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The impact of macroprudential policy on the economy of Lithuania

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This thesis represents my personal views and opinions.

Jaunius Karmelavičius
Vilnius
14th March 2022

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Introduction

In the 2000's loose monetary policy, financial deregulation and advances in finance greatly contributed to increasing financial leverage across the globe, thus fuelling asset prices in an unsustainable manner. This led to the biggest global financial crisis since the Great Depression, characterised by asset price fall, credit defaults and bank failures both in the US and Europe. The documented *new business cycle facts* by Jordà et al. (2017) reveal that the world economy became more and more dependent on the financial system with increasing concordance of business and financial cycles. Studies show (Claessens et al., 2009; Crowe et al., 2013; Jordà et al., 2013, 2017) that economic booms accompanied by rapid credit growth are usually associated with deeper and longer lasting recessions. Financial crises that are characterised by a credit crunch can be particularly excruciating.

Similar patterns of a boom-and-bust highlighted the 2000's in Lithuania. Credit to the private sector grew at an average pace of 51% per year from 2003 to 2007. Most of that growth was financed by a persistent current account deficit and hot money inflows from Scandinavia through domestic subsidiaries of foreign banks, inflating the economy's domestic and external debt. This process contributed to the tripling of house prices, and expansion of the construction and real estate sectors, with spillovers to other parts of the economy. Nominal GDP grew at 8% on average from 2000 to 2007. The boom coincided with deepening of the financial sector, therefore policy-makers and analysts attributed this strong growth to the catching-up of Western economic powers (see an *ex post* discussion Kuodis and Ramanauskas, 2009), although there had been sounds of warning (e.g. Ramanauskas, 2005).

However, these trends were reversed in 2008 when credit stalled and house prices dropped by around 25% from their peak. While Lithuania did not have any bank runs or a solvency crisis, the banking sector experienced combined losses amounting to 1.14 billion Euro over 2009 and 2010. The materialisation of credit risk and negative expectations about the future lead to a sharp reversal of foreign financing and withheld domestic lending. An increase in unemployment from 4% to over 16%, as well as the rise in the interbank offer rate (VILIBOR) that had been used as a basis for variable interest rates, contributed to the worsening of household and corporate finance, thus aggravating the slump. For more about the boom and bust, please see Kuodis and Ramanauskas (2009) and Ramanauskas (2011).

The running up to the crisis and its nature show that banks are central to how any economy operates, therefore banking institutions received special treatment from policy-makers and economists during the crisis and its aftermath. Banks are indeed special institutions that have the ability to issue private money in addition to central bank-issued reserves (monetary base). They are enabled so by a couple of reasons. First, banks are able to accept deposits which are considered to be universal means of payment, unit of account and store of value, i.e. they satisfy money properties and therefore can function as money. Government-backed deposit insurance is important in keeping that principle and ensuring trustworthiness of a bank and its deposits. Second, due to the principle of double-entry bookkeeping, a bank simultaneously creates a loan entry on the asset side of the balance sheet, and credits the borrower's bank account with an equal amount, thus creating a deposit which is brand new money – a liability of the bank. Conversely to the widespread "knowledge", there is no need to have pre-accumulated resources to create money out of thin air. And it is exactly this reason why banks exert tremendous power and influence not only on financial flows across agents but on the real economy, as can be seen from the 2000's in Lithuania and elsewhere.

Preceding the financial crisis, the global viewpoint of banking supervision, including that in Lithuania, was more micro-oriented. The post-crisis period saw an emergence of tools that address the systemic approach and are designed to decrease the formation of systemic risk, and increase the resilience of markets, institutions and the general economy. Although some of the elements had already existed in the twentieth century, it is now known as *macroprudential policy*. Nearly all macroprudential policy instruments are directed towards banks because of their involvement in the build-up to the crisis as well as possible amplification of the downfall. The policy tools can be divided into three parts (for more see Hoon Lim et al., 2011). The first is liquidity measures among which are requirements for net stable funding ratio and liquidity coverage ratio or reserves. The second group is asset-based measures, for instance, loan-to-value (LTV) ratio caps, debt to income caps, interest rate sensitivity test, etc. The third group is capital-based measures that concern how much capital needs to be held or govern rules on loan loss provisions. In a broad sense, macroprudential policy tools that are addressed towards banking institutions, can be thought as limiting or influencing the creation of money.

The European Union and Lithuania adopted and adapted the enhanced Basel III framework. Historically, in 2011 the Bank of Lithuania enacted the Responsible Lending Regulations (*Atsakingojo skolinimo nuostatai*) which regulated mortgage and consumer credit lending. The loan size to collateral value (LTV) was capped at 85%, implying a minimal downpayment of 15%. Also, the debt service to income (DSTI) ratio was limited to 40%, as was the maximum loan maturity to 40 years. In September 2014 the Parliament of the Republic of Lithuania granted the Macroprudential policy mandate to the Bank of Lithuania, in effect allowing the authority to issue legal acts for the development of macroprudential framework.

2015 marked an imposition of two capital buffers, namely the countercyclical capital buffer (CCyB) and conservation buffer, over the existing microprudential capital requirements. What is more, in November of 2015 there were three amendments to the existing Responsible Lending Regulation. The maximum mortgage loan maturity was shortened to 30 years. Also, due to then existent low interest rate environment, a DSTI stress test was introduced, in addition to the prevailing 40% DSTI limit. The borrower's DSTI shall not exceed 50% after a 5 p.p. interest rate sensitivity check. Lastly, for sound borrowers the DSTI limit can be extended but for no more than 5% of new mortgage loans. The development of the macroprudential framework, marks a new era of stricter and presumably safer financial environment not only in Lithuania but in Europe as well.

Research problem

While macroprudential policy seems to be a promising toolset which could allow policy-makers to steer the financial part of the economy towards more stability, it is still under development. Therefore it is unclear how the tools or the changes in policy stance affect the financial system and especially the real economy. There are studies available which focus on the time series aspect (e.g. Noss and Toffano, 2016; Kanngiesser et al., 2017; Richter et al., 2018), or on micro-data (e.g. González et al., 2016; Glancy and Kurtzman, 2018; Mihai et al., 2018). However, the framework has been introduced recently and is still under development, e.g. in Europe, therefore relatively not much time has passed for an accurate assessment using historical data.

Although macroprudential policy in Lithuania is in place since 2011, very few academic studies (e.g. Rubio and Comunale, 2016; Reichenbachas, 2020) exist that would shed light on the topic or provide estimates of the policy's impact in the country. Moreover, the introduction of different macroprudential tools happened simultaneously, thus it is hard for researchers to disentangle different instrument effects as well as their interactions. As an alternative to historical data analysis using econometric techniques, it is possible to analyse these issues using a general equilibrium framework. Dynamic stochastic general equilibrium (DSGE, hereafter) models have been widely used to assess macroprudential policy and its interactions with the macroeconomy. Among the virtues of the modelling setting are that it allows to make evaluations for each instrument separately and to explore different kinds of settings that are still non-existent, similarly to a sandbox.

The failure to predict the crisis as well as the nature of the recession called for an extension of DSGE models to include financial frictions and housing. Building on the models of Kiyotaki and Moore (1997) and Iacoviello (2005) as well as Bernanke et al. (1999) (henceforth BGG) the literature on financial frictions flourished. Among a large body of writings a few notable examples could be Iacoviello and Neri (2010) and Iacoviello (2015), Gerali et al. (2010), Gertler and Kiyotaki (2015). The focus usually is on frictions that exist both on the borrower's and on the lender's side. The instrumentation allows for the assessment of the impact and design of macroprudential policy tools (see, e.g. Angelini et al., 2014; Quint and Rabanal, 2014; Chen and Columba, 2016; Lozej et al., 2017).

As was previously discussed, private money issuance is at the core of banking. While money creation is an undeniable accounting fact (see McLeay et al., 2014; Werner, 2014), it is still unclear, whether mainstream macroeconomic models, like DSGE, have the "financing through money creation" features. For example, Borio (2011) claims that real macroeconomic models cannot capture the relationships of the financial system and the macroeconomy. The author is concerned that most of the macroeconomic models that look "monetary" are actually disguised "real" ones. Jakab and Kumhof (2015) claim that, besides only a handful of models, the post-crisis literature "is almost without exception based on a version of the intermediation of loanable funds model of banking". The conventional view, as will be seen in depth in Chapter 1, states that banks are mere financial intermediaries that collect savings and distribute them in the form of loans, abstracting from money creation possibilities. Goodhart et al. (2013) even claim that "there is no theoretical analysis of banking worthy of the name". The relevant discussion implies that in order to have properly functioning banks within a model setting, one has to allow for money creation. Therefore, we deem it important to make assessments of macroprudential policy tools whatsoever in a framework that is consistent with bank money creation.

While the literature that focuses on the impact of macroprudential policy deals mostly with output costs and stability gains, authors usually do not look at the effect on long-term growth and economic convergence. For example, indebtedness as in Pintus (2007, 2011) is known to have an impact on the shape of the economic growth in the long-term. Limitations on economy's indebtedness, like macroprudential policy, can influence the chances of falling into that volatile trajectory. Lithuania has macroprudential policy requirements in place for a little more than decade, but it is not clear what is the impact on the long-run growth and volatility. Therefore, it is of interest to further study the limits on indebtedness and their impact on the long term.

Objective and tasks

The objective of this dissertation is to assess the impact of macroprudential policy on the economy of Lithuania. By achieving this objective, we seek to contribute to the local literature on macroprudential policy, and provide estimates on the policy's impact that could be of practical relevance for analysts and policy-making institutions. As we develop models for small-open economies that contain macroprudential tools, we also seek to make a contribution to the international theoretical literature on macro-financial modelling.

To achieve this dissertation's objective, and in doing so make a contribution to the literature, the doctoral study is done by completing these research tasks:

1. Discuss the international literature about bank money creation

and the importance in having a macroeconomic model with this feature.

2. Build a stylised model for Lithuania which would have money creation characteristics, and calibrate it to match first moments of Lithuanian data.

3. Provide the necessary conditions that allow a macroeconomic model to be compatible with the financing through money creation view.

4. Extend the stylised model to include housing, mortgages and credit risk, and recalibrate the system for Lithuania.

5. Using the enhanced modelling framework, quantify the impact of macroprudential policy tightening on the macroeconomy of Lithuania in various settings.

6. Develop a neoclassical model of economic growth with debt and macroprudential policy, as well as endogenous interest rates, for a small-open economy.

7. Assess the impact of macroprudential policy that limits indebtedness on the speed and shape of economic long-run convergence.

Research methods

Overall, the research carried out in this dissertation work relies heavily on mathematical modelling of macroeconomic systems, with particular emphasis on general equilibrium models. Chapters 1 and 2 are devoted to the theoretical analysis of the short run using DSGE models. That is, we study discrete time infinite-horizon dynamic systems using the representative agent paradigm. We formulate assumptions about the behaviour of each agent (sector) and solve their constrained inter-temporal optimisation problems separately, using dynamic programming and the Lagrangian method. The solutions to separate problems for each agent are then connected for market clearing in a general equilibrium for model solution. To analyse the relevant economic questions, we exogenously shock different variables of the system in order to find the system responses, by the means of impulse-response functions (IRF). The methodical literature on DSGE models is enormous, with Romer (2012) and Dejong and Dave (2007) serving as introductory references for our purposes. In this dissertation we rely on the more specialised literature on DSGE models with financial frictions, with Iacoviello (2005, 2015), Gerali et al. (2010), de Walque et al. (2010), Jakab and Kumhof (2015, 2019) being the main references for model developments.

Chapter 3 also utilises general equilibrium modelling, but this is done in a continuous time setting, using differential equations, instead of difference equations. We formulate infinite-horizon decentralised Ramsey problem for the consumer and solve it using Pontryagin's maximum principle. Consumer's behavioural equations are brought together with results from firm's optimisation to have an equilibrium solution. In this setting we have a system of differential equations, which we analyse using the Jacobian matrix and its determinant to infer about the rate of convergence and the trajectory of the economy. The general modelling methods that we use are well described in Barro and Sala-i Martin (2004) and Acemoglu (2009), with specific setting for our purposes detailed in Barro et al. (1995) and Pintus (2011). For empirical testing of the theoretical model, we use growth regressions, i.e. econometric models for panel data on economic growth, as described in Mankiw et al. (1992) and Barro and Sala-i Martin (2004).

Scientific novelty

The line of research that is presented in this dissertation is novel in at least a couple of facets. We contribute to the local literature on macroprudential policy's impact on the economy of Lithuania, with known papers only by Rubio and Comunale (2016) and Reichenbachas (2020). While these two articles focus only on the aspects of LTV ratio for mortgage loans – a single policy tool, we study the effect of three macroprudential measures, namely, capital requirements and risk weights in addition to the LTV limit. The provided estimates of the tightening of these three macroprudential tools, should be of practical relevance for economic analysts and policy-makers. Furthermore, the DSGE models that are developed in this dissertation work are one of the few that were created specifically for Lithuania (e.g. Karpavičius, 2008; Proškutė, 2012; Pušinskaitė, 2014; Rubio and Comunale, 2016). Our designed model for Lithuania stands out from other cited articles in that it contains money-creating banks with housing, mortgage credit risk and macroprudential policy in an open economy setting.

With regards to methodical novelty in the international literature, we highlight the importance of bank money creation, and thus this line of research is one of the few attempts to discuss and incorporate bank money creation in a DSGE setting. We formulate and outline the necessary conditions for a macroeconomic model to have money creation properties and thus rectify the critique of Jakab and Kumhof (2015, 2019) on mainstream models. We build and calibrate a DSGE model with financial frictions that has mortgage credit risk component, which is modelled as in de Walque et al. (2010) – to better capture the multidimensionality of household default – alternatively to the more prevalent Bernanke et al. (1999) framework. The model presented in this dissertation is one of the very few attempts to model both multi-period loans, via the dynamic LTV constraint, and credit risk simultaneously. Importantly, unlike other papers, we assume that the bank also takes into account the LTV constraint, thus this instrument becomes not only a demand-side constraint, but also has a direct impact on the supply side of credit.

This dissertation also brings a new angle into the literature on macroprudential policy by studying its impact on the long-term properties of economic growth such as convergence. We generalise and extend the neoclassical model of a small-open economy growth (Barro et al., 1995; Pintus, 2007, 2011) by introducing both the macroprudential limit on indebtedness, as well as endogenising interest rates. Previous authors studied long-term growth dynamics in a setting where interest rates are exogenously set to a constant and relatively low world rate, whereas we introduce a microfounded way to set the interest rate internally, using the concept of bargaining power. As the pricing of interest rates and bargaining power are closely related to market concentration and competition, our findings on macroprudential policy also complement the literature on competition and financial stability.

Statements presented for defence

1. We build and calibrate a small-open economy DSGE model for Lithuania and show that it has bank money creation features. On the basis of this model, we identify the prerequisites that are necessary for any macroeconomic model to have money creation: i) flexible, or near-flexible, prices that are quoted in money or deposit terms; ii) general equilibrium framework that ensures stock-flow consistency; iii) some level of heterogeneity between or within agents to have money and loans; iv) banks with double-entry bookkeeping balance sheets. In effect, most main mainstream DSGE models that maintain these prerequisites, and are designed either for Lithuania or other countries, may be compatible with the money-creationist view of banking.

2. The extended DSGE model shows that macroprudential tools which are in place in Lithuania may have a negative but small effect on the country's economic activity. The impact of a 1 p.p. permanent rise in the mortgage LTV limit would be associated with a -0.1% drop in GDP. An increase in bank capital requirements by 1 p.p. would cause a fall in GDP by -0.04%. A macroprudential policy authority-induced raise in mortgage risk weights by 5% (2.5 p.p.) would affect economic activity by less than 0.002% – a minuscule impact.

3. After a comparison of different macroprudential tools on taming growth in the Lithuanian mortgage market, we find that the tightening of broad-based capital requirements is less effective and

does more harm to the corporate sector and the economy as a whole. Measures that are more targeted to housing credit, such as a cap on LTV and risk weights, could be used more efficiently when the objective is only to target risks in the housing market. Therefore, instruments such as the counter-cyclical capital buffer are suboptimal measures in times when cyclical risks are building up in Lithuania only in the mortgage sector.

4. The developed neoclassical model of small-open economy growth with indebtedness and endogenous interest rates shows that macroprudential limits may reduce Lithuania's long-term speeds of convergence. Nonetheless, macroprudential policy can also stabilise the economy's long-term growth. Otherwise, if there were no tools in place, the economy could experience a volatile path of convergence, characterised by boom-and-bust cycles, similar to the ones experienced by Lithuania in the 2000's. Promotion of competition in the financial industry of Lithuania could increase the economy's bargaining power for lower interest rates, thus lower debt service costs, and therefore decrease the chance of having boom-and-bust periods. However, one has to bear in mind that the model highlights only the interest rate channel of competition, without taking into account the possible negative effects on financial stability through the risk-taking channel.

Structure of dissertation

The doctoral dissertation is structured so as to complete the research tasks and thus achieve the main research goals. The next two chapters are devoted to analysis of short-term by the means of DSGE modelling. Namely, Chapter 1 builds a DSGE model that has money creation, and Chapter 2 extends the model to assess the impact of macroprudential policy. Chapter 3 builds a model of long-term growth, which is devoted to study how macroprudential policy and interest rates affect economic convergence and volatility.

Chapter 1

Modelling bank money creation

After the Global financial crisis, we are in a period with greater analytical and regulatory emphasis put on the banking sector, and an emergence of augmented DSGE models that would contain banking and financial frictions, with examples of Gerali et al. (2010), Quint and Rabanal (2014), Iacoviello (2015), Clerc et al. (2015). The ability to create credit and money out of thin air is the most fundamental property of any banking system or a single bank, thus it should be properly accounted for in any macroeconomic model that concerns banking. It is especially important for models that emphasise the bank lending channel, such as those suited to analyse macroprudential policy, as is the topic of this dissertation.

However, Jakab and Kumhof (2015, 2019) argue that almost all mainstream DSGE models, that are either used in the academia or in central banking, treat banks not as creators of money, but as mere financial intermediaries which rather transfer real goods, instead of money. The distinction between the creation of money and intermediation of loanable funds is important, as it may have profound implications for the movement of financial flows as well as real economy aggregates, as suggested by the authors. This view is also confirmed by Werner (2014) who has an even stronger claim that "the vast majority of articles published in leading economics and finance journals in the last thirty to forty years is based on the financial intermediation theory as premise".

Given this void in macroeconomic modelling of banking, Jakab and Kumhof (2015, p. 15) develop a set of seven essential ingredients that should be included in DSGE models to reflect the financing through money creation view of banking. The authors show that their own model, containing these ingredients, is compatible with the money-creationist view of banking. In addition, Jakab and Kumhof (2015, 2019) and Kumhof and Wang (2020) note that only their and a handful of other DSGE models, e.g. Goodfriend and McCallum (2007), Beneš and Kumhof (2012), Beneš et al. (2014a,b), Lozej et al. (2017), Clancy and Merola (2017), have money-creationist features.

Seeking to analyse the macroeconomic impact of macroprudential policy, and to address the concerns, raised by Jakab and Kumhof (2015) and others, this chapter aims to build a model that would contain banking and be compatible with money creation.[1] To this end, we develop and calibrate, using Lithuanian data, a New-Keynesian DSGE model with banks, and show that it has money creation properties. In our view, we rectify the ingredients put forth by Jakab and Kumhof (2015), and argue that a macroeconomic model features money creation if it has the following: i) flexible, or near-flexible, prices that are quoted in money or deposit terms; ii) general equilibrium framework that ensures stock-flow consistency; iii) some level of heterogeneity between or within agents to have money and loans; iv) banks with double-entry bookkeeping balance sheets. The small-scale model of this chapter will be used later as a basis for further extensions and macroprudential policy assessments in Chapter 2.

The chapter is structured as follows. First, we present bank money

[1] This chapter builds on research findings that were also published in Ramanauskas and Karmelavičius (2018) and Karmelavičius and Ramanauskas (2019).

creation as a fact of accounting and discuss its limits, among which is macroprudential policy requirements. Second, we build a small-open economy DSGE model that features banks which lend funds and issue deposits. Third, we carry out a shock analysis and investigate the responses of the model in different credit financing settings. Lastly, we provide some concluding remarks, based on our findings.

1.1 A basic fact of accounting

In essence, there are two views on banking. One is that banks are financial intermediaries that collect savings in the form of deposits and lend them out as loans. This view is called the intermediation of loanable funds (ILF) theory and describes a bank as a mere financial intermediary which transfers someone's savings and thereby finances someone else's activities. Note that during this act of lending, the bank transfers existing purchasing power, instead of creating new one.

Another view claims that banks do not need any pre-accumulated saving in order to create a lending operation. It can rather finance a loan through the creation of money, and with it, a creation of new purchasing power. This approach to lending is called financing through money creation (FMC) and views banks as institutions that have the ability to create money out of thin air.[2] However, the FMC view is not only a theory, but an accounting fact, as witnessed by Werner (2014) and described by Bank of England economists McLeay et al. (2014) and

[2]This distinction of views to ILF and FMC follows Jakab and Kumhof (2015, 2019). Werner (2014) offers three distinctions which are labelled as *financial intermediation theory*, *fractional reserve theory of banking*, *credit creation theory of banking*. The first corresponds to the ILF, while the last coincides with the FMC approach. The fractional reserve theory of banking entails the idea that banks individually cannot create money during the act of lending, however, collectively as a banking system they can. This view is a middle ground between the other two approaches coined by Werner (2014), and is taught in most economics textbooks, including *Macroeconomics* textbook of Mankiw (2007, p. 510-515).

Jakab and Kumhof (2015, 2019).

To fix ideas, see Figure 1.1 that depicts a stylised bank's balance sheet before and after lending occurs. At the beginning Stage 0, the bank has some assets, consisting of loans and central bank reserves, that are "financed" by capital (or equity, own funds) and deposits. Consider that the bank agrees to extend a loan to a client during Stage 1. What happens is that the bank simultaneously creates a loan entry on the asset side of the balance sheet, and credits the borrower's bank account with an equal amount, thus creating a deposit which is brand new money – a liability of the bank (see also Werner, 2014; McLeay et al., 2014). Notice that during the act of lending, the amount of bank reserves or capital does not change, no pre-accumulated savings were required. In principle, this process of lending and money creation can go *ad infinitum*.

