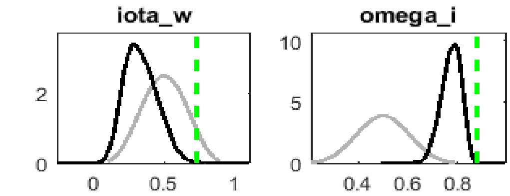
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