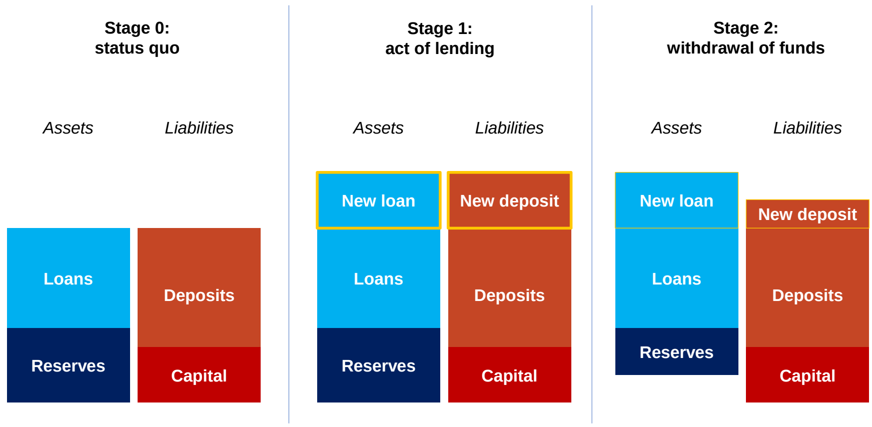


Figure 1.1: Bank's stylised balance sheet before and during the act of lending, and after some money has been withdrawn or transferred by the client.

The principal difference that allows money creation for banks, and distinguishes them from other financial institutions, is that banks can issue or accept deposits. Essentially, bank deposits are IOU leaflets that are universally accepted as money and satisfy money properties, i.e. they serve as a unit of account, medium of exchange and store of value. Their universal acceptance as money is not only state-legislated but also backed by deposit insurance.[3] Non-bank financial intermediaries act merely as a "pipe" for the flow of money, transferring funds from one party to another, as they are not able to issue deposits that would be commonly understood as the *money*. For instance, electronic money institutions are able to create their own electronic money, however, they are not publicly regarded as money. In fact, non-banks can lend money, however, they need to borrow first to obtain bank-created deposits which can be lent out, as argued by Jakab and Kumhof (2019).

By the act of lending banks or banking systems as a whole create their own form of financing, as the FMC view suggests, therefore the privatisation of money issuance puts enormous powers to private commercial banks. As per the quantity theory of money, the volume of money may determine the price level, giving banks huge control over the determination of inflation. Furthermore, using the New-Keynesian argument, banks, by affecting the money supply, also have the ability to impact real macroeconomic variables and influence business cycles, as well as financial cycles, what we witnessed in the 2000's in Lithuania and across the rest of the globe.[4]

Limits to money creation

One should not think that this process of money creation by the act of lending is limitless. Market forces such as interest rates and credit demand, as well as credit risk, are natural limits that influence bank's

[3]It is known that deposit insurance creates moral hazard problem, however, it is crucial for the public trust in commercial bank issued money, thus is a pillar of the modern monetary system. Moral hazard can be mitigated by the requirement for banker's to have some *skin in the game*, or own funds, by capital requirements.

[4]Regarding the boom-and-bust cycle in Lithuania, see Introduction and an extensive discussion by Ramanauskas (2011) and Ramanauskas et al. (2016a,b, 2018).

profitability and hence the creation of money (see also McLeay et al., 2014). Note that, as visualised in Figure 1.1 Stage 1, the amount of reserves or capital are unaltered, however, they can indirectly balance money creation. For instance, if a bank unwisely extends too many loans to unworthy debtors at cheap interest rates, it will experience losses that will eat into the bank's pre-accumulated capital (or equity) on the liability side.

For another example, suppose the client that just received brand new money into her account, intends to purchase an item, and that the seller has an account at a different bank. The buyer has to either withdraw the funds from the bank that issued the loan, or transfer them to a seller's account to another bank. Let us assume that during Stage 2, the borrower transfers some amount of newly issued money to finance the purchase. During this transaction the deposit base of the bank, as well as reserves, held at the central bank, are decreased by the same amount simultaneously. In general, if a voluminous lending process, that is accompanied by the same amount of deposit creation, is followed by client withdrawals or fund transfers, the bank will soon run out of reserves and experience a liquidity crisis. It is crucially important for smaller banks that have smaller client base, or scarce reserves, to take into account the fact that the newly created deposit will likely leave the bank, taking along the same amount of reserves. For the banking system and the economy as a whole, credit and money creation will likely lead to money and reserve drainage through the current account, e.g. in the form of financing imports or factor payments to abroad.

These above examples suggest that this credit $\Rightarrow$ money one-way causal interpretation is not absolute. Indeed, the bank needs some initial funds in the form of central bank reserves in order to finance lending activities, since the created money is expected to leave the bank or the banking system. This argumentation suggests that the ILF paradigm is not entirely incorrect, in the sense that the bank needs some amount of liquidity (in reserves) for what happens after loan issuance occurs, or at

Stage 2 in Figure 1.1 terms. On the basis of this argument, Ramanauskas (2017) suggested a theory of loan-deposit-liquidity cycle, whereby banks need some form of liquidity in order to finance the creation of money through credit. That is, a bank needs to increase its own liquidity or central bank reserves by attracting customer (cash) deposits from other banks, interbank loans, liquidity loans from the CB, issue debt or equity instruments, or gather financing from parent banks, etc. This liquidity cycle theory in effect offers a *de facto* reconciliation between the FMC and ILF paradigms, and suggests of a two-way causal relationship credit $\Leftrightarrow$ money.

However, Jakab and Kumhof (2015, 2019), Ramanauskas (2017) argue that the role of reserves as a limit to money creation is weakened, by the fact that commercial banks can acquire reserves on demand. As modern central banks usually target or set interest rates, rather than targeting monetary aggregates, they will supply reserves as much as needed to achieve a specified interest rate (see also Decker and Goodhart, 2018). For example, if there is a demand for credit issuance from the private sector, and reserves become a binding constraint, there will be an upward pressure for interbank interest rates. To counteract these pressures the central bank will supply more reserves to keep the interbank rates constant. Interestingly, the bank-issued loans, that were financed through money creation *ex nihilo*, can be used as collateral when borrowing reserves from the central bank, in effect creating a vicious circle. In the words of Jakab and Kumhof (2015), the "quantity of reserves is therefore a consequence, not a cause, of lending and money creation". Moreover, the recent accommodative monetary policy regime of low interest rates and quantitative easing has made the lack of reserves problem practically void, as commercial banks have an abundance of liquidity. For example, in recent years a record high number of 30-40% of Lithuania's banking assets are comprised of central bank reserves.

Macroprudential policy as a limit to money creation

Although there are natural limits to money creation, McLeay et al. (2014) see monetary policy as the ultimate limit. By setting interest rates on interbank lending, central bank lending and deposit facility, or employing quantitative easing, central banks affect the quantity of reserves as well as lending rates, and therefore money creation. However, in the 2000's monetary policy was seemingly too loose as there was a great expansion of credit, coupled with the inflation of asset price bubbles across the world. In some cases, e.g. Lithuania, domestic monetary policy might be at all absent, or imported, due to a fixed-exchange rate regime or currency board agreement. As monetary policy alone cannot maintain both price stability and financial stability, according to the modified Jackson hole consensus and Tinbergen principle, macroprudential policy should come into play. Together with micro-prudential bank-level requirements, macroprudential policy can influence the money creationist capabilities of the whole banking system. During the recent era of expansionary monetary policy and ultra-low interest rates, macroprudential tools have strong significance to limit the risk-taking behaviour and expansion of the financial sector. To illustrate how macroprudential liquidity and capital requirements can limit money creation, we introduce a stylised numerical example of a banking system's balance sheet expansion through money creation.

Suppose there exists a banking system that has 90 loans and 10 reserves at the central bank, which are "financed" by 90 deposits and 10 units of capital (equity), as depicted in Figure 1.2. Let us further assume that there is an authority which sets a reserve (liquidity) requirement of 5% from the deposit base, and a leverage or capital requirement of 5% from the loans base.[5] In effect, at the beginning 90 loans require 4.5 units of capital, and 90 deposits require 4.5 units of reserves. On the flipside, the

[5]In fact, reserve requirement is usually regarded as a monetary policy tool, rather than prudential requirement. However, in this stylised example, the reserve requirement acts as a proxy for liquidity requirements which are of prudential nature.

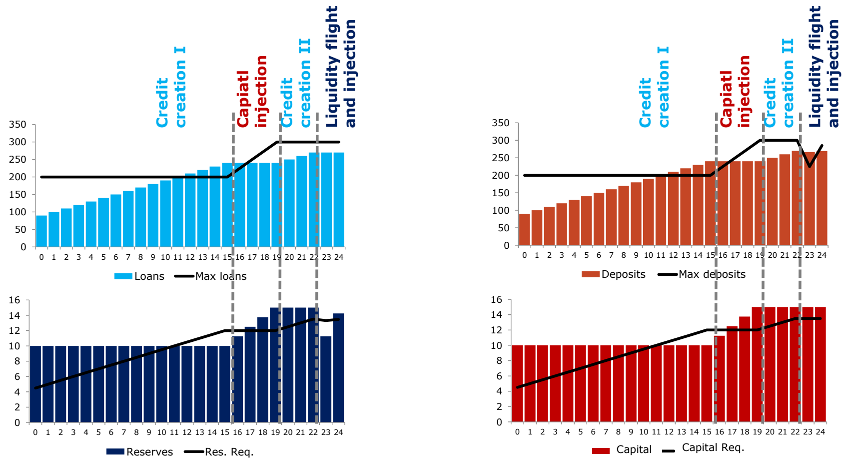


Figure 1.2: Stylised example of banking system's balance sheet expansion and its limitations due to reserve (liquidity) and capital (leverage) requirements.

requirements imply that 10 units of reserves and 10 units of capital can be matched by a maximum amount of 200 loans and 200 deposits – a multiplier effect of $20 = 1/0.05$.[6]

The situation gradually changes when banks start expanding their balance sheets through lending and simultaneous money creation (see region Credit creation I in Figure 1.2). As is expected by the FMC approach, there are no changes in central bank reserves or capital and

[6]There is a common misunderstanding about the money multiplier theory, as noted by Werner (2014) or Decker and Goodhart (2018). With brevity, money multiplier theory suggests that the amount of money issued is almost mechanically tied to the central bank reserves, therefore, any changes in reserves must be reflected in the stock of broad money. In fact, the money multiplier should only be interpreted as a maximum limit on the amount of private money issuance that is associated with a specific amount of reserves. The reserves in the banking system might explode after an expansion of the central bank's balance sheet, however this does not imply that deposits or privately issued money will change. For instance, the quantitative easing policies of the late 2000's and 2010's greatly increased the monetary base (reserves and cash), but the amount of broad money supply has barely followed, as observed by Decker and Goodhart (2018).

the expansion is fully self-sufficient. However, as there exist prudential requirements, we see that the required levels of both reserves and capital to meet their respective requirements also increase. At the end of the credit expansion phase, the banking system does not satisfy the requirements anymore, and both deposits, or created money, and loans breach their maximum limits.

This situation shows that while the banking system, or individual banks, can self-finance their expansion, macroprudential policy requirements on liquidity or capital can put a backstop on aggregate credit flows. In fact, all the usual macroprudential requirements that are in the competent authorities' toolkit, namely, liquidity (LCR, NSFR), capital requirements and borrower-based measures, can be used to limit or influence credit and money creation. As argued by Jakab and Kumhof (2015), "regulatory capital or liquidity requirements can potentially have very strong effects on credit growth, by affecting banks' incentives to lend in a much more targeted fashion than the policy rate."

The supervisory or monetary authority could in principle relax these requirements or provide more liquidity in the form of reserves, however, it would not be prudent if the expansion is already causing inflationary pressures. The bankers elect to increase their own funds or capital levels in the banking system. As capital may be brought from the international markets (from abroad), we see a commensurate increase in both levels of actual capital and reserves. We now see from Figure 1.2 region Capital injection that both reserve and capital requirements are met and the maximum limit on loan and deposit, or money, issuance is increased. This stage is followed by a further process of credit-money creation. Alternatively, capital can be accumulated by the use of retained earnings, assuming that the previous banking system's expansion was protifable.

Let us assume that there is a slight liquidity flight which drains the deposits and reserves by 3.75 units. This liquidity leakage from the deposit base perspective is rather small, however, from the reserves perspective it is quite a significant loss and the banking system does not satisfy the reserve or liquidity requirements anymore. Bank management tries to restore the liquidity position and makes a liquidity injection by borrowing funds from abroad, so that the reserve requirements are met, and there is still space for further expansion. It is interesting to note that from the individual bank's, or the whole banking system's, perspective capital injections lax both liquidity and capital requirements, whereas liquidity injection serves only liquidity or reserve requirements. Alternatively, the reserves gap can be filled with a loan taken from the central bank, that can be done on demand with a constant interest rate, as argued before, also stressed by Jakab and Kumhof (2015).

These latter examples show that the banking system can be highly elastic in the sense that it can expand further even when faced with prudential requirements. While macroprudential tools can be highly restrictive and influence credit flows and the creation of money, the banking system can be quite elusive and expand further even when satisfying these requirements.

1.2 Model setup

In this section we will describe our stylised model of a small open economy with the functional banking sector.[7] Some features of the model, such as the foreign ownership of banks or the absence of domestic monetary policy rules, reflect the specificities of the Lithuanian economy but the main insights are quite general.

The model economy comprises three sectors – households, firms and banks – and engages in economic and financial transactions with the rest of the world (see Figure 1.3). The household sector is completely standard. It consists of an infinitely-lived representative household that

[7] Among models that deal with small open economies with banking sector, and share some features with our model, are a model for Latvia by Vītola and Ajevskis (2011) and models for Ireland by Clancy and Merola (2017) and Lozej et al. (2017).

values real consumption and leisure, and provides labour services to firms (which are owned by the household sector). The household earns wages and is entitled to the dividend stream of firms. The household does not borrow and is a net saver – all its savings are deposited in a bank, earning a market-determined interest income.

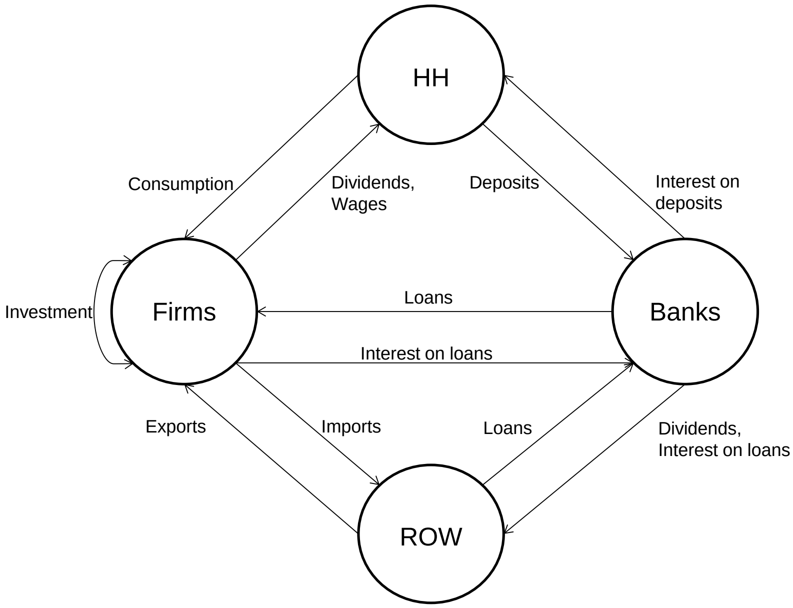


Figure 1.3: Schematic view of the model.

The firm sector is divided into competitive final goods producers, or a primitive "assembly and packaging" industry, and monopolistically competitive intermediate goods producers, which are central to the firm sector. This distinction between final and intermediate goods producers is just a standard modelling device to ensure that the productive sector as a whole retains some pricing power, governed by demand elasticity parameters. The final good is homogeneous and can be either consumed or invested. Firms (more specifically, intermediate goods producers) employ labour and capital. They are the owners of physical capital and finance its accumulation from retained earnings and bank loans.

Since producers of intermediate goods are monopolistically competitive, they earn non-zero profits, decide on the dividend policy and are set to maximise discounted dividend streams. Intermediate goods producers are subject to investment and price adjustment costs.

The firm sector is a net borrower and takes loans from the bank. Notably, firms do not have access to bank deposits but they adjust their outstanding loan balances instead. Contrary to Jakab and Kumhof (2015, 2019) we do not necessitate borrowers to simultaneously take bank loans and hold deposits or explicitly record a bank loan as a newly created deposit in the borrower's account. Though banks credit borrowers' accounts with newly created money (and, as a result, borrower's deposits increase within a time period), we make a simplifying assumption that the borrower uses all those funds for settlements or debt repayment and the end-of-period balance of the borrower's deposit account is always zero. Therefore, in the formulation of our model the borrower (firm) is not allowed to have deposits.

A competitive representative bank takes deposits from the household sector, extends loans to firms and intermediates the domestic economy's borrowing from (or lending to) the rest of the world. The bank is subject to capital requirements and wants to hold a capital buffer above the minimum requirement. The banker aims to maximise the utility derived from the stream of bank dividend payouts, which are consumed abroad. Importantly, bank's deposits are the instrument of both settlement and saving in the economy. Accounting relationships in the general equilibrium setting ensure that an increase in bank loans results in a contemporaneous rise in deposits accompanied by stronger domestic demand and inflationary pressures.

In the remainder of this section we outline the model's building blocks in more technical detail.

1.2.1 Households

The representative household obtains utility from consumption and disutility from labour. The instantaneous utility function is given by:

$$U(C_t, L_t) = U_t = \frac{C_t^{1-\theta_C}}{1-\theta_C} - \sigma_L \frac{L_t^{1+\theta_L}}{1+\theta_L}, \tag{1.1}$$

where C_t is consumption and L_t is labour. The household's flow budget constraint states that the household's disposable income, comprised of wage income, dividends and interest income, can be spent on consumption or saved in the form of bank deposits. Formally it is:

$$W_t L_t + Div_t + r_{D_{t-1}} D_{H_{t-1}} = P_t C_t + \Delta D_{H_t}, \tag{1.2}$$

where W_t is the nominal wage, Div_t denotes nominal dividends received from firms, P_t is the price level, D_{H_t} is the end-of-period stock of nominal deposits and $r_{D_{t-1}}$ is the nominal interest rate on deposits held in period $t-1$.

Note the timing convention whereby the deposit is determined at the end of the period, as a result of household's saving vs. consumption choice, and is held for one period into the future. So, the deposit contracted in period $t-1$ will yield an *a priori* agreed interest payment in period t and this will contribute to the household's disposable income of period t. Also note that the budget constraint is expressed in nominal terms, importantly to facilitate the transactional flows in money, rather than real goods. We do not apply a special notation to distinguish between real and nominal variables, therefore to avoid possible confusion we will explicitly point out which variables are which in the text.

The household maximises its expected discounted lifetime utility by choosing optimal paths of consumption, labour and deposits. The associated Lagrangian function is:

$$\mathscr{L}_H = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \nu_t \big(U(C_t, L_t) + \\ + \lambda_{H,t} \left(P_t C_t + D_{H_t} - (1 + r_{D_{t-1}}) D_{H_{t-1}} - W_t L_t - Div_t \right) \big),$$

where β is the household's impatience parameter, $\lambda_{H,t}$ is the Lagrange multiplier, and ν_t is a shock to intertemporal preferences that is equal to unity unless the shock is instituted. Differentiating the Lagrangian with respect to C_t, L_t and D_{H_t} we get the labour supply and Euler equations:

$$\sigma_L L_t^{\theta_L} = \frac{C_t^{-\theta_C} W_t}{P_t}, \tag{1.3}$$

$$\beta \mathbb{E}_t \left[\frac{\nu_{t+1}}{\nu_t} \frac{(1 + r_{D_t}) P_t}{P_{t+1}} C_{t+1}^{-\theta_C} \right] = C_t^{-\theta_C}. \tag{1.4}$$

Equation (1.3) states that, all else being equal, the household supplies more labour as real wages rise, and the response depends on the Frisch elasticity parameter, $1/\theta_L$. Equation (1.4) is a standard Euler equation. An unexpected increase in ν_{t+1} over ν_t can also be interpreted as a positive willingness to save shock.

1.2.2 Firms

The firm sector is comprised of competitive producers of final goods and monopolistically competitive intermediate good producers. The homogeneous final goods are produced from intermediate goods and are suitable for both consumption and investment and can be used domestically or exported.

Production of final goods

A representative perfectly competitive producer of final goods relies on the Dixit-Stiglitz production technology to produce the final goods from the continuum of different intermediate goods:

$$Y_t = \left(\int_0^1 y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where Y_t is the quantity of the final good produced, $y_{j,t}$ is the amount intermediate good j used in the production process and ε is a nonnegative parameter governing elasticity of demand for intermediate goods. The firm decides on the quantities of intermediate goods to maximise its profits.

$$\max_{y_{j,t}} = P_t \left(\int_0^1 y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 p_{j,t} y_{j,t} dj,$$

which results in the following demand curve for the j-th intermediate input:

$$y_{j,t} = Y_t \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon}. \tag{1.5}$$

Given that ε is nonnegative, this equation essentially ensures the downward sloping demand curve for individual producers of intermediate goods.

Intermediate goods producers

Modelling intermediate goods production is considerably more elaborate. Producers of intermediate goods act in a monopolistic competition market, they employ capital and labour to produce their products, with the aim of maximising dividend pay-outs, subject to various constraints. Firm j produces j-th intermediate good using the standard

Cobb-Douglas technology:

$$y_{j,t} = A_t K_{j,t-1}^{\alpha} L_{j,t}^{1-\alpha}, \tag{1.6}$$

where A_t is the Hicks-neutral total factor productivity that is common to all firms. $K_{j,t-1}$ and $L_{j,t}$ are, respectively, physical capital and labour employed by firm j. Note again the timing and accounting conventions whereby $K_{j,t}$ denotes the capital stock at the end of period t, and only fully installed capital, i.e. last period's capital $K_{j,t-1}$, can be used for production of period t output. Likewise, capital starts to depreciate once it is employed in the production process. The capital motion equation is given by:

$$K_{j,t} = K_{j,t-1}(1-\delta) + I_{j,t}, \tag{1.7}$$

where $I_{j,t}$ is firm j's real investment and δ is a constant depreciation rate. So, the capital stock of period $t-1$ is put in production and depreciates in period t, whereas period t investment expenditure contributes to contemporaneous increase in capital stock with an effect on production in period $t+1$.

In addition to physical constraint of capital motion, firms must obey the following accounting balance-sheet constraint:

$$P_t K_{j,t} = L_{F_{j,t}} + \Pi_{j,t}, \tag{1.8}$$

which states that firm's assets, i.e. physical capital in nominal terms, must be financed either externally, with nominal bank loans $L_{F_{jt}}$, or internally, with firm equity Π_{jt}. Firm equity is simply retained earnings – last period's equity plus current period's profits π_{jt} minus current dividend pay-outs Div_{jt}:

$$\Pi_{j,t} = \Pi_{j,t-1} + \pi_{j,t} - Div_{j,t}, \tag{1.9}$$

Our simple firm has its balance sheet, and we can also formulate its profit/loss (P&L) account in accordance with basic business accounting principles:

$$\pi_{j,t} = p_{j,t}y_{j,t} - W_tL_{j,t} - P_t\delta K_{j,t-1} - r_{L_{t-1}}L_{F_{j,t-1}} - \\ - \Omega^I_{j,t} - \Omega^P_{j,t} + K_{j,t-1}\Delta P_t. \quad (1.10)$$

This equation essentially states that firm j's nominal profit is the difference between firm's nominal sales and all expenses. The firm incurs the wage bill, capital depreciation expenses, and financial expenses in the form of previously agreed interest payments $r_{L_{t-1}}$ on outstanding bank loans. We also impose on the firm investment adjustment costs $\Omega^I_{j,t}$ and price adjustment costs $\Omega^P_{j,t}$. This is needed in order to technically smooth out model's responses but these expenses – or output losses related to installation of new capital or adjusting prices – also naturally show up in the P&L account. The last term in firm's P&L account is the nominal capital gains. It is a logical inclusion from the accounting perspective but, in modelling terms, it is also necessary in order to ensure that the firm's balance sheet (Equation (1.8)) remains balanced as prices change. Lastly, we specify Rotemberg adjustment costs:

$$\Omega^P_{j,t} = \frac{\psi_P}{2}\left(\frac{p_{j,t}}{p_{j,t-1}} - 1\right)^2 P_t y_{j,t}, \quad (1.11)$$

$$\Omega^I_{j,t} = \frac{\psi_I}{2}\left(\frac{I_{j,t}}{I_{j,t-1}} - 1\right)^2 P_t I_{j,t}. \quad (1.12)$$

ψ_P and ψ_I are the parameters regulating the costliness of respective adjustment processes.

In our model, we take a rigorous account of the financial structure of the firm sector and this ensures that the institutional environment is rich enough to enable us to track economic and financial flows between sectors and ensure the model's internal consistency at the macro level. On the other hand, the profit function in Equation (1.10) may not be immediately recognisable in the context of DSGE modelling. Moreover, the nominal capital gains term in the profit function has little to do with real shareholder value. Therefore we postulate that firms are more concerned about the discounted dividend pay-outs as their optimisation objective. One can easily derive the expression for dividends from the profits equation (1.10) by substituting in constraints (1.7)-(1.9) and applying some algebraic manipulation:

$$Div_{j,t} = p_{j,t}y_{j,t} - W_t L_{j,t} - P_t I_{j,t} + L_{F_{j,t}} - (1 + r_{L_{t-1}})L_{F_{j,t-1}} - \Omega^I_{j,t} - \Omega^P_{j,t}. \quad (1.13)$$

We thus have obtained the expression for dividend pay-outs, which is not necessary for the model solution *per se*, but it more closely resembles the textbook formulation of firm's optimisation problem. Comparing to the profit formulation in Equation (1.10), we can immediately see that the dividend pay-out is a cash-flow concept, as one has to exclude non-cash items such as depreciation expenses or unrealised capital gains but add such cash flows as borrowing from banks. The important insight from this simple analysis is that DSGE models can incorporate a reasonably high level of institutional detail and the gap between business accounting principles and the DSGE accounting framework is not necessarily very significant.

Before putting together the firm's optimisation problem formally, we introduce one more financial constraint. With the aim of being able to calibrate more precisely the level of firm indebtedness, we assume that firms face the loan-to-value (LTV) constraint, which implies that there can be only collateralised lending to firms and it may not exceed η_K fraction of the value of firm capital pledged as collateral:

$$L_{F_{j,t}} \leq \eta_K P_t K_{j,t}. \quad (1.14)$$

Firm j is assumed to maximise the expected discounted dividend stream subject to constraints (1.7)-(1.9) and (1.14). The resulting Lagrangian is given by:

$$\mathscr{L}_{F,j} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_F^t \left\{ \frac{Div_{j,t}}{P_t} + \right.$$
$$+ \lambda_{1,j,t} \left(\Pi_{j,t} - \Pi_{j,t-1} - \pi_{j,t}(\cdot) + Div_{j,t}\right) +$$
$$+ \lambda_{2,j,t} \left(P_t K_{j,t} - L_{F_{j,t}} - \Pi_{j,t}\right) +$$
$$+ \lambda_{3,j,t} \left(L_{F_{j,t}} - \eta_K P_t K_{j,t}\right) +$$
$$+ \lambda_{4,j,t} \left(K_{j,t} - (1-\delta) K_{j,t-1} - I_{j,t}\right) +$$
$$\left. + \lambda_{5,j,t} \left(A_t K_{j,t-1}^{\alpha} L_{j,t}^{1-\alpha} - Y_t \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon} \right) \right\}.$$

Here β_F is the discount factor that represents the impatience of the firm's management. The condition $\beta_F \leq (1+r_L)^{-1}$ ensures that the management is impatient enough so that the LTV constraint is binding in the steady state (and in the small neighbourhood around it). $\lambda_{i,j,t}, i = \{1, \ldots, 5\}$, denote the Lagrange multipliers associated with specific constraints. The formulation of the Lagrangian also uses the expression for profits (1.10) and the demand for the j-th intermediate good (1.5). Differentiating the Lagrangian with respect to $Div_{j,t}$, $\Pi_{j,t}$, $L_{F_{j,t}}$, $I_{j,t}$, $L_{j,t}$, $p_{j,t}$, $K_{j,t}$, and assuming firm symmetry, which allows us to drop subscripts j, we get the following first order conditions of firm's optimisation problem:

$$\lambda_{2,t} = -\frac{1}{P_t} + \beta_F \mathbb{E}_t \left[\frac{1}{P_{t+1}} \right], \tag{1.15}$$

$$\lambda_{3,t} = -\frac{1}{P_t} + \beta_F \left(1 + r_{L,t}\right) \mathbb{E}_t \left[\frac{1}{P_{t+1}} \right], \tag{1.16}$$

$$\lambda_{4,t} = -\frac{1}{P_t} \frac{\partial \Omega_t^I}{\partial I_t} - \beta_F \mathbb{E}_t \left[\frac{1}{P_{t+1}} \frac{\partial \Omega_{t+1}^I}{\partial I_t} \right], \tag{1.17}$$

$$\lambda_{5,t} = \frac{L_t}{(1-\alpha) P_t Y_t} \left(W_t + \frac{\partial \Omega_t^P}{\partial L_t} \right) - 1, \tag{1.18}$$

$$Y_t\left(1+\varepsilon\lambda_{5,t}\right)=\frac{\partial\Omega_t^P}{\partial P_t}+\beta_F\mathbb{E}_t\left[\frac{P_t}{P_{t+1}}\frac{\partial\Omega_{t+1}^P}{\partial P_t}\right], \tag{1.19}$$

$$\begin{aligned}\left(\eta_K P_t\lambda_{3,t}-P_t\lambda_{2,t}-\lambda_{4,t}\right)=\beta_F\mathbb{E}_t\Bigg[\alpha\frac{Y_{t+1}}{K_t}\left(1+\lambda_{5,t+1}\right)+1-\delta-\frac{P_t}{P_{t+1}}-\\-\lambda_{4,t+1}\left(1-\delta\right)-\frac{1}{P_{t+1}}\frac{\partial\Omega_{t+1}^P}{\partial K_t}\Bigg].\end{aligned} \tag{1.20}$$

Expressions for partial derivatives of adjustment costs are provided in the equation list in Appendix A.

1.2.3 Banks

The financial sector in the model consists of a representative competitive foreign-owned bank. Foreign ownership is chosen to reflect the structure of the Lithuanian banking industry which is mostly controlled by foreign banking groups (over 90%). The use of a single representative bank is a modelling device to simplify the optimisation problem and model solution. The bank has a stylised balance sheet comprised of just one asset (loans to firms), liabilities in the form of deposits and foreign debt (F_t), and equity (E_t):

$$L_{F_t}=D_{H_t}+F_t+E_t. \tag{1.21}$$

Just like in the intermediate firms' case, the bank's balance sheet is expressed in nominal terms, not in real – a feature to ensure consistency with the FMC approach that lending creates new nominal purchasing power. Bank equity is defined in a similar way as firms' equity:

$$E_t=E_{t-1}-DivB_t+\pi_t^B, \tag{1.22}$$

where $DivB_t$ denotes endogenous bank dividends and π_t^B is bank profits. Assuming that bank dividends are non-negative, the bank may accumulate equity only from retained earnings; thus, external equity financing is assumed away for simplicity.

The model in its present form does not incorporate credit risk, which will be incorporated in Chapter 2. Furthermore, in the competitive equilibrium, profits, and thereby the value of equity, would naturally go to zero. In order to institute positive bank equity we exogenously impose a Basel-style minimum capital requirement and also assume a financial cost inversely related to the capital buffer in excess of the minimum requirement. The bank earns interest income on loans and pays interest on deposits and foreign borrowing, as well as incurs financial costs related to the capital buffer, which results in the following bank profit function:

$$\pi_t^B = r_{L_{t-1}} L_{F_{t-1}} - r_{D_{t-1}} D_{H_{t-1}} - r_{F_{t-1}} F_{t-1} - \Omega_{t-1}^B, \tag{1.23}$$

where r_{L_t}, r_{D_t} and r_{F_t} denote, respectively, nominal interest rates on loans, deposits and banks' foreign debt and Ω_{t-1}^B is the financial cost associated with thin capital buffer. Note that the specification of the bank profit function implies that today's profits are determined by yesterday's decisions. This reflects the inherently intertemporal nature of finance but in the absence of credit risk the timing choice does not materially change the optimising and forward-looking banker's problem. Notably, other authors apply varying interest timing conventions, depending on their analytical objectives (e.g. Gerali et al., 2010; Iacoviello, 2015).

To specify the financial cost Ω_t^B we employ a logarithmic function as in Furfine (2001):

$$\Omega_t^B = -\gamma \log\left(\frac{E_t}{\omega L_{F_t}} - \mu_t\right) L_{F_t}, \tag{1.24}$$

where μ_t is the minimum capital requirement, ω is a risk weight and γ is the parameter reflecting the financial pain associated with the thin capital buffer. The logarithmic cost function is well defined and yields a negative value when the argument, i.e. capital buffer, is between zero and unity, therefore we assume that γ is a nonnegative parameter. It should be said that this formulation is a simplification suitable because it simply does not allow bank capital to go below the required minimum as that would result in infinitely large financial cost to the bank.

We also specify the upward sloping foreign financing supply function, similar to Schmitt-Grohé and Uribe (2003). It states that the interest rate on banks' foreign debt positively depends on the nominal foreign debt-to-GDP ratio:

$$r_{F_t} = r_t^* \left(\phi_0 + \phi_1 \frac{F_t}{P_t Y_t} \right), \tag{1.25}$$

where r_t^* is the risk-free interest rate on borrowing in foreign financial markets and ϕ_0 and ϕ_1 are non-negative parameters. One can interpret r_t^* as the interbank rate that can be directly affected by exogenous monetary policy shocks.

It is assumed that banks are owned by an impatient foreign household who receives dividends and spends them on consumption abroad. The flow budget constraint is $P_t^* C_t^* = DivB_t$, where P_t^* is the foreign price level and C_t^* is foreign consumption of the banker. The instantaneous utility function is $\log C_t^*$ and the banker maximises the expected discounted lifetime utility by controlling the bank. The banker's Lagrangian function is as follows:

$$\mathscr{L}_B = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_B^t \left\{ \log\left(DivB_t\right) - \log P_t^* + \lambda_{B,t} \left(E_t - E_{t-1} + DivB_t - \pi_t^B \right) \right\}.$$

Plugging in the expression for bank profits (1.23), substituting out deposits using the balance sheet equation (1.21), applying the expression for the supply of foreign lending (equation (1.25)) and then maximising the transformed Lagrangian with respect to $DivB_t$, L_{F_t}, F_t, and E_t yield the following first-order conditions:

$$\frac{1}{DivB_t} = \beta_B \mathbb{E}_t \left[\frac{1}{DivB_{t+1}} \right] \left(1 + r_{D_t} + \gamma \frac{L_{F_t}}{E_t - \mu_t \omega L_{F_t}} \right), \tag{1.26}$$

$$r_{L_t} - r_{D_t} = \gamma \left(\frac{E_t}{E_t - \mu_t \omega_t L_{F_t}} - \log \left(\frac{E_t}{\omega L_{F_t}} - \mu_t \right) \right), \tag{1.27}$$

$$F_t = P_t Y_t \frac{r_{D_t} - \phi_0 r_t^*}{2\phi_1 r_t^*}. \tag{1.28}$$

There is a close analogy between the banker's Euler equation (1.26) and the household's Euler equation (1.4). The banker equates the marginal rate of substitution between dividends today and tomorrow to the relative price of dividend pay-outs. Thus, withholding dividend pay-outs for one period spares the bank from paying alternative financing cost r_{D_t} to depositors and also reduces the marginal financial cost associated with a thin capital buffer. Notably, the larger the capital buffer gets, the more inclined the banker becomes to pay out the dividends, all else being constant.

Equation (1.27) establishes that bank's capital buffers are increasing along with an increasing interest rate margin. Equation (1.28) governs demand for foreign debt. Foreign debt is positive when the difference between deposit rates and the risk-free foreign rate is sufficiently large, in other words, when foreign borrowing is relatively cheap. Also, all else being equal, the lower risk-free foreign rate naturally implies stronger demand for bank's borrowing from abroad.

1.2.4 General equilibrium

In equilibrium, all markets clear, i.e. supply matches demand. Adding the household's budget constraint together with the firm's and bank's balance-sheet constraints, we obtain the following aggregate resource constraint and the balance-of-payments identity:

$$P_tY_t = P_tC_t + P_tI_t + \Omega_t^I + \Omega_t^P + \Omega_t^B + P_tNX_t, \tag{1.29}$$

$$P_tNX_t - DivB_t - r_{F_{t-1}}F_{t-1} = -\Delta F_t, \tag{1.30}$$

where NX_t is the net exports. Equation (1.29) is simply a variant of the basic national accounting identity, or decomposition of the gross domestic product (net of lost output) by expenditure approach. Equation (1.30) is the simplified balance-of-payments identity, which states that the combined current and capital account, comprised of net exports and net financial income from abroad in this simple economy, must equal the financial account, or in this case simply the change in foreign debt.

Finally, we need one more equation to identify the price level and close the model in order to yield determinacy of the solution. The standard closure using the Taylor rule is not appropriate for a small member state of a monetary union, in which the monetary policy does not actually react to changes in that specific economy. We therefore assume that the domestic price level is determined by external competitiveness. To this end, we endogenise net exports to be a function of the price level and consumption:

$$NX_t = n_1P_t^{-n_2} - n_0C_t. \tag{1.31}$$

External competitiveness, and net exports in particular, is assumed to be negatively linked to the real exchange rate, determined solely by the domestic price level, since the exchange rate and foreign price levels are both exogenously fixed. Also, consumption negatively affects net exports through imports channel.[8]

Equation (1.31) should not be interpreted in isolation but rather as an

[8] We endogenise net exports in a simple way, very similar to the approach taken by Vītola and Ajevskis (2011) in their model of the Latvian economy, where imports are assumed to be linearly related to consumption expenditure, and exports are negatively dependent on the price level.

additional constraint. Net exports are determined by aggregate supply and demand conditions in the general equilibrium (see equations (1.29) and (1.30)).

This completes the model. A full list of model equations is presented in Appendix A.

1.3 Calibration

We calibrate the model's parameters to broadly match some general macroeconomic ratios of the Lithuanian economy at annual frequency. For calibration purposes we primarily use Statistics Lithuania and Bank of Lithuania data spanning 1995-2018 at various frequencies. The calibrated parameter values are presented in Table 1.1. We now turn to briefly discussing the calibration process.

The numerical values for β_F, α, ε, δ, and η_K are chosen simultaneously to produce the following steady state ratios: bank loans to GDP ratio of 66%, investment to GDP ratio of 20%, the capital share in aggregate income of 31%[9] and firms' return on equity of 8.3%, in line with the corresponding historical averages in Lithuania, based on Statistics Lithuania data ranging from 2001 to 2016. The α estimate is close to the estimates of 0.297 and 0.32 obtained, respectively, by Karpavičius (2008) and Proškutė (2012). $\delta = 0.12$ and $\beta_F = 0.949$ are close to the values of 0.1 and 0.99 in Proškutė (2012). The calibrated value of $\varepsilon = 34$, compared to say Rubio and Comunale (2016) is rather large, directly implies a mark-up of 3%. LTV cap parameter η_K gives the firms' equity to liabilities ratio of 1.5, which is close to the long-term average figure from the national accounts.

The investment adjustment cost parameter $\psi_I = 0.63$ is taken from the

[9] The empirical counterpart is calculated by adding to gross capital consumption a halved sum of gross operating surplus and mixed income.

Bayesian mean estimate in Vītola and Ajevskis (2011). The price adjustment cost parameter $\psi_P = 95$ in our model would correspond to a 75% chance that prices will remain unchanged in a given quarter – a typical probability in models with Calvo pricing. The households'

Table 1.1: Calibrated parameter values.

Parameter	Description	Value
α	Capital share in the production	0.29
δ	Depreciation rate for physical capital	0.12
ε	Elasticity of demand for intermediate goods	34
η_K	Loan to value cap for firms loans	0.4
ψ_P	Price adjustment costs parameter	95
ψ_I	Investment adjustment costs parameter	0.63
β_F	Firm's discount rate	0.949
β	Households' discount rate	0.987
θ_C	Households' risk aversion	1
σ_L	Weight of labour disutility	0.887
θ_L	Inverse of the Frisch elasticity	1
γ	Capital buffer financial cost	3.981×10^{-3}
ω	Average risk weight	0.7
μ	Minimum capital adequacy ratio	0.145
β_B	Banker's discount rate	0.878
ϕ_0	Risk-free interest rate effect on r_{F_t}	0.715
ϕ_1	Foreign indebtedness effect on r_{F_t}	1.818
n_0	Imports to consumption share	0.9
n_1	Constant net exports demand	1.8
n_2	Price elasticity of net exports demand	1

discount factor $\beta = 0.987$, which is close to Proškutė (2012), corresponds to the historical average nominal interest rate on private sector deposits (including both sight and term deposits) of 1.3%. The household's instantaneous utility function parameters θ_C and θ_L are for simplicity set equal to 1, implying logarithmic utility from consumption and quadratic from leisure (as in Gerali et al., 2010). σ_L is selected so that steady state labour would be equal to unity.

The value of γ, governing the financial cost associated with a thin capital buffer, is consistent with the historical average of nominal rates on loans to the private sector, which is equal to 4.2%. The combination of the willingness to hold the capital buffer, governed by parameter γ, and banker's impatience parameter $\beta_B = 0.878$ determines the steady state level of bank capital held, which is set in line with the typical post-crisis capital ratio of 19% and the required minimum level of about 14.5% (which includes both Pillar I and Pillar II capital requirements). The calibrated value β_B is rather small, however, it is necessary to account for the fact that Lithuanian banks historically have quite thick voluntary capital buffers. The risk weight parameter $\omega = 0.7$ corresponds to the average risk weight for banks operating in Lithuania. Foreign financing supply parameters ϕ_0 and ϕ_1 are calibrated to make bank's foreign debt to GDP ratio equal to 14.5%, as Lithuanian banks' gross foreign debt fluctuated around that level in the post-crisis period.

Turning to the parameters related to the foreign trade, the parameter $n_0 = 0.9$ reflects the historical average imports to consumption ratio in Lithuania. As there is little empirical evidence about the long-term equilibrium level of trade balance, we arbitrarily choose the parameter n_1 to ensure that in the steady state there is a small trade surplus, which would offset financial outflows in the form of bank dividends and interest rate payments on foreign debt (resulting in the balanced current account in the steady state). The value of the parameter n_2, governing the price elasticity of net exports, is set equal to 1, like in Vītola and Ajevskis (2011).

1.4 Bank lending in FMC and ILF settings

The purpose of this section is to study the properties of the previously outlined model. The basic concern of Jakab and Kumhof (2015) and others is whether macroeconomic models that contain bank lending do have money-creationist features. In other words, the questions rises, whether DSGE models, such as the one presented here, are compatible with the FMC view of banking – creation of new money is simultaneous to the act of lending, without the need to resort to pre-accumulated resources. This is exactly the issue we aim to study by designing an experiment in which we analyse the macroeconomic system's response to unexpected, permanent and positive shocks to bank lending. Similarly to Jakab and Kumhof (2015, 2019), using their naming convention, we employ a shock to banker's willingness to lend and treat it as an exogenous and sudden subjective increase in the propensity to lend.

The crucial question is whether the induced shock to banker's willingness to lend causes a response that is compatible with the FMC approach, or rather the ILF view. To this end, we construct two settings. One is where the FMC approach holds and we characterise it as a flexible-price case. The ILF approach is modelled as a case where prices are assume to be fixed. We conduct the analysis in comparing the short- and medium-term response of macrofinancial variables to the banker's willingness shock in both settings and describe the results.

1.4.1 Describing the FMC and ILF settings

To differentiate between the FMC and ILF views, we introduce the flexible- and fixed-price settings. The flexible-price environment is an approximation of a nominal monetary economy, in which prices can adjust in response to forces of supply and demand, and changing monetary aggregates, and thus is the environment that should allow for money creation.

Conversely, the fixed-price setting invalidates the nominal price adjustment mechanism and makes the model "real", in which nominal money creation cannot be possible. To be more precise, the fixed-price case specifies the model as real, so that there is no exchange of money, only that of goods. As such, credit and deposits, instead of being monetary stocks, really represent stocks of real goods, and therefore, the process of lending cannot be completed without either foreign borrowing, or internal saving (foregone consumption) of goods.

We briefly describe the distinction between the flexible-price case and the fixed-price case in model terms. The flexible-price case is simply the model presented in the previous section. Note that prices in the flexible-price case can still be subject rigidities, such as the positive Rotemberg adjustment costs that are assumed in our model, or Calvo-type adjustment. In essence, with adjustment costs present, the prices are flexible, however, with staggered and slow adjustment, maintaining the model as monetary.

The fixed-price case is obtained by exogenising prices and setting them to $P_t = 1$. As there is one less endogenous variable in the model system, one equation has to be removed to have a model solution. Since the prices are fixed, the net exports equation (1.31), used for price determination, can be removed. Alternatively, practically the same results could be achieved after assuming a large value to parameter n_2 from equation (1.31) – high elasticity of net exports to price changes.

1.4.2 Banker's willingness to lend

For the analysis of the mechanism of credit and money creation we need to induce a shock to banker's (subjective) willingness to lend. To this end, we slightly change the formulation of banker's utility function by adding an additive term representing utility from loans:

$$\log C_t^* + \psi_{Lf,t} \log L_{F_t},$$

which is a "loans in the utility" specification. Plugging the foreign banker's budget constraint into the above specification will produce:

$$\log DivB_t - \log P_t^* + \psi_{Lf,t} \log L_{F_t}.$$

We use this expression instead of using $\log DivB_t - \log P_t^*$ in the banker's problem. This changes banker's first-order condition (1.27) to the following equation:

$$\psi_{Lf,t}\frac{1}{L_{F_{t+1}}} + \beta_B \mathbb{E}_t\left[\frac{1}{DivB_{t+1}}\left(r_{L_t} - r_{D_t} - \gamma\left(\frac{E_t}{E_t - \mu_t \omega L_{F_t}} - \log\left(\frac{E_t}{\omega L_{F_t}} - \mu_t\right)\right)\right)\right] = 0.$$

In essence, the adjusted first-order condition implies that the banker takes into account the increased pressure or willingness to supply more loans, when making decisions on capital and distribution of dividends.

We treat the variable $\psi_{Lf,t}$ as a shock to banker's willingness to lend and set it to zero in the steady state. In the steady state, and in all cases when $\psi_{Lf,t} = 0$, the banker's willingness to lend is neutral. A positive value of the shock is associated with a greater subjective incentive to lend funds to firms. Likewise, a negative value of the shock corresponds to the situation when the banking institution for some exogenous reason wants to contract the flow of credit.

1.4.3 A comparison of model responses

To simulate the model and analyse its responses, we induce an unexpected and permanent change in the banker's utility function by shocking the variable $\psi_{Lf,t}$, as described above. The shock makes the banker more willing to extend loans to the private sector. The size of the banker's preference shock is calibrated so that the resultant impulse-response function of deposits would reach a value of 1% at the end of a twenty-year horizon. The responses of main model variables are depicted in Figure 3.1 in Appendix A.

The fixed-price or ILF case

After the positive shock occurs, the banking sector permanently increases loan supply, thus over the long run the economy moves to the new steady state of higher productive capacity. Essentially, the bank uptakes a permanent role of more active financial intermediation. The increased loan supply puts a downward pressure on loan rates. For the market to absorb this new lending, loan rates instantaneously fall with some undershooting, and stay decreased. In response to cheaper loans and the banker more willing to extend loans, there is a marked rise in firm investment, leading to a gradual rise in the stock of physical capital. Very importantly we note that the economic output, as measured by GDP, responds very sluggishly, and even falls during the first years of credit expansion.

As there is greater demand for goods and the economy's output initially does not increase, there is a rise in imports. Although the cost of debt services decreases for firms, they contract their dividend payments to households. Moreover, there is a drop in employment and the growth in salaries is sluggish, resulting in falling household disposable income. In spite of this, household consumption increases – households use their accumulated deposits to finance their demand for goods and services, thus the saving rate becomes negative.

In response to dwindling deposits and the increased need to fund new lending, banks raise the deposit rate. Since a higher interest rate for deposits does not bring the required result, banks must fill the financing gap by borrowing from abroad. In balance of payments terms, the current account deficit, that is associated with increased exports, is financed with foreign debt. As the bank's foreign indebtedness increases, this puts upward pressure on the interest rates for external funding, in addition to the already increased deposit rates.

One can see that a subjective increase in the banker's willingness to lend puts downward pressure on net interest income, and this results in a huge drop in bank profits. Since there are capital requirements in place, the bank needs to accumulate more capital in order to keep up with balance sheet expansion. This is done by reduced dividend payouts, concurrently to fallen profitability.

The flexible-price or FMC case

By analysing the flexible-price case, we can immediately see from Figure 3.1 in Appendix A that in response to the banker's willingness shock real variables converge to the same new steady state levels as in the fixed-price setting, however, the transition dynamics is very different. This is consistent with macroeconomic theory that nominal prices do not matter in the long run.

Unlike in the fixed-price setting, the prices can vary, thus there is a distinction between nominal and real variables, with latter being marked by diamond-lines in Figure 3.1. As is expected again, increased loan supply puts downward pressure on both nominal and real loan rates which fall substantially. As debt financing becomes significantly cheaper, corporate sector increases investment and accumulation of physical capital for productive activities. In response to a greater demand for goods, this time firms can increase their prices and inflation picks up. Lower interest rates, combined with higher productive capacity and higher prices leads to greater profitability for the firm sector.

To meet the new demand for products, and in addition to the new stock of physical capital, firms demand more labour, what materialises into an increase in employment services and growing salaries. Although the resulting growth in labour income significantly raises household disposable income, consumption increases only mildly, due to inflation. This process contributes to an increase in household saving rate and results in an expansion in stock of deposits.

At the same time, we see a concurrent rise of loans and nominal deposits – almost a one-to-one relationship in absolute terms. As banks create deposits and loans in a simultaneous fashion, almost no foreign financing is needed. In contrast to the ILF setting, banks do not scramble to attract deposits, but create their own financing, thus the deposit interest rates drop. The subjective willingness to extend loans puts a downward pressure on banking sector's net interest margins, thus profitability decreases and dividend payments are withheld.

Bank's balance sheet under both FMC and ILF cases

We summarise and contrast the simulation results when looking at the same shock but different settings. Figure 1.4 suggests that the expansion of loans is quite similar in magnitude, but the financing mechanism is very different. Under the fixed-price case, we see that the bank is not able to collect deposits even after raising the interest rates, thus resorts to foreign funding instead. However, in the flexible-price setting deposits increase together with the issuance of new loans, what suggests of a simultaneous expansion of both sides of the balance sheet – financing through money creation. Moreover, under the FMC case, as self-financing is achieved through loan issuance, almost no foreign funding is needed. Under both ILF and FMC settings, we see a concurrent rise in bank capital that is needed to meet the (macroprudential) capital requirements – in spite of decreased profitability.

In addition, this exercise shows that the ILF and FMC views have a tremendous impact not only on bank balance sheets, but also on the economy as a whole. As the FMC mechanism does not require any redistribution of resources, but rather creates new purchasing power, it can significantly raise economic activity and inflation.

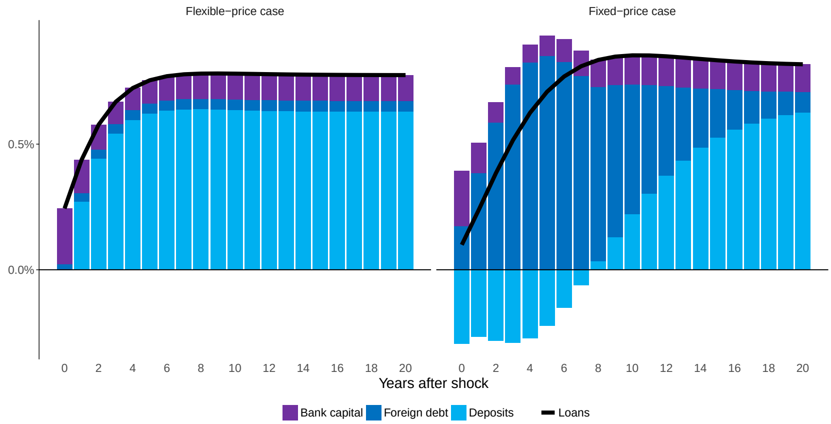


Figure 1.4: Decomposition of the loan stock under flexible- and fixed-price settings, after a positive shock to banker's willingness to lend.

1.5 Concluding discussion

In this chapter we re-established an accounting fact that banks are able to create credit through simultaneous creation of money, or funding, which is the FMC view. Although notions that banks fund loans with deposits, or that banking is essentially financial intermediation, are comfortable constructs, they are indeed fallacies. Banks, unlike other financial firms, have the unique ability to create credit out of thin air, which puts them huge powers over our monetary system. However, there are limits to bank money creation, among which is macroprudential policy that can restrain balance sheet expansion through liquidity, capital and other requirements.

As this dissertation requires, we construct a simple New-Keynesian DSGE model for Lithuania and show, in response to the critique of Jakab and Kumhof (2015, 2019), that it has money creation features. Our conducted experiment allowed us to compare the macrofinancial responses to an exogenous increase in credit supply under both FMC and ILF settings. We see that under the FMC case, the expansion in lending operations is simultaneously followed by an increase in nominal deposits or money without the need to resort to household saving or some pre-accumulated resources. The credit and money creation is expansionary in a sense that is able to boost real productive activities, besides inducing price inflation.

The main ingredients that were necessary to have model features that are compatible with money creation are as follows (without a particular order). First, we need a general equilibrium model with proper nominally-expressed balance sheets and accounting identities to keep track of flows and stocks of variables, so that the model is stock-flow consistent. This is to ensure that deposit expansion can be associated with increase in lending, so that there are unaccounted residual effects. Second, we need to have prices that are at least to some extent flexible, even with sluggish responses, and quoted in deposit or money terms. Third, we need to have at least some heterogeneity in agents to facilitate borrowing and lending – banks are a necessary part of this equation. Fourth, banks need to to have have double-entry bookkeeping balance sheets, so that credit expansion could be placed on the asset side and the deposit, or money, expansion could be matched on the liability side.

Our suggested model prerequisites for money creation are less binding than those given by Jakab and Kumhof (2015). For example, differing from Jakab and Kumhof (2015, 2019) or Kumhof and Wang (2020), we do not formulate any transaction technology, money-in-the-utility, or cash-in-advance constraint, to force the household to use deposits as a means of settlement. Moreover, we do not find it necessary to explicitly model ownership of deposits for the borrowing agent, in addition to loans. We deem that deposits that were credited to the borrower are instantaneously spent within a given period (intraperiod). Lastly, as we did not include credit risk, it does not seem a necessary condition for money creation properties of a DSGE model with banking. The contribution of this chapter in the literature on money creation can be viewed as narrow-down of the ingredients laid out by Jakab and

Kumhof (2015). In essence, as our model is simple and rather traditional in the New-Keynesian literature, we deem that most DSGE models with banking, that satisfy our four prerequisites, have money creation.

Chapter 2

Macroprudential policy

This chapter builds on the model from Chapter 1 to introduce heterogeneity within the household sector and include household mortgage borrowing as well as the associated credit risk. Introduced is an alternative to BGG framework of mortgage defaults a la de Walque et al. (2010), coupled with multi-period loans as in Gelain et al. (2015, 2018) or Iacoviello (2015). Unlike in the literature, we model defaults and bank asset seizure so that the LTV constraint is also constraint on bank lending, not only on the borrower's side. Since the model is as stock-flow consistent system, with prices and banks that have nominal balance sheet identities, the banking sector is truly monetary in the sense that it features money creation as in Chapter 1.

The model includes three (macro-)prudential policy tools whose impact is evaluated. That is a requirement on bank capital, LTV limit and regulation on bank risk weights. We conduct simulations in which we assess the impact on the economy of a permanent increase in each of the requirements. We show that different assumptions about bank collateral seizure after a household default can have different implication for the effect of LTV tightening. Moreover, we conduct experiments to assess the impact of timing of announcement of different prudential measures, as well as compare the efficiency in taming the growth of secured lending to households.

2.1 Literature and contribution

The storm of 2008 caught policy makers off guard and showed that the models they had in possession were unable neither to predict the crisis, nor explain it. Later inclusion of housing and financial frictions into the existing New Keynesian framework, proved to give a better understanding of the recession and what factors where behind the depth. For more about this, see excellent review by Vlcek and Roger (2012) or more recent perspective from Christiano et al. (2018). Mortgage delinquencies were one of the central themes of the past crisis, in large part responsible for subsequent shrinkage of bank lending across the world. As Goodhart and Tsomocos (2011) and Goodhart et al. (2013) correctly point, macro models with financial intermediaries must allow for the possibility of defaults. Dellas et al. (2010) in their New Keynesian model use exogenous firm default shocks on banks. Iacoviello (2015) uses exogenous household defaults and show that these shocks can lead to deleveraging of the banking industry. Deleveraging causes a credit crunch in the productive sector, thus amplifying the impact and leading to an overall recession.

While exogenous defaults are a simple and tractable way to improve model fit and explain cycle fluctuations (see Iacoviello, 2015), loan delinquency is in most occasions a reaction of a debtor to a deterioration in economic circumstances, being endogenous in nature. Modelling defaults in an endogenous fashion is complicated because it is a discrete event, not a continuous variable (see more in Goodhart and Tsomocos, 2011). The pioneering work of BGG introduced a framework where a sufficiently negative idiosyncratic shock to an entrepreneurial family member's net worth would trigger a default event. Integrating over all family members the percentage of defaults would amount to probability of default. This framework has been applied for mortgage defaults in Forlati and Lambertini (2011), where household-saver seizes borrower's fraction of housing after a delinquency. In their model, an unexpected increase in housing investment risk triggers a recession characterized by rising defaults, interest rates and a drop in lending. Among other applications of BGG's approach in modelling mortgage delinquencies are Darracq Pariès et al. (2011), Quint and Rabanal (2014), Clerc et al. (2015), Nookhwun and Tsomocos (2017) and Lozej et al. (2017) to name a few.

Abovementioned papers that use the BGG framework for household mortgage defaults rely on two rather dubious assumptions. The first is that within a continuum-family of an impatient household, each member's house value is subject to an idiosyncratic shock whose distribution is either constant or exogenously evolving over time. The second assumption is that these papers rely on an automatic rule for default decisions. When an individual member's value of the house falls below the debt plus interest, that member defaults. This setting is plausible to some extent, since there were many cases where households found themselves "under water" with their house value being much below the debt level and just "handed the keys" to the bank. However, this approach ignores the multidimensionality of personal household finance, because a decision to default depends on more variables than the ratio of house value to debt. There are many cases where borrowers default even if their house value is close to that of a mortgage, but their income is not in enough for servicing the debt burden. Here we take the approach of de Walque et al. (2010) and model mortgage defaults in a truly endogenous fashion. The framework takes the probability of default to be a choice variable in household's optimisation problem. The virtue of this setting is that the decision maker takes into account all of the financial circumstances like income, consumption of goods and housing, and housing value with respect to debt, and does not rely on one automatic rule. After a negative shock hits the household and income falls, the marginal benefit of default becomes relatively sizeable compared to the cost, which is future search and collateral seizure, outweighs the benefits like extra consumption of goods and housing. The approach, besides being more plausible in the mentioned dimensions, compared to BGG framework, also allows for multiperiod debt contracts.

Most papers that are concerned with mortgage defaults in an infinite horizon discrete time DSGE framework use one period housing loans with variable rates (see, e.g. Forlati and Lambertini, 2011; Bekiros et al., 2017; Nookhwun and Tsomocos, 2017). Brzoza-Brzezina (2014) and Brzoza-Brzezina et al. (2014) criticise this framework and using their model show that the effectiveness of macroprudential policy can be overestimated when using the one-period debt contracts. The reason for this argument is that the one-period debt contract makes the level of debt, which coincides with new borrowing, much more reactive to changes in, for example, loan to value requirements. A similar case has been made by Gelain et al. (2018) where they argue that in a multi-period loan framework unexpected increases in interest rates only weakly influence household debt, and tend to increase debt to GDP ratio in the short run. Also, the authors claim that when multiperiodicity is introduced, a DSGE model can better match empirical regularities. As a consequence of this discussion we allow for a dynamic borrowing limit in the mortgage default framework. Our approach is essentially a simplification of Gelain et al. (2015, 2018) used in Iacoviello (2015). The model simulations suggest that indeed a policy tool like the limit on the loan to value ratio reduces the mortgage debt level in a multiperiodic framework.

On the basis of a DSGE model without financial intermediation Justiniano et al. (2015) argued that looser lending constraints, not borrowing constraints, where responsible for lower interest rates, increase in leverage and house prices in the United States. The authors of the paper characterise loose lending constraints as increases in credit supply and low borrowing standards as credit demand effects. The convention that a borrowing limit is a demand constraint was popularised by Kiyotaki and Moore (1997) and Iacoviello (2005), and now it is prevalent in most DSGE models (see any reference above for example). Moreover, the limit on loan to collateral value is also considered as a macroprudential policy borrower-based measure. In this chapter we argue that the LTV limit is a borrowing constraint and a lending constraint. The reasons why it qualifies as a lending constraint is that when banks are making lending decisions they expect that some of the households will default and some of the collateral will be seized. In an environment with falling house prices, the bank will be able to cover more loan losses if the LTV constraint was tight at the initiation of a loan. And conversely, if the constraint was loose at the initiation of a loan contract, i.e. loan was very high compared to collateral value, this hinders the bank's ability to cover loan losses with a seized house.

A loosening of such constraint should increase interest rates, unlike in Justiniano et al. (2015), for two reasons. As is common, allowing the borrower to take more credit while keeping collateral value constant, increases loan demand and puts upward pressure on interest rate margins. Loose lending, higher overall debt and interest rates increase mortgage delinquencies over time. In addition to that, lower cap on loan to collateral ratio means that banks are more vulnerable to small collateral price swings and likely to experience bigger losses in case of a household default on a mortgage. In our model banks effectively price in those risks by reducing the loan supply, after the collateral constrained is looser, and increasing the interest rate for mortgages. In other words a loose borrowing constraint implies tight lending supply, and conversely, a tight LTV constraint will loosen lending. To our knowledge, there are no DSGE models that would use an LTV limit in bank's optimisation problem.

Model-wise, our contribution to the literature is that we develop a DSGE model for an open economy, with housing and banking that allows for mortgage defaults that are truly endogenous in nature and alternative to the more widespread BGG framework. While other DSGE models use

LTV only as a borrowing constraint, in our model the LTV limit is also a credit supply constraint. Moreover, we use the set-up from Iacoviello (2015) and Gelain et al. (2018) to accommodate multi-period housing loans and allow for smoother response of interest rates and mortgage debt. Lastly, our treatment of firm and bank accounting relationships is more accurate than in other DSGE models and thus should give more realistic dynamics of model variables.

We recalibrate the extended model to match first moments of Lithuanian historical data and use it to assess the short-term economic impact of macroprudential policy tools.

2.2 The extended model

The figure below describes the sectors and agents of the economy and the connecting financial flows. In the extended model, the macroeconomy is

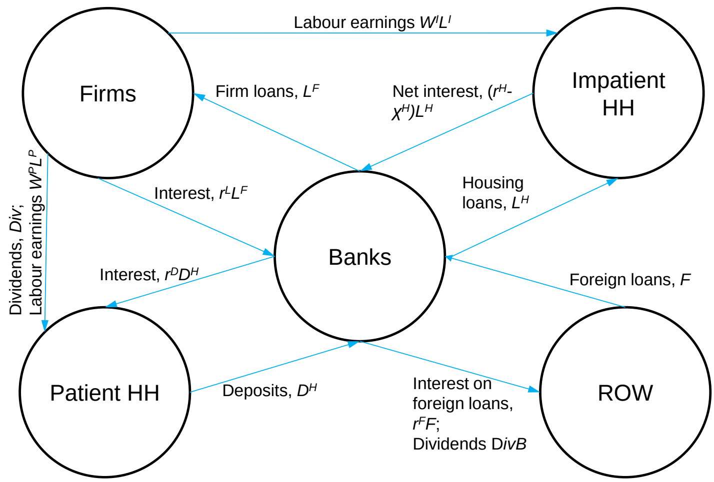


Figure 2.1: Schematic view of the financial flows within the extended model.

populated by two representative households of which one is patient and the other one is impatient, with lower discount factor. The motivation for this difference is that we want to maintain household deposits and have household debt in the model. Both households provide labour services to the firm sector and earn wages, however, only the patient also the firm dividend stream. The impatient household can borrow for interest, and has the ability to default on a fraction of the debt. Banks now have a portfolio allocation problem because they extend loans to the corporate as well as the household sector.

The model shares similarities to papers of Iacoviello (2005, 2015) and Gerali et al. (2010), de Walque et al. (2010), Vītola and Ajevskis (2011). In this setting we devote much attention to accounting identities (in nominal terms) of firms and banks for a realistic treatment. Much of the variables are nominal in the model, except consumption, investment, output, housing, labour, physical capital. In the remainder of this section we outline the model's building blocks in more technical detail.

2.2.1 Households

The household sector is comprised of two representative households, of which one is patient and the other one is impatient. Since the patient household has a higher rate of time preference $\beta_P > \beta_I$, it is the depositor in this model, while the impatient one borrows from banks, subject to a collateral constraint. In addition to, each provides labour services to the intermediate good sector, where their productivity is not necessarily identical. The patient household is assumed to be the owner of intermediate firms, thus receives dividends from them. Otherwise, both households are identical in their valuation of consumption of goods, housing and dislike of labour, what is instituted in an identical instantaneous utility function:

$$U\left(C_t^s, H_t^s, L_t^s\right) = U_t^s = \log C_t^s + \sigma_H \log H_t^s - \frac{\sigma_L}{2}\left(L_t^s\right)^2, s \in \{P, I\}, \qquad (2.1)$$

where superscript ^{P} denotes the patient household and ^{I} the impatient. U_t^s is household's utility at time t, C_t^s denotes consumption, H_t^s is housing and L_t^s is labour. σ_H and σ_L are weights in the utility function for housing and labour that are identical across households. We turn to describe each household in more detail.

2.2.1.1 Patient household

The patient household's budget is the same as in Chapter 1, except that it also includes house purchases:

$$W_t^P L_t^P + Div_t + r_{t-1}^D D_{t-1} = P_t C_t^P + \Delta D_t + P_t^H \left(H_t^P - H_{t-1}^P\right), \tag{2.2}$$

where W_t^P is the patient's nominal wage rate, Div_t denotes nominal dividends received from firms, D_t is the end of period t stock of nominal deposits and r_{t-1}^D is the nominal interest rate on deposits held in period $t-1$. P_t and P_t^H are prices of consumption goods and housing, respectively.

The household maximises its expected discounted lifetime utility by choosing optimal levels of consumption, housing, labour and deposits. The associated Lagrangian function is:

$$\begin{aligned}\mathscr{L}^P = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_P^t \Bigg(& U\left(C_t^P, H_t^P, L_t^P\right) + \\ & + \lambda_t^P \Big(P_t C_t^P + D_t + P_t^H \left(H_t^P - H_{t-1}^P\right) - \\ & - \left(1 + r_{t-1}^D\right) D_{t-1} - W_t^P L_t^P - Div_t \Big) \Bigg),\end{aligned}$$

where β_P is the household's rate of time preference, λ_t^P is the Lagrange multiplier. Differentiating the Lagrangian with respect to C_t^P, H_t^P, L_t^P and

D_t we get the labour supply, Euler and housing demand equations:

$$\sigma_L L_t^P = \frac{W_t^P}{P_t C_t^P}, \tag{2.3}$$

$$\beta_P \left(1 + r_t^D\right) \mathbb{E}_t \left[\frac{1}{P_{t+1} C_{t+1}^P}\right] = \frac{1}{P_t C_t^P}, \tag{2.4}$$

$$\frac{\sigma_{H,t}}{H_t^P} + \beta_P \mathbb{E}_t \left[\frac{P_{t+1}^H}{P_{t+1} C_{t+1}^P}\right] = \frac{P_t^H}{P_t C_t^P}. \tag{2.5}$$

Equation (2.5) equalises marginal utility of housing to marginal disutility of foregone consumption when buying one unit of housing.

2.2.1.2 Impatient household

Although preferences are identical across households, the impatient has a more complex problem to solve. Moreover, this agent is of particular macroprudential interest because it has the ability of taking out mortgages and defaulting on them. The defaulting framework used here is adopted from de Walque et al. (2010), alternatively to more prevalent BGG setting (see e.g., Forlati and Lambertini, 2011; Darracq Pariès et al., 2011; Clerc et al., 2015). It is important to note that default rate is positive in the steady state, as well as off it.

The household earns labour income and is able to additionally borrow to finance nominal consumption, debt service net of delinquencies, accumulation of housing net of asset seizure, pay search costs associated with previous mortgage defaults. This is represented by the following budget constraint:

$$W_t^I L_t^I + \Delta L_t^H = P_t C_t^I + P_t^H \left(H_t^I - H_{t-1}^I\right) + \left(r_{t-1}^H - \chi_t^H\right) L_{t-1}^H + \Omega_t^H + S_t, \tag{2.6}$$

where W_t^I is the impatient's nominal wage rate, ΔL_t^H is change in stock of debt at the end of period t, r_{t-1}^H is the predetermined[1] interest rate

[1] An important note is that for household default to have a real effect it is important to

associated with $t-1$ period debt. χ_t^H is an endogenous fraction of debt defaulted, Ω_t^H is search costs and S_t is bank asset seizure, both associated with period $t-1$ default decisions.

Now we describe the latter three items in more detail. In this setting, a representative impatient household has full control of the default rate χ_t^H on previous period's debt (L_{t-1}^H). This fraction can also be interpreted as the share of individual household family members who have fully defaulted on their debt obligations. A virtue of this way of modelling is that the household does not automatically default on the basis of some specific rule, like in Bernanke et al. (1999), but takes into account all relevant variables and weighs the costs of default against the benefits.

The search costs are understood as an inconvenience or rejected loan applications for the impatient household sector as a whole, resulting from past default decisions and worsening of credit score. The costs incurred at time t due to default at period $t-1$ are:

$$\Omega_t^H = \frac{\psi_D}{2} \left(\chi_{t-1}^H L_{t-2}^H\right)^2 . \tag{2.7}$$

It is important that search costs are quadratic in the nominal size of the default ($\chi_{t-1}^H L_{t-2}^H$), what ensures model stability. The parameter ψ_D controls the magnitude of search costs, and hence influences the willingness to default. In contrast to de Walque et al. (2010)'s specification, we do not find necessary to include the (linear) default stigma costs in the instantaneous utility function, neither for model stability, nor for determinacy.

We assume that household's borrowing from the banking sector is secured with housing. As is usual, the household can borrow up to a certain limit which is a fraction of the nominal value of housing which serves as a collateral[2]. The standard borrowing limit, popularised by

have non-state-contingent interest rates that are predetermined. Otherwise, there would be an instantaneous change in the interest rate equalling the amount of delinquency, what completely offsets any bank losses.

[2]Some papers like Forlati and Lambertini (2011) or Darracq Pariès et al. (2011) do

Kiyotaki and Moore (1997) and used in papers with mortgages (e.g. Iacoviello, 2005; Gerali et al., 2010; Angelini et al., 2014) and mortgage default (e.g. Bekiros et al., 2017; Nookhwun and Tsomocos, 2017), is most suitable for one-period loans. However, introduction of multi-period loans can have an impact on monetary or macroprudential policy transmission mechanism (see e.g., Brzoza-Brzezina et al., 2014; Brzoza-Brzezina, 2014). Gelain et al. (2015, 2018) showed that multi-periodicity can be modelled using a stock mortgage variable entering the budget constraint conventionally, however, the borrowing limit should be an autoregressive version of the traditional Kiyotaki and Moore (1997) constraint. It has also been applied in Iacoviello (2015) and Chen and Columba (2016), among others. To account for multi-periodicity and more accurate loan dynamics, we use the following dynamic borrowing constraint:

$$L_t^H \leq \rho L_{t-1}^H + (1-\rho)\eta_{H,t} P_t^H H_t^I, \tag{2.8}$$

where ρ coefficient controls the jumpiness of mortgage stock (L_t^H). The parameter approaches zero for one-period loans and unity for long term borrowing. η_t^H is an exogenous policy variable that we interpret as a loan to value cap. The specification suggests that for multi period loans changes in LTV policy should have a prolonged impact. Long term mortgage stock to housing value ratio is equal to η_H.

Unlike in de Walque et al. (2010), we assume that any default would result in asset seizure by the bank. Otherwise, the collateral constraint would serve only as a limit on borrowing, and the word *collateral* would be meaningless. In fact, the problem of moral hazard and asset seizure is the motive behind the prevalent usage of LTV constraints. The already mentioned example models of Darracq Pariès et al. (2011) and Forlati and Lambertini (2011), their followers Bekiros et al. (2017) and Nookhwun and Tsomocos (2017), have both BGG framework for mortgage default and housing seizure.

not explicitly introduce an exogenous LTV constraint but rather derive it endogenously.

Any delinquency should result in bank's seizure of a fraction of household's assets that is proportional to the size of the default rate. For the baseline version of the model we choose that the bank always seizes the whole house (proportional to the fraction defaulted χ_t^H) and sells it at the market value P_t^H:

$$S_t = P_t^H \chi_{t-1}^H H_{t-2}^I. \tag{2.9}$$

In normal times, when house prices are relatively stable, this type of asset seizure would incur large costs on the household because the nominal value of the seized house would be much higher than that of the defaulted amount. To see the point of this argument, let us assume for now that $\rho = 0$, and that the LTV constraint (2.8) holds with equality. Asset seizure at time t would be the following:

$$S_t = P_t^H \chi_{t-1}^H H_{t-2}^I \equiv \chi_{t-1}^H \frac{1}{\eta_{H,t-2}} \frac{P_t^H}{P_{t-2}^H} L_{t-2}^H.$$

If we divide nominal size of asset seizure by the nominal amount defaulted, we have:

$$\frac{S_t}{\chi_{t-1}^H L_{t-2}^H} = \frac{1}{\eta_{H,t-2}} \frac{P_t^H}{P_{t-2}^H} \lesseqgtr 1.$$

Using this equation, and ignoring search costs, one can see that if the house price drops by at least $\eta_{H,t-2}$, the seized amount is lower than the amount defaulted. Alternatively, the seizure is relatively high compared to the amount defaulted, and the process is painful for the delinquent party. The household can still default because it is highly impatient (see Equation (2.13), where costs and benefits of default are compared). For alternative asset seizure specification, please, see Subsection 2.4.2 andAppendix B. Judging from the equation above, one can immediately see the virtue of the LTV limit at the origination. Higher LTV implies a lesser down payment for the household and makes asset seizure relatively smaller compared to the size of the default. On the other hand, loose LTV is a concern for the bank because it makes the bank more susceptible to house price drops.

The impatient household chooses paths of C_t^I, L_t^I, H_t^I, L_t^H and default rate χ_t^H to maximise its expected discounted lifetime utility subject to the borrowing limit (2.8) and budget constraint (2.6). The Lagrangian is the following:

$$\mathscr{L}^I = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_I^t \Bigg(U\left(C_t^I, H_t^I, L_t^I, \chi_t^H\right) + \\ + \lambda_{1,t}^I \Big(P_t C_t^I + \left(1 + r_{t-1}^H - \chi_t^H\right) L_{t-1}^H + P_t^H \left(H_t^I - H_{t-1}^I\right) + \\ + \left(P_t^H \chi_{t-1}^H H_{t-2}^I\right) + \frac{\psi_D}{2}\left(\chi_{t-1}^H L_{t-2}^H\right)^2 - W_t^I L_t^I - L_t^H \Big) + \\ + \lambda_{2,t}^I \Big(L_t^H - \rho L_{t-1}^H - (1-\rho)\eta_{H,t} P_t^H H_t^I \Big) \Bigg).$$

Optimisation results in the following conditions:

$$\sigma_L L_t^I = \frac{W_t^I}{P_t C_t^I}, \tag{2.10}$$

$$\beta_I \mathbb{E}_t \left[\frac{1}{P_{t+1} C_{t+1}^I} \left(1 + r_t^H - \chi_{t+1}^H\right) + \rho \lambda_{2,t+1}^I + \beta_I \psi_D \left(\chi_{t+1}^H\right)^2 \frac{L_t^H}{P_{t+2} C_{t+2}^I} \right] = \frac{1}{P_t C_t^I} + \lambda_{2,t}^I, \tag{2.11}$$

$$\frac{\sigma_{H,t}}{H_t^I} - (1-\rho)\eta_{H,t}\lambda_{2,t}^I P_t^H + \beta_I \mathbb{E}_t \left[\frac{P_{t+1}^H}{P_{t+1} C_{t+1}^I} \right] = \frac{P_t^H}{P_t C_t^I} + \beta_I^2 \mathbb{E}_t \left[\chi_{t+1}^H \frac{P_{t+2}^H}{P_{t+2} C_{t+2}^I} \right], \tag{2.12}$$

$$\frac{L_{t-1}^H}{P_t C_t^I} = \beta_I \mathbb{E}_t \left[\frac{1}{P_{t+1} C_{t+1}^I} \left(P_{t+1}^H H_{t-1}^I + \psi_D \chi_t^H \left(L_{t-1}^H\right)^2 \right) \right] \tag{2.13}$$

Labour supply equation (2.10) is no different from that of patient household's. The Euler equation (2.11) takes discounted expected cost of borrowing, what consists of interest, debt repayment net of defaults and future search costs, and equalises to marginal utility of additional consumption, taking into account the collateral constraint ($\lambda_{2,t}^I$). The housing demand equation (2.12) also has cost and benefit terms. On the benefit side of additional housing there is positive value from a looser borrowing constraint and positive future consumption in case of a resell if house prices increase. Note, that high LTV limit ($\eta_{H,t}$) increases the marginal utility coming from the borrowing constraint. The cost side involves foregone current consumption and future loss of housing (two-periods ahead) in case of default. The last equation equalises marginal utility of default, which is more consumption, to a marginal cost, which is lost future housing and increased search costs.

The collateral constraint (2.8) is binding around the small neighbourhood of the steady state[3] as long as $\beta_I < \eta_H$, presuming that shocks hitting the economy are sufficiently small.[4]

2.2.2 Firms

Firm sector is identical to that described in Chapter 1. However, in this setting there are two households which provide labour services at their respective wage rates. The total labour employed by the intermediate producer is the following index:

$$L_t = \left(L_t^P\right)^{\nu}\left(L_t^I\right)^{(1-\nu)}. \tag{2.14}$$

Cost minimisation of total labour expenditure $W_t L_t \equiv W_t^P L_t^P + W_t^I L_t^I$ gives the optimal labour demand ratio:

$$\frac{L_t^P}{L_t^I} = \frac{\nu}{1-\nu}\frac{W_t^I}{W_t^P}. \tag{2.15}$$

2.2.3 Banks

The bank has a stylised balance sheet comprised of two assets (loans to firms and households), liabilities in the form of deposits and foreign

[3]Most papers assume that the borrower is impatient enough so that the inequality constraint is binding at all times. Guerrieri and Iacoviello (2017) use an occasionally binding constraint which. In our case policy changes are sufficiently small that in the small neighbourhood around the steady state the LTV constraint is always binding.

[4]In fact, there is an additional condition for the constraint to be binding: $\beta_I\left(1+r^H\right) - \beta_I^2\frac{\chi^H}{\eta_H} < 1$. However, given the assumption $\beta_I < \eta_H$ and our subsequent calibration of the model, that additional condition is always satisfied.

debt (F_t), current profits (π_t^B) and accumulated earnings (Π_t^B):

$$L_t^H + L_t^F = D_t + F_t + \pi_t^B + \Pi_t^B. \tag{2.16}$$

Note that in this specification current quarter's profits enter the balance sheet separately from bank accumulated earnings which is considered as regulatory capital[5]. The motion equation for bank capital is the following:

$$\Pi_t^B = \Pi_{t-1}^B - DivB_t + \pi_{t-1}^B, \tag{2.17}$$

where $DivB_t$ denotes endogenous bank dividends and π_{t-1}^B is bank profits transferred from last period's balance sheet. Assuming that bank dividends are non-negative, the bank may accumulate capital only from retained earnings; thus, external equity financing is assumed away for simplicity.

Our specification differs from other papers (e.g., de Walque et al., 2010; Gerali et al., 2010; Vītola and Ajevskis, 2011; Iacoviello, 2015; Pedersen, 2016) in at least three dimensions. Firstly, current quarter's profits are unaudited (π_t^B), thus do not count as regulatory bank capital, in line with European regulation[6]. Secondly, all bank capital from the previous period Π_{t-1}^B is carried forward to current period, whereas abovementioned authors assume that a small fraction is used up for bank management. Thirdly, dividend stream is fully endogenous and at banker's discretion in our model, whereas some authors assume that they are a fixed fraction of bank capital/equity. We believe that our set of assumptions are more realistic and hence should produce more convincing dynamics of bank capital and other balance sheet items.

The bank earns interest income on loans (corporate and household) and pays interest on deposits and foreign borrowing. Impatient household mortgage defaults reduce the bank t period profits by $\chi_t^H L_{t-1}^H$ but the

[5] Here terms regulatory capital, bank capital or accumulated earnings will be used as synonyms.

[6] See Article 26(2)(a) of Regulation (EU) No 575/2013 CRR.

bank is able to seize the impatient's house as a collateral and sell it in the open market the next period $t+1$ for $(1-o)\chi_t^H P_{t+1}^H H_{t-1}^I$, where o represents a fraction that is considered as monitoring or administration costs such as bailiff fees [7]. All these items are reflected in the profit equation:

$$\pi_t^B = \left(r_{t-1}^H - \chi_t^H\right) L_{t-1}^H + r_{t-1}^L L_{t-1}^F - r_{t-1}^D D_{t-1} - r_{t-1}^F F_{t-1} + \\ + (1-o)\chi_{t-1}^H P_t^H H_{t-2}^I,$$

where r_t^H, r_t^L, r_t^D and r_t^F denote, respectively, nominal interest rates on loans (household and firm), deposits and banks' foreign debt.

The last term in the bank's profit equation is income after asset seizure, resulting from previous mortgage defaults (see Subsection 2.2.1.2 for more details). The way it is specified it is not directly influenced by the bank. However, it is no surprise from the bank's perspective that loose lending would result in higher future foreclosures and receipts from asset seizure. Since the collateral constraint (2.8) of the impatient household is binding, the bank is aware of that. Therefore, we plug the LTV constraint in place of H_{t-2}^I in the profit equation:

$$\pi_t^B = \left(r_{t-1}^H - \chi_t^H\right) L_{t-1}^H + r_{t-1}^L L_{t-1}^F - r_{t-1}^D D_{t-1} - r_{t-1}^F F_{t-1} + \\ + \frac{(1-o)}{(1-\rho)} \frac{\chi_{t-1}^H}{\eta_{H,t-2}} \frac{P_t^H}{P_{t-2}^H} \left(L_{t-2}^H - \rho L_{t-3}^H\right). \tag{2.18}$$

Now it is evident that banks are aware that past lending might influence profitability through defaults and asset seizure. If house prices are falling, and especially when the rate of fall is bigger in magnitude than $1-\eta_{H,t-2}$, the defaults can be very dangerous to bank profitability, because the collateral is not enough to cover the losses. The administrative

[7] Alternatively, Nookhwun and Tsomocos (2017) call it costly state verification after Townsend (1979). Regarding the recipient of these outlays, Clerc et al. (2015) consider it as a deadweight loss, while Nookhwun and Tsomocos (2017) or Quint and Rabanal (2014) assumed some share attributed to households.

cost parameter o is calibrated so that the bank would not profit off asset seizure in a stable house price environment.

Most authors tend to include LTV constraint in the optimisation of the borrowing party, as we did. However, the expanded profits specification above suggests that LTV caps directly influence banker's optimisation problem, and thus credit supply, what will be evident in later simulations.

Before we move to optimisation, a couple of things should be addressed. Firstly, the banks are owned by a foreign-based banker who is a hand-to-mouth consumer and finances her foreign consumption with dividend payouts. Secondly, although the model in its form does incorporate household credit default risk, that does not imply that a significant share of bank financing should come in the form of equity financing. In order to institute positive bank equity we assume that the banker receives utility from increasing bank capital buffer over the regulatory minimum. Below is the banker's instantaneous utility function:

$$U_t^B = \log\left(C_t^* + \Omega_t^B\right), \tag{2.19}$$

where C_t^* is banker's foreign consumption and Ω_t^B is a utility term that captures the benefit of excess bank capital. We specify the latter as a logarithmic function as in Furfine (2001):

$$\Omega_t^B = \gamma \log\left(a + CR_t - \mu_t\right)\frac{RWA_t}{P_t^*}, \tag{2.20}$$

$$RWA_t = \omega_{H,t} L_t^H + \omega_{F,t} L_t^F, \tag{2.21}$$

$$CR_t = \frac{\Pi_t^B}{RWA_t}, \tag{2.22}$$

where CR_t is the (regulatory) capital adequacy ratio, μ_t is the minimum requirement, RWA_t denotes risk-weighted assets, $\omega_{H,t}$ and $\omega_{F,t}$ are exogenous risk weights. γ is the parameter reflecting the utility associated with a thick capital buffer.

The specification of banker's preferences requires detail. To start with equation (2.20), we assume a logarithmic function because we think there should be diminishing returns from excessive capital. Since the domain of the log involves capital buffer in terms of capital ratio, it is necessary to amplify the magnitude of capital ratio benefits when the bank balance sheet is large, thus is multiplication by the risk-weighted assets, otherwise it would be dwarfed by the magnitude of consumption C_t^*. Assuming $a = 0$, the log function would not be defined when capital buffer vanishes, thus we introduce $a > 0$ to allow for a possibility for the capital to be below requirement (as in Furfine, 2001). $\mu_t - a$ can be interpreted as an excruciating level of capital ratio that would be associated with log that is not defined.

The utility function (2.19) is essentially a double log in terms of capital adequacy, what is a special case of the Greenwood–Hercowitz–Huffman (GHH) preferences. There are a couple of reasons why we chose this form. Firstly, the GHH preferences imply that, like in consumption and labour problem for a typical household, the capital adequacy choice is roughly independent of the level of banker's consumption. We believe this is realistic to assume, because when banker's dividends (consumption) go down, the bank still has to be compliant with capital regulation and all other requirements. Secondly, particular functional form of these preferences allows for an analytical steady state solution and model calibration.

We also specify the upward sloping foreign financing supply function, similar to Schmitt-Grohé and Uribe (2003). It states that the interest rate on banks' foreign debt positively depends on the nominal foreign debt-to-GDP ratio:

$$r_t^F = r_t^* + \phi \frac{F_t}{P_t Y_t}, \tag{2.23}$$

where r_t^* is the risk-free interest rate on borrowing in foreign financial markets and ϕ is a non-negative parameter that controls the risk premium.

After we combine banker's budget constraint ($P_t^* C_t^* = DivB_t$) with utility function (2.19), profit equation (2.18), balance sheet (2.16), foreign debt supply rule (2.23) and bank capital motion equation (2.17), we have the following Lagrangian:

$$\begin{aligned}\mathscr{L}^B = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_B^t \Big\{ & \log\left(DivB_t + \gamma \log\left(a + CR_t - \mu_t\right) RWA_t\right) - \log P_t^* + \\ & + \lambda_{1,t}^B \Big(\pi_t^B - \left(r_{t-1}^H - \chi_t^H - r_{t-1}^D\right) L_{t-1}^H - \left(r_{t-1}^L - r_{t-1}^D\right) L_{t-1}^F + \\ & \qquad + \left(r_{t-1}^F - r_{t-1}^D\right) F_{t-1} - r_{t-1}^D \pi_{t-1}^B - r_{t-1}^D \Pi_{t-1}^B - \\ & \qquad - \frac{(1-o)}{(1-\rho)} \frac{\chi_{t-1}^H}{\eta_{H,t-2}} \frac{P_t^H}{P_{t-2}^H} \left(L_{t-2}^H - \rho L_{t-3}^H\right) \Big) + \\ & + \lambda_{2,t}^B \left(\Pi_t^B - \Pi_{t-1}^B + DivB_t - \pi_{t-1}^B\right) \Big) \Big\}.\end{aligned}$$

Maximising with respect to π_t^B, $DivB_t$, L_t^H, L_t^F, F_t and Π_t^B yield the following first-order conditions:

$$\frac{1}{DivB_t}\left(\frac{a + CR_t - \mu_t}{\gamma + CR_t - \mu_t}\right) = \beta_B \mathbb{E}_t \left[\frac{1}{DivB_{t+1}}\right]\left(1 + r_{D_t} + \frac{\gamma}{a + CR_{t+1} - \mu_{t+1}}\right), \tag{2.24}$$

$$\lambda_{1,t}^B = -\left(DivB_t \left(1 + \frac{\gamma}{a + CR_t - \mu_t}\right)\right)^{-1}, \tag{2.25}$$

$$\begin{aligned}\beta_B \mathbb{E}_t \Bigg[& \lambda_{1,t+1}^B \left(r_t^H - \chi_{t+1}^H - r_t^D\right) + \lambda_{1,t+2}^B \beta_B \frac{(1-o)}{(1-\rho)} \frac{\chi_{t+1}^H}{\eta_{H,t}} \frac{P_{t+2}^H}{P_t^H} - \\ & - \lambda_{1,t+3}^B \rho \beta_B^2 \frac{(1-o)}{(1-\rho)} \frac{\chi_{t+2}^H}{\eta_{H,t+1}} \frac{P_{t+3}^H}{P_{t+1}^H} \Bigg] = \gamma \omega_{H,t} \lambda_{2,t}^B \mathscr{Z}_t,\end{aligned} \tag{2.26}$$

$$\beta_B \mathbb{E}_t \left[\lambda_{1,t+1}^B \left(r_t^L - r_t^D\right)\right] = \gamma \omega_{F,t} \lambda_{2,t}^B \mathscr{Z}_t, \tag{2.27}$$

$$F_t = P_t Y_t \left(\frac{r_t^D - r_t^*}{\phi}\right), \tag{2.28}$$

$$\mathscr{Z}_t = \left(\frac{CR_t}{a + CR_t - \mu_t} - \log\left(a + CR_t - \mu_t\right)\right).$$

There is a close analogy between the banker's Euler equation (2.24) and the household's Euler equation (2.4). The banker equates the marginal rate of substitution between dividends today and tomorrow to the relative price of dividend pay-outs. Expansion of bank capital reduces the alternative cost of deposit-financing and increases marginal utility stemming from wider capital buffer.

Equations (2.26) and (2.27) establish that bank's capital buffers are increasing along with an increasing interest rate margin. What is more, mortgage supply rule (2.26) states that interest rates are higher when expectations for future defaults, net of asset seizure, increase. Tight collateral constraint or expectations of house price growth suppress the mortgage interest rate margin. Equation (2.28) governs demand for foreign debt, which is positive when deposit rates are higher than the risk-free rate. Also, all else being equal, the lower risk-free foreign rate naturally implies stronger demand for bank's borrowing from abroad.

2.2.4 General equilibrium

Adding the households' budget constraints together with the firm's and bank's balance-sheet constraints, we obtain the following identities

$$P_t Y_t = P_t \left(C_t^P + C_t^I \right) + P_t I_t + \Omega_t^I + \Omega_t^P + \Omega_t^H + o\chi_{t-1}^H P_t^H H_{t-2}^I + P_t NX_t, \quad (2.29)$$

$$P_t NX_t - DivB_t - r_{t-1}^F F_{t-1} = -\Delta F_t, \quad (2.30)$$

where NX_t is the net exports. Equation (2.29) is simply an aggregate resource constraint. Equation (2.30) is the simplified balance-of-payments identity, which states that the combined current and capital account, comprised of net exports and net financial income from abroad in this simple economy, must equal the financial account, or in this case simply the change in foreign debt. The nominal gross domestic product is defined as net output (output minus adjustment costs):

$$NGDP_t = P_t Y_t - \Omega_t^I - \Omega_t^P. \quad (2.31)$$

Since monetary policy is absent from this economy, Taylor rule is unavailable. Therefore, a closing equation is necessary to be able to identify the price level, as in Aoki et al. (2018). We assume that the domestic price level is determined by an external competitiveness condition which relates net exports to the the real exchange rate and domestic consumption:

$$NX_t = n_1 \left(\frac{P_t}{P_t^*} \right)^{-n_2} - n_0 \left(C_t^P + C_t^I \right). \tag{2.32}$$

A very similar approach is taken by Vītola and Ajevskis (2011) in their model of the Latvian economy, as well as Aoki et al. (2018). We assume there is no inflation in foreign economy:

$$P^* = P_t^* = 1. \tag{2.33}$$

The supply of housing is fixed, which implies the following clearing condition:

$$H_t^P + H_t^I = 1 \tag{2.34}$$

A full list of model equations is presented in Appendix B.

2.3 Calibration

We calibrate the model's parameters to match some general macroeconomic ratios of the Lithuanian economy at quarterly frequency. The matched first moments of the data are tabulated in Table 2.1, and chosen parameter values are presented in Table 2.2. The numerical values for α, β_F, δ, and η_K are chosen simultaneously to produce the following steady state ratios: corporate loans to annual GDP ratio of 24%, investment to GDP ratio of 21%, the capital share in aggregate income of 31% and firms' return on equity of 8%, in line with the corresponding historical averages in Lithuania, using Statistics Lithuania data ranging from 2001 to 2016. α and δ are the same as in annualised version in Table 1.1. The value of $\varepsilon = 34$ is large compared to Rubio and Comunale (2016), however, it was chosen so that the β_F would be sufficiently low in the (simultaneous) calibration exercise, what would imply a binding firm collateral constraint. The ε-implied elasticity of demand for intermediate goods constitutes a mark-up of 3%.

Table 2.1: Matched steady state ratios (annualised).

Variable	Interpretation	Value (%)
L_F/PY	Corporate debt to GDP ratio	24
I/Y	Investment share	21
WL/PY	Labour compensation share	69
π/Π	Firm's ROE	8.2
r^D	Interest rate on deposits	1.2
$L^H/P^H H^I$	Loan to collateral ratio (average)	78
L_H/PY	Mortgage debt to GDP ratio	16
χ^H	Mortgage non-performing loans ratio	5
μ	Bank capital requirement (average)	14.5
CR	Bank capital adequacy ratio	19
r^H	Interest rate on mortgages	3.4
r^L	Interest rate on firm loans	3.9
$\pi^B/(\pi^B+\Pi^B)$	Banks' ROE	10
r^*	Risk-free interest rate	1.06
F/PY	Bank net external debt to GDP ratio	12

The investment adjustment cost parameter $\psi_I = 2.65$ is taken from the Bayesian mean estimate in Vītola and Ajevskis (2011). The price adjustment cost parameter $\psi_P = 380$ in our model would correspond to a 75% chance that prices will remain unchanged in a given quarter – a typical probability in models with Calvo pricing. Both ψ_I and ψ_P correspond to the same values taken from Table 1.1.

The patient household's discount factor $\beta = 0.987$ corresponds to the historical average nominal interest rate on private sector deposits (including both sight and term deposits) of 1.3%, as in Table 1.1 and similar to Proškutė (2012). $\nu = 0.75$ is chosen to approximate the share of impatient households to be around 25%, what is consistent with historical share of housing purchases financed with bank debt. $\eta_H = 0.78$ is equal to the historical average LTV of new housing loans – the same as in

Table 2.2: Parameter values.

Parameter	Description	Value
α	Capital share in the production	0.29
δ	Depreciation rate for physical capital	0.039
η_K	Loan to value cap for firms loans	0.18
β_F	Firm management's discount factor	0.986
ε	Elasticity of demand for intermediate goods	34
ψ_P	Price adjustment costs parameter	380
ψ_I	Investment adjustment costs parameter	2.65
β_P	Patient household's discount factor	0.997
ν	Patient household's share of labour income	0.75
η_H	Housing loans to collateral value ratio	0.78
ρ	AR parameter in mortgage LTV equation	0.7
σ_H	Utility from housing	0.66
σ_L	Disutility from labour	1.05
β_I	Impatient household's discount factor	0.75
ψ_D	Size of quadratic default search costs	2.537
μ	Minimum capital requirement	0.145
a	Parameter related to bank capital level	0.085
ω_H	Risk weight on mortgages	0.5
ω_F	Risk weight on corporate loans	1.55
γ	Banker's utility from capital buffer	1.212×10^{-3}
o	Mortgage monitoring costs	0.44
β_B	Banker's discount rate	0.988
ϕ	Foreign debt interest rate sensitivity	7.291×10^{-3}
n_0	Imports to consumption share	0.9
n_1	Constant exports demand	1.8
n_2	Price elasticity of exports demand	1

Rubio and Comunale (2016). $\rho = 0.7$ is taken from Iacoviello (2015) what ensures that mortgages are a slow moving variable, with average maturities over 20 years. σ_H is consistent with mortgage debt to annual GDP ratio of 16% and σ_L ensures that impatient's labour is equal to unity in the steady state. $\beta_I = 0.75$ – a rather large value, compared to 0.94 in Iacoviello (2015) – chosen sufficiently low to ensure that the LTV constraint is binding and household default rate is positive. $\psi_D = 2.537$ corresponds to an average mortgage NPL rate of 5% in Lithuanian banking sector.

Minimum bank capital requirement parameter $\mu = 0.145$ corresponds to recent value of average capital requirements for banks in Lithuania (including Pillar I and Pillar II capital). Value of $a = 0.085$ was chosen so that the excruciating capital ratio would be associated with 6%. These are roughly Basel 2 type capital requirements excluding capital buffers and additional individual bank requirements. $\omega_H = 0.5$ is consistent with historical average risk weight on mortgages in Lithuania's banking sector. We jointly calibrate parameter values of ω_F, γ, o and β_B to produce capital ratio of 19%, average mortgage interest rate of 3.4%, corporate debt interest rate of 3.9% and bank ROE of 10%. The latter three ratios correspond to Lithuanian data averages, and capital ratio of 19% is a recent level of capitalisation in the banking sector. Foreign financing supply ϕ is calibrated to make bank's net foreign debt to GDP ratio equal to 12%.

Turning to the parameters related to the foreign trade, the parameter $n_0 = 0.9$ reflects the historical average imports to consumption ratio in Lithuania. As there is little empirical evidence about the long-term equilibrium level of trade balance, we arbitrarily choose the parameter n_1 to ensure that in the steady state there is a small trade surplus, which would offset financial outflows in the form of bank dividends and interest rate payments on foreign debt (resulting in the balanced current account in the steady state). The value of the parameter n_2, governing the price elasticity of exports, is set equal to 1, like in Vītola and Ajevskis (2011).

2.4 Analysis and results

This section is devoted to the analysis of the short term impact of tightening of three prudential policy instruments, namely, the bank capital requirement, mortgage risk weight and cap on loan to value for mortgages.

2.4.1 Some steady state conditions

In this subsection we take a look at some of the analytically derived steady states from the banker's problem, to understand what impacts the capital ratio and interest rates on loans in the long term. Although this comparative statics exercise is done for the steady state, it sheds light on the short-run dynamics as well. The steady state bank capital adequacy ratio can be expressed as:

$$CR = \mu - a + \frac{\gamma(1-\beta_B r^D)}{1-\beta_B r^D - \beta_B}. \tag{2.35}$$

It is visible that in the steady state the capital ratio (CR) increases one-to-one with the regulatory minimum μ. The excess capital buffer $(CR-\mu)$ positively depends on the deposit interest rate r^D, which is the cost of debt financing. Rising banker's impatience, roughly the opportunity cost of accumulating bank capital, decreases the CR ($\beta_F \downarrow \Longrightarrow CR \downarrow$). This can be understood as rising returns outside the banking sector, which decrease the willingness to hold more bank capital.

Although the CR is calculated as the ratio of capital to risk weighted assets, the steady state CR is independent of the risk weights. However, risk weights (ω_F, ω_H) can be understood as capital intensity of each asset type, exerting influence on portfolio allocation and interest rates. The steady state interest rates of corporate and mortgage loans can be expressed as:

$$r^L = r^D + \omega_F \mathscr{M}, \tag{2.36}$$

$$r^H = r^D + \omega_H \mathscr{M} + \chi^H \left\{ 1 - \frac{\beta_B(1-o)(1-\beta_B\rho)}{(1-\rho)\eta_H} \right\}, \tag{2.37}$$

with $\mathscr{M} = \frac{\gamma}{\beta_B}\left(\frac{CR}{(a+CR-\mu)} - \log(a+CR-\mu)\right)\frac{(a+CR-\mu)}{(a+CR-\mu-\gamma)}$ being overall cost of equity. We see that in the latter two pricing equations, risk weights act as loan-specific linear transformations from the cost of equity to interest rates. When a risk weight of a certain type of loan rises, that loan becomes more capital-intensive, which translates into higher capital costs and thus interest rates.

The interest rate on corporate loans is a sum of cost of debt (r^D) and cost of equity ($\omega_F \mathscr{M}$), whereby the mortgage rate also includes the risk premium. One can see that when mortgage delinquencies (χ^H) rise in the steady state, the interest rates are incremented less than 1-to-1. This is because after a delinquency occurs, the bank is able to seize household's collateral and sell it in the open market. Careful inspection of the risk premium suggests that when administrative or monitoring costs (o) rise, bank's net losses are greater, so the premium is higher. Given the baseline assumption that the bank seizes the whole house (see discussion in Subsections 2.2.1.2 and 2.2.3), in case of mortgage delinquency and absent monitoring costs ($o = 0$), the bank can profit in stable house price environment. The size of monitoring costs is calibrated so that the bank wouldn't profit from asset seizure, and that the risk premium would be positive.

Interestingly, the cap on loan to value ratio (η_H) is also present in the pricing equation (2.37). This result, as can be seen in later simulations, is a direct result of the banker's awareness that high collateral seizure is associated with past loose lending. When collateral constraint becomes tight, the household has to use more own-funds for a house purchase, therefore the bank becomes more covered in a case of default. As a result of the increased banker's protection, the mortgage riskiness decreases and thus the interest rate is lower. It implies that the LTV limit has a direct impact on the credit supply. While tight constraint has a positive effect on the supply, a loose constraint can leave the bank vulnerable to asset price drops, and thus contributes negatively to the credit supply.

Using the formulas above, the mortgage spread can also be expressed in this convenient fashion:

$$r^H - r^D = \underbrace{\frac{\omega_H}{\omega_F}\left(r^L - r^D\right)}_{\text{opportunity cost}} + \underbrace{\chi^H \left\{1 - \frac{\beta_B(1-o)(1-\beta_B\rho)}{(1-\rho)\eta_H}\right\}}_{\text{risk premium}}, \tag{2.38}$$

where one could see that mortgage spreads and corporate spreads are positively related. As in a typical problem of portfolio management, corporate loan rate can be considered as an opportunity cost of allocating funds towards mortgages. Any increase in the profitability of corporate lending should reduce the mortgage supply and increase the rates thereafter. The sensitivity of this pass-through is defined by the ratio of mortgage to corporate risk weights. The more mortgages are capital intensive, compared to corporate loans, the greater the pass-through from higher corporate returns, all else being equal.

2.4.2 LTV tightening

Here we take a look at the model's responses to a permanent decrease in LTV limit by 1 p.p. This can be understood as a reduction in the regulatory risk appetite in order to safeguard the debtors and lenders. LTV constraint is usually understood as a demand-side-only constraint, entering borrower's optimisation (see e.g., Kiyotaki and Moore, 1997; Iacoviello, 2005; Gerali et al., 2010; Justiniano et al., 2015). Using the baseline asset seizure assumption, we show that a tightening of LTV limit has non-negligible credit supply-side impact. We compare the model variable responses against the framework in which the bank is able to recover the whole amount defaulted, instead of seizing the whole house.

Baseline – seizure of the whole house

Model variable responses to a permanent LTV tightening by 1 p.p. are visible in Figure 3.2 of Appendix B. There are three important developments related to household mortgages. Firstly, when an LTV cap is lower, the impatient household has comparatively more to lose when defaulting on a mortgage, thus the default rate decreases by around 1.75% over 5 years. Qualitatively, this response has been found in micropanel studies like González et al. (2016) or Mihai et al. (2018). Secondly, there is a significant reduction in interest rates on mortgages by 0.3 to 0.6 p.p. Thirdly, lending decreases immediately by 0.5%, followed by a peak decline of around 2% in the medium term and then 0.5% again in 5 years. Both interest rate and lending falls suggesting of a dominant negative demand factor in the market. However, the banker, when optimising, takes into account both household default rate and the LTV (see equations (2.26) and (2.37)). Both these factors make housing loans a safer investment from bank's perspective. *Lower loan to value ratio implies that a bank loses less after a default happens, but also the household default rate is decreased. This contributes to an increase in mortgage supply which reinforces the drop in interest rate (lower margins) but attenuates the negative response in mortgage loans.*

Lending to the corporate sector also decreases by around 0.1% in 5 years with interest rates being more or less the same. As per house prices, they decrease nominally by around 0.15% and in real terms by around 0.1%. Overall, there is a negative impact on GDP in 4 years being around 0.1%, what exactly coincides with the figure of Richter et al. (2018). Since there is a general drop in economic activity and prices, we would characterise such tightening of requirements as a net drag on mortgage demand and aggregate demand.

Alternative – recovery of the whole amount defaulted

Assuming that the bank is able to recover the amount defaulted, nominal asset seizure is:

$$S_t = \chi_{t-1} L^H_{t-2}.$$

The associated first order conditions for the impatient household and the banker can be found in Appendix B. Under this assumption, the steady state interest rate on mortgages can be expressed (similarly to equation (2.37)) as the following:

$$r^H = r^D + \omega_H \mathscr{M} + \chi^H \left(1 - \beta_B (1-o)\right). \tag{2.39}$$

The loan supply equation (3.4) as well as the steady-state pricing equation both omit the LTV cap, unlike under assumption of seizure of the whole house. Therefore, the LTV constraint does not directly impact the loan supply, only through defaults (χ^H_t). Note that, absent monitoring costs ($o = 0$), mortgage defaults would result only in an intertemporal discomfort for the banker, because she would be able to recover the defaulted amount the next period. As such the interest rate risk premium would be equal to $\chi^H (1 - \beta_B)$.

Under this setting, the responses of variables to a permanent tightening by 1 p.p. are compared in Figure 3.3 of Appendix B. There is a substantial difference in how mortgage default and interest rates react. When a bank is able to recover the whole amount defaulted, the default rate, in fact, permanently increases by around 1 p.p. This translates to a roughly 50BP higher interest rate on housing loans. Also, actual mortgage stock falls by more than 1 p.p. compared to the baseline setting. These large movements in the interest rate and mortgage stock point to a negative shift in credit supply, which is mainly caused by a gradual increase in household delinquencies.

The discrepancy can be explained by two factors. First, the default reacts in opposite directions under the two settings. The second factor is the reaction of credit supply.

Under the baseline setting, bank seizure of the whole house after delinquency results in extraction of household's equity. For instance, say, LTV limit is 85% at the initiation of a mortgage, but household defaults, and the whole house is taken (including the collateralised part and the down payment). In this case the loss for the household is equal to 100%-85% = 15%. When LTV is tightened to say 75%, the net loss would amount to 25% which is greater. This equity extraction associated with default discourages any delinquency. Therefore, under the baseline assumption, the tightening of LTV constraint decreases the demand for debt but also default percentage. However, under the alternative setting, the household increases the default rate mainly because of the financing constraints. Since the ability to borrow is diminished, the household experiences hardship which leads to a greater marginal benefit of defaulting, thus increasing delinquencies.

Again, under the baseline setting, the credit supply directly depends on the mortgage default rate as well as the LTV cap. Since the LTV cap is lower, the bank loses less in case of default, so it expands its credit capacity. The lower mortgage default rates go down and this creates more positive supply pressure in the market. With reference to the discussion above, the LTV constraint does not directly impact the mortgage pricing and thus credit supply. However, the increased mortgage delinquencies raise the risk premium and thus create a negative shift in credit supply. These arguments are depicted in Figure 3.4 of Appendix B.

2.4.3 Tightening of bank-based measures

While the limit on loan to value ratio is considered to be a borrower-based instrument, bank capital requirements and risk weight floors are bank-based measures. In our model the LTV limit is internalised in the decision making of both the bank and the borrower, whereas the bank-based measures are not taken into account when optimising by the impatient household.

Bank capital requirements

In this subsection we do not differentiate between different capital add-ons or buffers. We assume that a regulatory authority requires all banks to permanently hold 1 p.p. higher capital ratio. The responses of our model economy are depicted in Figure 3.5 of Appendix B.

Accumulation of resources in the form of bank capital implies an opportunity cost in terms of foregone consumption for the owners, what directly translates into higher interest rates on bank loans. Firm rates respond smoothly, being 15-12 basis points (BP) higher. The response of mortgage rates is relatively more pronounced in the beginning with 7BP and normalises to 3BP in 5 years. The short-term estimate is close to 9.5BP estimate for commercial real estate loans of Glancy and Kurtzman (2018), where authors used micro level data. The reason why these two rate reactions differ is the increase in mortgage default rate in the medium term, which shows up as a higher mortgage risk premium. Overall, interest rate on firm loans increases more because the latter type bears higher risk weight than household loans.

While both types of lending contract by a similar amount of 0.2% in the longer term, corporate loans do decrease more than mortgages in the short run. This finding has been established in several other bank panel (e.g. Budrys et al., 2017; Mayordomo and Rodriguez-Moreno, 2018) and multivariate time series (e.g. Noss and Toffano, 2016; Kanngiesser et al., 2017) studies. An important source of this difference is that risk weights for corporate exposures are usually higher than those of mortgages. We also see that, as the bank is deleveraging, it reduces the amount of deposits (and foreign financing) and is able to steadily accumulate bank regulatory capital, even with higher dividend payouts. Higher dividend payouts are possible because of higher profits, which result from higher interest rate margins. The result that capital requirements can increase bank profitability is visible also in models of Gerali et al. (2010) and Vītola and Ajevskis (2011). When higher capital requirements are implemented for an individual bank, a response by raising interest margins would produce a loss in demand and therefore profitability. However, when capital requirements are applied for the sector as a whole, all banks increase their margins at the same time and thus can be more profitable.

With regards to the general macroeconomy, we see that responses of house prices and consumption are modest compared to that of investment, because corporate lending and its margins react more severely. Although the nominal house prices deflate, it is not as high as general deflation, making real house prices grow for some time. The impact on GDP is small and equal to around -0.02% in the short term and around -0.04% in the medium term. Judging from variable response, a tightening of bank capital requirements can be thought of as a negative credit supply shock (increased rates, reduced lending, e.g. see Justiniano et al., 2015) which traslates into a negative drag on aggregate demand (reduction in output and deflation).

Mortgage risk weight

Bank asset risk weights in reality are endogenous variables that move over time in response to bank's assessment of the underlying riskiness of its assets. As the economy expands, the perception of risk decreases, thus making risk weights counter-cyclical. Recent data shows (see Bruno et al., 2017) that after the financial crisis the risk weights of assets have been moving downwards, especially of those banks that use the internal ratings based (IRB) method. For a regulator this can cause a concern, whether these trends truly reflect the underlying asset riskiness. European Capital Requirements Regulation Art. 458 allows designated national authorities to exercise national flexibility measures and implement a floor for risk weights for a particular type of assets like mortgages. For some banks this floor might be binding, essentially raising the average risk weight (risk weight density) prevailing in the market for mortgages.

We implement a simulation of the model where risk weights on mortgages are raised by 5% (or 2.5 p.p. under baseline calibration) indefinitely. Such action increases overall risk-weighted assets, requiring more bank capital to keep the capital ratio constant. Special treatment of mortgage risk weights induces the latter asset class to be more capital-expensive. The model variable simulations are produced in Figure 3.6 of Appendix B. We see that mortgage interest rates rise by around 4BP in 5 years. This estimate is very close to the micro data based estimate of 3.5BP by Glancy and Kurtzman (2018)[8]. As per loan portfolio, corporate loans fall by up to 0.01% and mortgages by up to 0.1%. This clearly shows that there is a negative supply side shock in loans market, and a reshifting of bank portfolio towards corporate loans. Tight conditions in the mortgage market coupled with increased interest rates lead to a minuscule increase in household mortgage defaults. As in the case of tightening of capital requirement, the banking sector substitutes debt financing towards equity financing, as bank regulatory capital grows and leverage decreases. Also, the banking industry as a whole is able to accumulate capital even with increased bank dividends, resulting from higher profitability due to higher interest margins.

Like capital requirements, mortgage risk weight brings down the nominal house and goods prices in the economy, but overall deflation is higher than that of housing, leaving real house prices a bit higher. Since negative lending supply shock is a drag on domestic demand (consumption and investment), wee see the prices falling and through net exports

[8]In their estimation they used high volatility commercial real estate (HVCRE) risk weights that were increased from 100% to 150%, what amounts to an increase in interest rates by 35BP. Proportionately, if 50% – 35BP, then a 5% increase would imply a 3.5BP change in the interest rate.

increase. Although real GDP falls initially, it picks up in the medium term due to increased exports. All in all, the effects of changing mortgage risk weights are rather minuscule, as can be seen from the next subsection.

2.4.4 Comparison of effectiveness

Previous simulations show that all three instruments when tightened, can have negative impact on credit, mortgages and economic activity. Bank capital regulation is intended to safeguard banks against credit losses, which are a risk that can be of structural and cyclical nature. However, there can be an incentive for a regulator to use, for example, bank capital regulation for mortgage market stabilisation purposes. Demanding more bank capital might have unintended consequences for the economy and especially for the production sector. In this subsection, we compare the impact of the three prudential measures on the mortgage market and the general economy. To this end, we perform a simulation, in which all measures are separately tightened on a permanent basis. For the results to be comparable, we induce requirement changes so that the peak negative impact on credit market is equivalised to 0.1%. The resulting changes are depicted in Figure 3.7 of Appendix B.

One can immediately notice that tightening of capital requirements has the biggest negative drag on firm credit supply, i.e. the reaction of interest rate and credit is stock is the highest. This reduction in availability of funding leads to highest losses in output, compared to other scenarios. Increases in mortgage risk weights have the smallest impact on corporate debt credit market. These response functions indicate that broad based capital requirements is the least suitable instrument of the triplet for reducing mortgage growth, because it has non-negligible distortionary effect on production sector. Risk weight management and tightening of LTV limits seem like the more viable option for leaning against, for instance, unsustainable growth in the mortgage market. Capital requirements, e.g. the countercyclical capital buffer, can be better used as a tool address broad-based risks arising in the whole financial sector, not limited to some specific sector. The sectoral countercyclical capital buffer would be a more effective tool in dealing with cyclical risks that are of confined to a specific sector.

2.4.5 On timing

Here we compare the impacts of different timing of policy announcements and their welfare effects. We consider three scenarios or routes in which requirements are announced and implemented.

- Instant – in this route a requirement is announced and compliance is immediate
- Future – this scenario involves an announcement of a new requirement that would be effective after a year
- Gradual – this route includes an announcement that half of the new requirement should be implemented after 2 quarters, and the other half after another two quarters. This is a middle-ground version of Instant and Future scenarios.

Implementation of these three routes is done using deterministic simulations with perfect foresight. The results for the main model variables are depicted in Figure 3.8 of Appendix B.[9] It is visible that the Instant route for all prudential policy tightenings produces an instantaneous jump in interest rates and biggest drop in lending. As per house prices, all three routes produce similar a reaction. Regarding GDP, only the tightening of loan to value limit via Instant route produces the biggest drop compared to Future and Gradual. The peak differential is around 0.05 p.p. that

[9] The interest rate and loans variables are arithmetic averages of corresponding corporate and household variables.

is reached after the first announcement. Changes in output are very small for capital-related policy tightenings, as well as the differentials stemming from different scenarios.

Although looking at responses of different variables can be informative, it does not give the big picture. Next we look for the type of route that works best in terms of welfare. We define welfare as an *ex post* sum of both agents' discounted utility that was realised over 5 years:[10]

$$\mathscr{W}_t = \mathscr{W}_t^P + \mathscr{W}_t^I = \sum_{i=0}^{20} \left(\beta_P^i U_{t+i}^P + \beta_I^i U_{t+i}^I \right). \tag{2.40}$$

We compute welfare, defined above, for every scenario and compare Future and Gradual generated welfare against that of Instant route. Computed values are tabulated in Table 3.3 of Appendix B. Compared to the Instant route, both Gradual and Future routes are welfare improving, especially the latter. Although the losses in welfare of Instant route are very small, they add up to moral consequences and damage done by an a announcement of requirement that should be compiled with immediately. This is especially important for an LTV limit tightening. A household usually targets a house of some nominal value and saves for the down payment that is not covered by the loan. If an LTV limit is tightened without an early announcement, a fraction of people would have to postpone their purchase or buy a cheaper home, likely to generate less utility.

Figure 3.9 of Appendix B depicts the stock and annual growth rate of mortgages before and after the introduction of loan to value limit equal to 85% in Lithuania. The limit took effect in period 0, but there was an announcement of such policy change at least a half a year in advance. It is visible that significant frontloading happened, where people would take an advantage of such announcement and take out higher loan erlier.

[10]We focus more on the short term here, because there are no differences in the scenario impact in the long run. Also, the results are qualitatively the same if we take 200, 20, or 5 quarters for welfare comparison.

The red line shows that the rate of credit fall stabilised right around the introduction of the LTV limit. A similar frontloading is also visible in our DSGE model, where loan fall was smaller under Gradual and Future scenarios before the implementation of lower limit.

2.4.6 Mortgage monitoring costs

As was discussed in Subsection 2.4.1, the deadweight costs (o) that the bank experiences after collateral seizure, in case of loan default, are priced in the mortgage interest rates. Using our model, we conduct an experiment in which we unexpectedly and permanently lower the monitoring costs by 10% to see what effect it brings to the macroeconomy as a whole. The results are populated in Figure 3.10 of Appendix B.

Bank's mortgage administrative costs control the impact of mortgage defaults on pricing through risk premium, what can be seen from Equation (2.37). For example, if the $o = 1$, the costs of foreclosure are so high that all seized assets are lost. In effect, the default rate is carried through to the interest rate in full amount. Moving to the other extreme, where $o = 0$, there are no costs when seizing assets, thus the impact of default rates in loan pricing is minimal. In essence, any reduction in o can be seen as an increase in credit supply. This is clearly seen from Figure 3.10 that over around 5 years the mortgage stock expands by around 0.5% and the interest rate decreases by around 30BP. From bank portfolio allocation perspective, it can be viewed that there is a slight shift from corporate lending towards mortgaging. As lending to firms is decreased, investment in physical capital slows down and there is a decline in economic activity. This result could be unexpected, because one might think that any reduction in administrative costs for the banking sector should do good for the economy.

The result is similar to that of Jakučionytė (2018), where a decrease in household protection increases the amount of household lending but puts a strain on corporate debt and thus on economic activity. Also, this discussion is relevant in the spirit of secondary market for mortgage NPLs (see, e.g. Fell et al., 2017). If banks could sell non-performing mortgages in a market, this could potentially reduce their administrative burden for dealing with such delinquencies, in effect lowering o. As we have already seen, this case can expand mortgage portfolio, but at a price of lower corporate lending.

2.5 Concluding remarks

The origin and nature of last financial crisis showcased the importance of the financial sector, especially banking, for macroeconomic dynamics. From regulatory perspective, a new systemic risk approach arose to make the financial industry safer and less harmful for the real economy during a crisis. Macroprudential policy is still in its early years, thus any empirical impact estimation is complicated. DSGE models featuring financial frictions can be a useful tool to understand the nature of the past financial crisis as well predict the possible impact of the new regulatory instruments and their interaction.

In this chapter we build and calibrate a small open economy DSGE model with banking and two-sector lending. The model features household mortgages that are risky from bank's perspective, and thus are collateralised with housing, which can be seized after a delinquency. Following Iacoviello (2015) and Gelain et al. (2015, 2018), mortgage dynamics reflect that of multi-period loans, which is unusual among models that feature household default. It is assumed that the bank is aware of the collateral constraint and asset seizure when making lending decisions, thus making the LTV limit also a supply-side factor, whereas it is usually deemed as only a demand-side constraint.

We simulate tightening of three macroprudential policy measures – LTV cap, bank capital requirement and risk weights – and assess their economic impact. Various experiments are conducted regarding the timing of announcement and comparison of effectiveness of different tools. Amongst the more interesting findings is that lowering of LTV limit can have non-negligible positive credit supply effects under one type of collateral seizure. Also, raising the minimum bank capital requirement can have a big impact of bank portfolio allocation. Therefore, broad-based capital requirement is less effective in fighting against risks confined to the mortgage market and does more harm to the corporate sector and the economy as a whole. More targeted tools as cap on LTV and risk weight regulation can produce a better effect when the objective is to target risk in secured household debt. Also, reduction in the administrative costs of housing loan NPLs can cause a rebalancing of bank portfolio towards mortgages, creating a negative drag on economic activity.

Chapter 3

Indebtedness and long-term growth

Previously we studied how macroprudential tools can affect Lithuania's economic activity and other macroeconomic indicators in the short run, by assessing the cost side of changes in policy. In this chapter we focus on the long run and assess how macroprudential policies that limit the economy's indebtedness affect long-term growth and volatility. Similarly to the settings of Chapters 1 and 2, we assume a small open economy in which agents are able to borrow against an amount of collateral to finance investment and growth. Methodically, we move to continuous time and differential equations, instead of discrete time and difference equations that were utilised previously. Note that the notations we use here are entirely different from the first two chapters.

The impact of indebtedness on convergence rates as well as the shape of the growth path was analysed by Barro et al. (1995) and Pintus (2007, 2011). The authors developed a theory of open economy neoclassical growth, where they assumed that human capital and labour are completely immobile, whereas physical capital is partially mobile and can serve as a collateral for issuing debt. In addition, they assumed, as is most prevalent in the literature, perfect competition in the financial sector, implying that households can borrow funds at the world interest rate.

Here we take the small-open economy neoclassical model of growth and further develop it to allowing for different levels of indebtedness, guided by macroprudential policy. We assume that there exists a macroprudential policy authority that limits how much the economy can borrow. That is, there is a macroprudential LTV limit λ on the ratio of debt to the value of collateral of its existing capital stock, much the same as in equation (1.14) of Chapter 1 or equation (2.8) of Chapter 2. Alternatively, the LTV limit can also be understood as a limit on capital flows across countries.

Unlike previous authors, who assume interest rates to be fixed to the world rate, we deem it implausible for a developing economy with a highly concentrated banking industry like Lithuania to borrow funds at the world interest rate. Instead, we endogenise the interest rates on debt and allow them to be between the world rate and the internal rate of return in the economy. We assume that the proximity of interest rates to the world rate depends on the degree of bargaining power of the economy.

We use the term bargaining power as a general modelling tool to impose a spread over the world rate. Nonetheless, debtors and lenders' bargaining power can be closely linked to financial industry factors such as concentration, degree of competition or market power, risk appetite, etc. For example, there exists a single financial intermediary which borrows the funds from the world capital market and lends it with a mark-up. In the case of Lithuania, the banking sector is highly concentrated, thus bankers are able to obtain high bargaining power when negotiating for loan terms with local businesses and households. Therefore, by understanding more about the impact of bargaining power, we may also understand how financial industry competition can affect growth, at least through the interest rate channel.

The aim of this chapter is to investigate the effect of macroprudential policies, as well as bargaining power on long-term speeds of convergence as well as the shape of convergence path. As the modelled economy is small and open, the conclusions that we draw can be applied to Lithuania.

We proceed in the following three steps:

1. Microfound the discrepancy between the interest rate on debt and the world interest rate. To this end, we use two approaches. We use a simple game-theoretic model describing the loan market with different number of financial intermediaries, where we utilise the Cournot-Nash equilibrium. Alternatively, we use a principal-agent problem in which a bank owner, such as a parent-bank, requires a high interest rate and a branch manager (subsidiary) wants a lower interest rate on funds. We use generalised Nash product and each agent's bargaining power to determine the agreed rate.

2. Build a theoretical model of neoclassical growth based upon Barro et al. (1995), Pintus (2007, 2011) papers, allowing for different macroprudential policy limits (λ) and imperfect bargaining power. Differential equations and dynamic programming are used to build and solve the model. We analyse the log-linearised model's implied convergence path as well as convergence rates, using the basics of linear algebra.

3. We empirically test our general theoretical findings using a panel data model, utilising long-term cross-country variation in levels of indebtedness, interest rates and growth.

Our proposed framework has a few main qualitative implications that are suitable for most economies, including Lithuania. Firstly, we show that a combination of different macroprudential policy limits and imperfect bargaining power can vastly influence the speed at which an economy converges. Secondly, loose macroprudential limits can generate substantial volatility along the growth path. Thirdly, low interest rates, as a result of competition or high bargaining power, can reduce the chance of falling into a volatile growth trajectory. In other words, if Lithuania had low interest rates, as a result of high debtors' bargaining power rate or competition among lenders, it could experience stable and fast growth, while having relatively loose macroprudential policy.

3.1 Brief overview of literature

3.1.1 Neoclassical model of growth

The economic growth literature has felt a renaissance since 1980's start of endogenous growth theory. Solow (1956) old neoclassical model of growth had been attacked by the New Growth theorists (e.g. see Romer, 1987) who had argued that the model had been a failure for predicting convergence against hard-nosed facts. However, Barro (1991), Mankiw et al. (1992) were able to show empirically that the neoclassical model of growth was still relevant. Their findings supported the notion of conditional convergence, what meant that countries tend to converge to their respective different steady states, not one country to another.

3.1.2 Open economy models

What was still unclear, neoclassical model of growth failed to predict low convergence rates for open economies. The conventional wisdom was that open economies should convergence much faster than closed economies at least on paper but at the time that did not accord with the empirical evidence. Theoretically, if the economies were completely open, capital would instantaneously flow into them and equate the marginal returns on capital to the world interest rate (real rate of return) and thus fix output and capital (per capita) at their steady state levels.

This was studied by Barro et al. (1995) in their famous paper 'Capital Mobility in Neoclassical Models of Growth'. They offered a theory, where human capital was completely immobile and physical capital was allowed to serve as a collateral for external debt. Although, this was enough to predict 2% speeds of convergence consistent with the empirics, their and other models in the literature still face some important caveats. They assumed that debt to physical capital ratio is equal to unity and households are able to perfectly bargain for low world interest rates when issuing debt. Although the assumption that the amount of net foreign debt cannot exceed capital level proved to be useful and easy to implement, a quick glance at Figures 3.12 and 3.13 in Appendix C would suggest that this is not entirely the case.

In response to BMS paper, Duczynski (1999) analysed an open economy neoclassical model of growth with perfect capital mobility and various versions of capital adjustment costs. The author was able to calibrate the model for sufficiently slow speeds of convergence and get richer dynamics than the model of BMS. His basic insight was that partial capital mobility is not necessary to produce realistic speeds of convergence. According to the author, partial capital mobility is less of a good assumption when thinking about, e.g., states in the United States or Japanese prefectures. In contrast, we stick to partial capital mobility assumption and exclude any adjustment costs.

In a more recent paper Pintus (2011) studied not the rates of convergence but the growth paths and volatility of key macroeconomic variables in open economy and partially mobile capital settings. He took the BMS idea of unit of physical capital serving as a collateral for a unit of net foreign debt and extended it allowing for a much more general version. The idea of the generalisation was supported by empirical evidence of Mendoza and Terrones (2008) that the debt to capital ratio is procyclical. Pintus showed that different values of indebtedness parameter λ might induce two different regimes and thus transition paths of the economy. For low λ values the economy is not highly indebted and thus nearly acts as a closed economy generating a monotonic transition saddle path to the steady state. Conversely, for high λ values (above some threshold) the economy is much more indebted and moves on a sink path characterised by volatility or boom and bust cycles to the steady state. This is in line with, what the author calls, the debt overhang regimes, when there is a high debt and agents use their savings to cut it, what in turn reduces investment in physical and human capital. Pintus model was a special case so as to study the volatility of the output path, leaving rates of convergence analysis aside, whereas our general model fills this gap.

Similarly, Aghion et al. (2004) built a discrete time model of growth with financial development, assuming a Leontief technology production function with complementary factors. The authors were able to show to generate output volatility as closed orbit cycles around the steady state.

3.1.3 Interest rates and bargaining power

Most of the times in exogenous open economy growth models the interest rate is assumed to be equal to the world interest rate which is fixed. This assumption is particularly easy to implement and makes further derivations easier. Barro et al. (1995), Pintus (2007, 2011), Aghion et al. (2004) are some of the many authors that make this assumption. In their papers, fixing the net return of capital to the world interest rate makes the output to capital ratio fixed which is in line with the stylised empirical evidence (see Kaldor, 1957).

Nonetheless, the assumption that an developing, small and open economy, e.g. Lithuania, can finance all its needs and wants with a constant and low interest rate is not plausible. Since the rates of return on investment in emerging economies are usually high because of the high productivity of capital, the borrowing rates should also be higher than the ones for the developed economies. Abstracting from productivity and profitability, there are other variables that determine the asked rate of return on investment. One of them is the investors perceived risk of the project and the economy. It is natural to think that riskier countries, e.g., with non-transparent governments, great amount of debt outstanding, all else equal, should borrow at a higher interest rate than the less risky ones. Abstracting from the risk factors, etc., investors and businesses (debtors) negotiate the rate of return on the project on the basis of the perceived productivity or/and future profits. Lastly, as in any negotiations, ability to persuade and other leverage, i.e. bargaining power, determine the outcome of the deal. For example, the higher the number of investors, the higher the bargaining power of the debtor is, because one could easily find a cheaper loan. Conversely, only one investor could act as a monopoly and price the loan much higher. And vice versa, the more businesses there are to invest in, all else being equal, the higher the bargaining power of the investor, because it might invest for the asked rate of return anywhere. The bargaining power, its microeconomic foundations and modelling will be discussed in the next section.

Bargaining power in the literature of economic growth is not prevalently used concept. For instance, the volumes of Handbook of Economic Growth (see Aghion and Durlauf, 2005, 2014) which are the symposia of the discipline. A search for an abbreviation "bargain" in the Handbooks, does not provide us with any of mentions of bargaining and bargaining power in open economy (or models with investors-debt) contexts. Instead, there are some mentions more related to labour and labour unions but more in the context of economic history, abstracting from mathematical modelling of the phenomenon. For example, in Chapter 10 of Acemoglu (2009) textbook model, worker's bargaining power parameter is introduced in the division of the final product over labourers and capital owners. On the basis of a social planner's problem, there is some positive $\lambda^* \in (0, 1)$ that maximises the output of the economy.

3.2 Theoretical modelling

We build a continuous time neoclassical model of growth with an infinitely lived Ramsey consumer. Firstly, we provide the core of the model we build. Secondly, we discuss about the foundations and intuition behind the bargaining power and formation of interest rates. Lastly, we solve the model and discuss its properties, propose empirically testable hypotheses.

The model generalises and extends the papers of Barro et al. (1995) and Pintus (2007, 2011). All variables are functions of time – $X(t)$, but will be denoted by X because of ease of exposition, as in above-mentioned papers. The time derivative of a variable is denoted by $dX(t)/dt \equiv \dot{X}(t) \equiv \dot{X}$.

3.2.1 The firms

A representative firm produces output using three factors of production: physical and human capital, labour. We assume a usual Cobb-Douglas form production function:

$$Y = AK^{\alpha}H^{\eta}(Le^{gt})^{1-\alpha-\eta},$$

where K and H are physical capital and human capital stocks, respectively, and L denotes the labour services. A is the fixed technology parameter, $\alpha, \eta \in (0,1)$, $\alpha + \eta < 1$ and Le^{gt} is the amount of effective labour, which grows at a rate of $n+g$, because labour is $L = e^{nt}$, i.e. grows at an exogenous rate of n, and g is the growth rate of labour augmenting technological progress. It is easier and thus conventional to present and analyse the model in terms of variables per effective labour:

$$y = Ak^{\alpha}h^{\eta}, \tag{3.1}$$

where $y \equiv Y/Le^{gt}$, $k \equiv K/Le^{gt}$, $h \equiv H/Le^{gt}$.

Firms pay for the rental services of physical, human capital and effective labor in the competitive factors market R_K, R_H, w, each per unit. Also, firms pay taxes as a proportion to their output, where tax rate τ is the proportion. This parameter, as explained by BMS, can be interpreted as various elements that affect the incentives to operate. For example, τ might include the risk of expropriation by the government, strong labour unions, or foreign invaders. In this context, τ might be interpreted as labour unions bargaining power. The greater the bargaining power of the unions, the greater proportion of the output is dedicated to the unions and left to the owners of firms. This interpretation is in the spirit of the mentioned model in Acemoglu (2009). Provided these assumptions, each moment the firms maximise real profits per effective labor with respect to k and h:

$$\pi = (1-\tau)y - w - R_K k - R_H h \longrightarrow \max_{k,h}. \tag{3.2}$$

The maximisation problem is identical in every moment because there are no adjustment costs, in contrast to Duczynski (1999) model. The first order conditions and the zero profit condition (perfectly competitive markets in the long-run):

$$\begin{cases} R_K = (1-\tau)\alpha\frac{y}{k} = (1-\tau)\alpha A k^{\alpha-1}h^{\eta} \\ R_H = (1-\tau)\eta\frac{y}{h} = (1-\tau)\eta A k^{\alpha}h^{\eta-1} \\ w = (1-\tau)Ak^{\alpha}h^{\eta} - R_K K - R_H H \end{cases}. \tag{3.3}$$

3.2.2 The consumer

There is an infinitely lived Ramsey consumer, who owns the physical capital and human capital stock and provides labour services to firms. The agent can invest in human and physical capital by issuing debt, of which the level outstanding will be denoted by D and the interest rate on this debt is r. It is logical to think of the debt as issued bonds or a bank loan, because the agent negotiates with investors over r. Ramsey consumer gets its instantaneous utility from consumption at every moment. The lifetime utility present value is modelled using the constant relative risk aversion (CRRA) instantaneous utility function:

$$U = \int_0^\infty u(C)e^{-(\rho-n)t}dt = \int_0^\infty \frac{C^{1-\theta}-1}{1-\theta}e^{-(\rho-n)t}dt,$$

where C denotes the consumption per capita level and ρ is the rate of time preference. The virtue of the CRRA function is that it is quite general and includes functions such as logarithmic (as $\theta \to 1$) and linear ($\theta = 0$), because θ parameter of risk aversion controls the concavity in C. Here we assume that $\theta > 1$ and $\rho > g$, where the latter is necessary for the integral to exist (be finite).
The evolution of the economy's stock of capital and debt is characterised by this differential equation:

$$\dot{K} + \dot{H} - \dot{D} = wLe^{gt} + R_K K + R_H H - \delta K - \delta H - rD - CL,$$

where $\delta \in (0,1)$ is the depreciation rate of both physical and human capital. However, the latter equation can also be written in variables per effective labour, which will be the form of our focus:

$$\dot{k} + \dot{h} - \dot{d} = w + (R_K - n - g - \delta)k + (R_H - n - g - \delta)h - (r - n - g)d - c,$$

where $d \equiv D/Le^{gt}$ and $c \equiv Ce^{-gt}$. Combining this equation with the zero profit condition from equation (3.3), the fact that $c \equiv Ce^{-gt}$ and the discounted utility U function, gives us the profit maximisation problem of the representative Ramsey consumer:

$$\begin{aligned} &U = \int_0^\infty \frac{e^{(1-\theta)gt}c^{1-\theta}-1}{1-\theta}e^{-(\rho-n)t}dt \longrightarrow \max_{c(t)} \\ &\dot{k} + \dot{h} - \dot{d} = (1-\tau)Ak^{\alpha}h^{\eta} - (n+g+\delta)k - (n+g+\delta)h - (r-n-g)d - c. \end{aligned} \tag{3.4}$$

The consumer maximises its discounted utility by choosing the path of consumption, subject to the motion of capital constraint and starting values of capital and debt $k(0), h(0), d(0) > 0$. We turn back to this maximisation problem, after we discuss some additional assumptions, regarding the capital motion equation.

3.2.3 The case of perfect capital mobility

Assuming that the home economy is small and open, capital is perfectly mobile, households can borrow and lend any amount they want at the going world interest rate r^{ω}. We also assume, as in the rest of this chapter, that labor cannot cross country borders and is perfectly immobile. Since the capital can absolutely move across borders, it equates the domestic interest rate r to the world interest rate. Investors face decisions to invest into capital markets which are perfectly open and therefore the net rate of return on physical and human capital are also equated to the world interest rate: $R_K - \delta = R_H - \delta = r = r^{\omega}$. Because the world interest rate r^{ω} is constant, this makes the physical and human capital ant thus output constant, all per unit of effective labour. That is, in this situation the economy instantaneously jumps to the steady state and remains there forever. The rates of convergence are infinite and, as stressed by Barro et al. (1995), are not observed in the real world. But again, Duczynski (1999) was able to show that assuming perfect capital mobility, one can get realistic rates of convergence by adding adjustment costs.

Here it is implicitly assumed that the bargaining power of the economy, the households, is perfect. In the case of perfect capital mobility this is realistic because there is an infinite amount of capital and investors in the outside world and all of them are ready to make a return equal to the world interest rate. If a household faces a "greedy" investor who seeks a higher return, e.g. $r^{\omega} + \varepsilon$, it can always find a "less greedy", who is willing to offer, e.g., $r^{\omega} + \varepsilon/2$. In this fashion, the agreed rate of return should iteratively converge to the world interest rate r^{ω}.

3.2.4 The case of partial capital mobility

As was mentioned in the preamble of the chapter, BMS' main idea was to introduce partial capital mobility into the neoclassical growth model with the Ramsey consumer, what made the implied speeds of convergence closer to the ones we observe in the real world. They assumed that labour and human capital were completely immobile, and that physical capital can serve as a collateral for debt. More precisely, the amount of debt outstanding cannot exceed the stock of physical capital: $D \leq K$. They analysed the situation, where the constraint was binding, i.e. when $k(0)+h(0)-d(0) < h^*$, $D = K$. An asterisk (*) over a variable denotes the steady state value of the variable, as time t approaches infinity. The net rate of return on capital was still equal to the world interest rate: $R_K - \delta = r^{\omega}$. This implied constant capital to output ratio: $k = (1-\tau)\alpha y/(r^{\omega}+\delta)$. Combining this expression, with the production function (3.1) and (3.4) maximisation problem, they got the same maximisation problem, but with a different constraint (motion of capital equation):

$$\begin{aligned} U &= \int_0^{\infty} \frac{e^{(1-\theta)gt}c^{1-\theta}-1}{1-\theta} e^{-(\rho-n)t} dt \longrightarrow \max_{c(t)} \\ \dot{h} &= (1-\alpha)(1-\tau)Bh^{\varepsilon} - (n+g+\delta)h - c. \end{aligned} \tag{3.5}$$

$B \equiv A^{1/(1-\alpha)}[(1-\tau)\alpha/(r^{\omega}+\delta)]^{\alpha/(1-\alpha)}$, $\varepsilon \equiv \eta/(1-\alpha)$. Here we see the rationale for the particular type of debt and physical capital constraint $d = k$, what implies that $\dot{k}$ and $\dot{h}$ cancel each other out.

Given $h(0) < h^*$, the maximisation problem's associated Euler equation is:

$$\theta\frac{\dot{c}}{c} = (1-\tau)(1-\alpha)B\varepsilon h^{\varepsilon-1} - (\delta+\rho+\theta g). \tag{3.6}$$

Now (3.6) and human capital motion equation from (3.5) compose a system of nonlinear differential equations, which (and the usual transversality condition) fully describe the dynamics of the economy. The steady state level of human capital per effective worker h^* is the same as in the model for the closed economy (see Barro et al., 1995) and equals:

$$h^* = \left[\frac{\varepsilon(1-\tau)(1-\alpha)B}{\delta+\rho+\theta g} \right]^{\frac{1-\alpha}{1-\alpha-\eta}}. \tag{3.7}$$

The convergence path to the steady state of consumption and human capital per effective worker is the usual saddle path, hence a monotonic transition to the steady state.

As we mentioned, the debt constraint $D \leq K$ was easy to understand and easy to implement. However, there are more general constraints in the literature. For example, Cohen and Sachs (1986) used a general functional form of this constraint: $D \leq f(K)$, where $f(\cdot)$ is a function. Later, in their paper they used a linear constraint $D \leq \lambda K$, with $\lambda \in (0,1)$ being a parameter (which depends on other parameters). The same linear form was used by Pintus (2007). Later Pintus (2011) generalised the constraint even more, making it $D \leq \lambda K (K/K^*)^\gamma, \gamma > 0$. The latter accords with the stylised fact of Mendoza and Terrones (2008) that the debt to output ratio is procyclical. As we have already discussed in the Literature review, Pintus (2007, 2011) was able to show that, assuming the constraint is binding, λ being above some threshold proved to produce system of differential equations, where the transition path of the economy to the steady state is characterised by boom and bust cycles. Patrick Pintus did not analyse speeds of convergence and thus assumed that the labour force was constant, and that there was no labour augmenting technological progress.

In this chapter we will use a more general debt constraint of Cohen and Sachs (1986) and Pintus (2007): $D \leq \lambda K, \lambda > 0$. This constraint along with the bargaining parameter ϕ will prove to generate some interesting, useful and empirically testable results. We depart from the corresponding specification used by Pintus (2011), because the procyclicality of debt to physical capital ratio did not prove to result in any substantial conclusions, hence $\gamma = 0$.

3.2.5 Microeconomic foundations of bargaining power

In this subsection we microfound the use of bargaining power of households (investors). Again, the idea is that households would like to borrow at the going world interest rate r^{ω} but are unable due to some mechanism which puts them in a worse bargaining position. That is, they must borrow at a higher interest rate than r^{ω} because their bargaining power is imperfect.

3.2.5.1 Bargaining power and the structure of the loan market

Here we show some ways to model the loan market in which originates imperfect bargaining power.

Cournot bank competition Suppose that households cannot go to the world capital markets and borrow necessary funds by themselves. Therefore, they have to rely on the loan market, in which N identical financial intermediaries, i.e. banks, operate. Each bank borrows funds in the perfectly competitive world capital market at a constant world interest rate r^{ω}. Therefore, the marginal cost of financing loans for the residents is equal to r^{ω}. Furthermore, let us assume that each bank faces Cournot competition from its rivals. The market inverse demand for loans function is $r = a - bd$, where d is total demand (households' debt) and r is the interest rate, i.e. price of loans. Since all residents are risk-free, there is no uncertainty, so that the profit function of firm i is deterministic:

$$\pi_i(d_i, d_{-i}) = rd_i - r^{\omega} d_i = \big(a - b(d_i + d_{-i})\big) d_i - r^{\omega} d_i \longrightarrow \max_{d_i}, \tag{3.8}$$

where $\pi_i(d_i, d_{-i})$ is the profit function of bank i, d_i is the amount of funds supplied by the i'th bank and $d_{-i} \equiv \sum_{j \neq i}^{N} d_j = d - d_i$. Each bank maximises its profits by choosing the amount of loans to supply. The first order condition is $a - 2bd_i - bd_{-i} - r^{\omega} = 0$. It is not necessary to solve for each and every $d_i, i \in \{1, 2, \ldots, N\}$, because all solutions will be identical, due to the symmetry of banks assumption. Therefore, the first order condition becomes $a - b(N+1)d_i - r^{\omega} = 0$ and the equilibrium total amount of loans in the market is $d^* = N(a - r^{\omega})/(N+1)b$. The equilibrium interest rate on debt is:

$$r^* = \frac{a + r^{\omega} N}{N+1}. \tag{3.9}$$

As one can see, the interest rate on debt depends on the number of banks, operating in the domestic loan market. If there exists a monopoly in the market, then $r^* = 0.5(a + r^{\omega})$. Another extreme case would be the perfect competition, where $r^* \to r^{\omega}$ as $N \to \infty$. In the latter case, the bargaining power of banks would erode, as there would be a plethora of them. If any bank offers to any household a higher interest rate on debt than the equilibrium rate r^{ω}, that household can go to any other bank, which could undercut that rate. The bargaining power of households, in this case, is perfect. The market power (monopoly power) can be measured by Lerner's index:

$$I \equiv \frac{r^* - r^{\omega}}{r^*} = \frac{a - r^{\omega}}{a + r^{\omega} N}. \tag{3.10}$$

When there exists a monopoly, market power is $I = (a - r^{\omega})/(a + r^{\omega})$, what is close to unity for low r^{ω}. In the case of perfect competition, market power erodes and the Lerner's index is approaching zero. Lerner's index marks the bargaining power of investors, i.e. banks, while the inverse is characterised as the bargaining power of households.

In this simple model, one can see that the bargaining power of households can depend on the structure of the loan market. As the number of competing banks increases, households gain more and more bargaining power and can borrow at lower rates.

One can assume that the market for loans is characterised by Bertrand competition. It is very well know that, having symmetric oligopolies in the model, we would have a Bertrand paradox, what means that the price of loans would be equal to marginal cost, i.e. $r = r^{\omega}$. Households could have perfect bargaining power even when there are only at least 2 banks in market. It is also know that Bertrand paradox does not hold, whenever we assume that the products are differentiated or there are capacity constraints. With respect to the former, product differentiation in the loan market would mean different loan contract conditions, e.g. collateral requirements, etc. Regarding the capacity constraints, it would be plausible to assume that banks cannot get themselves the required capital from the international capital market, what would produce Edgeworth cycles. These more flexible assumptions, could make the equilibrium interest rate, and therefore the bargaining power of households, dependent on, again, the structure of the market, i.e. number of banks operating.

Cooperation When there exists a monopoly bank in the market for loans, households are in an inferior bargaining position, since there is only one provider of loans, which can dictate terms and conditions, including the price of capital. However, households can outweigh monopoly power by cooperating themselves into some form of a credit union. Therefore, monopoly bank will have to negotiate over the terms of loan with a single entity, not with each and every household separately, so the interest rate on debt will be subject to some form of bargaining solution. In a similar fashion, banks or investors can also cooperate themselves. For instance, in the credit market with Bertrand competition banks might choose to collude and raise the interest rate on loans, what would make all households worse off. Of course this is plausible only if a cartel is stable, i.e. there does not exist an incentive for any of the banks to depart from cooperation. Similarly, if households are issuing bonds and the price is determined in an auction, investors might cooperate in some forms and bargaining for a higher rate of return. If investors do not cooperate, households are able to borrow at the world interest rate and hence their bargaining power is perfect.

3.2.5.2 Incorporating bargaining power

We incorporate the bargaining power into the model by specifying: $r = \phi r^{\omega} + (1-\phi)(R_K - \delta)$, with $\phi \in [0,1]$. The latter specification is very similar to the one of Kvedaras (2013). Here households can borrow at an interest rate that is somewhere between the world interest rate r^{ω} and the domestic rate of return, which is the net return on physical capital $R_K - \delta$. The specification binds the two capital markets: the domestic and the outer world. Suppose, someone wants to lend a household at an interest rate higher than the domestic rate of return (and higher than r^{ω}). The household can quickly obtain the amount of borrowing from the domestic capital market at a lower rate. Therefore, since the domestic and the outside world capital markets are binded, the interest rate on debt cannot be lower than the world interest rate or exceed the domestic interest rate.

The situation is depicted in Figure 3.11 of Appendix C, where is the domestic demand for assets (physical capital) and the world interest rate. It is easily seen that, when the macroprudential credit constraint is binding, the market does not clear. The interest rate on debt must be equal to the world interest rate or to the domestic rate of return, or somewhere in between. Investors would like to lend at the rate where the capital constraint k_1 crosses the investment demand curve. Conversely, households would like to borrow at the world interest rate. But the exact positioning and interest rate on debt is determined in the negotiation process of households and investors, where different bargaining powers collide.

We have assumed that $r^{\omega} < R_K - \delta$, which means that the world is more developed so that the marginal productivity of capital is lower (due to the decreasing returns) and the rate of return is therefore lower. ϕ would act as the bargaining parameter of households which balances the interest rate on debt between the domestic return and the world interest rate. The higher the value of ϕ, the higher the bargaining power of the households is and they can borrow at a lower interest rate, and vice versa. Conversely, $1-\phi$ is bargaining power parameter of investors (providers of finance).

In this subsection we showed can uneven bargaining power can originate from the structure of the banking market imperfect, i.e. number of financial intermediaries, barriers to entry, ability to collude, or the principal-agent problem.

3.2.6 Neoclassical model of open economy growth with bargaining power

Here we make a couple of formal assumptions that will be used to extend the (3.4) problem.

Assumption 1. *Let the macroprudential constraint be:* $d \leq \lambda k, \lambda > 0$.

Assumption 2. *Let* $r^{\omega} = \rho + \theta g$.

Assumption 3. *Let* $\phi \in [0,1]$ *be the bargaining parameter and* $r = \phi r^{\omega} + (1-\phi)(R_K - \delta)$.

Assumption 1 makes the debt to capital ratio constant and equal to λ – the macroprudential limit. That is, only a fraction λ of physical capital can be used to finance debt. The inequality constraint $d \leq \lambda k$ is binding, according to BMS and the proof by Pintus (2007), if the initial capital stocks are lower than the steady state human capital value: $k(0) + h(0) - d(0) < h^*$.
Assumption 2 assumes that the world interest rate is equal to that of the closed economy and is constant. The latter statement is derived from BMS model for the closed economy and the assumption is the same they used for open economy model with partial capital mobility.

Assumption 3 states that the interest rate on debt that a typical household faces is somewhere between the world interest rate and the internal net rate of return in the domestic economy. Also, this means that, if $R_K - \delta > r^{\omega}$, then $r > r^{\omega}$ for $\phi \in (0,1)$. And the latter is true because the internal rate of return for the developing open economy must be higher than the world interest rate, because of diminishing marginal returns on capital.

The capital motion equation in (3.4) still applies but is too general and needs to be reduced, while holding Assumptions 1 and 3. Rearranging terms in the interest rate (bargaining) equation (3.11) gives us:

$$R_K = (1-\tau)\frac{\alpha y}{k} \equiv \frac{r - \phi r^{\omega}}{1-\phi} + \delta, \tag{3.11}$$

where the first equality comes from the profit maximisation condition in system (3.3). Assuming the interest rate on debt and the world interest rate were constant, the output to physical capital ratio is also a constant, what is in parallel with the stylised facts. Rearranging the terms of the latter equation, we get the expression for k, the physical capital per effective worker, which we put again into the Cobb-Douglas production function (3.1) and solve for y as function of a sole argument h:

$$y = \Xi h^{\varepsilon}, \tag{3.12}$$

$$\text{with } \Xi \equiv A^{\frac{1}{1-\alpha}} \left[\frac{\alpha(1-\tau)}{\frac{r-\phi r^{\omega}}{1-\phi} + \delta} \right]^{\frac{\alpha}{1-\alpha}} \text{ and, } \varepsilon \equiv \frac{\eta}{1-\alpha}.$$

Assumption 1 and equation (3.12) implies that $\dot{h} + \dot{k} - \dot{d} = \dot{h} + (1-\lambda)\dot{k} = \dot{h} + \frac{(1-\lambda)(1-\tau)\alpha}{\frac{r-\phi r^{\omega}}{1-\phi}+\delta}\dot{y} = f(h)\dot{h}$, where $f(h)$ is defined as:

$$f(h) \equiv 1 + \frac{(1-\lambda)(1-\tau)\alpha\varepsilon}{\frac{r-\phi r^{\omega}}{1-\phi} + \delta} \Xi h^{\varepsilon - 1}. \tag{3.13}$$

Manipulating the right hand side of the capital motion equation in (3.4), gives us the same profit maximisation problem but with different constraint, which is consistent with the assumptions of imperfect bargaining power and capital mobility:

$$U = \int_0^\infty \frac{e^{(1-\theta)gt}c^{1-\theta} - 1}{1-\theta} e^{-(\rho-n)t} dt \longrightarrow \max_{c(t)},$$
$$f(h)\dot{h} = (1-\tau)(1-\alpha\xi)\Xi h^{\varepsilon} - (n+g+\delta)h - c, \tag{3.14}$$

$$\xi \equiv \frac{(n+g)(1-\lambda)+\lambda r+\delta}{\frac{r-\phi r^{\omega}}{1-\phi}+\delta}. \tag{3.15}$$

If $1-\alpha\xi < 0$, income net of physical capital depreciation and interest payments on debt is negative and hence human capital stock is dwindling. This can be due to permanent debt overhang situation, when borrowing is so large that interest payments and the capital depreciation are larger than income. The following assumption ensures us that this will not happen.

Assumption 4. *Let* $0 < \lambda < \bar{\lambda} \equiv \frac{\frac{r-\phi r^{\omega}}{\alpha(1-\phi)}+\delta(\frac{1}{\alpha}-1)-n-g}{r-n-g}$.

Assumption 4 ensures that $1-\alpha\xi > 0$ and the income net of interest payments and physical capital depreciation is always positive. In other words, λ is bounded from above so that the debt cannot be too large. Note that the latter assumption exploits Assumptions 2 and 3, so that $r > r^{\omega} = \rho + \theta g > n + g$.

If households are able to borrow as much as they own physical capital ($\lambda = 1$) and have perfect bargaining power ($\phi = 1$), i.e. $r = r^{\omega}$, then $\xi = 1$ and $B = \Xi$. Hence, the model with imperfect bargaining power of households is a generalisation of the basic model of Barro et al. (1995).

(3.14) problem can be solved using the Pontryagin's maximum principle.

The current value Hamiltonian is defined by:

$$\begin{aligned}\mathcal{H} = & \frac{e^{(1-\theta)gt}c^{1-\theta}-1}{1-\theta}e^{-(\rho-n)t}+ \\ & +\mu\left(\frac{(1-\tau)(1-\alpha\xi)\Xi h^{\varepsilon}-(n+g+\delta)h-c}{f(h)}\right),\end{aligned} \tag{3.16}$$

where $\mu \equiv \mu(t)$ is the time-variant Lagrangian multiplier. Solving the continuous time optimisation problem[1] gives us the system of differential equations of control variable c and state variable h:

$$\begin{cases} \theta\frac{\dot{c}}{c} = (1-\tau)(1-\alpha\xi)\varepsilon\Xi h^{\varepsilon-1}-(\delta+\rho+\theta g) \\ f(h)\dot{h} = (1-\tau)(1-\alpha\xi)\Xi h^{\varepsilon}-(\delta+n+g)h-c, \end{cases} \tag{3.17}$$

along with the transversality condition $\lim_{T\to\infty} e^{-(\rho-n)T}\mu(T)h(T) = 0$, which states that there should be no human capital left at the "end" of the time horizon or its shadow price should be zero. The latter system of first order nonlinear differential equations fully characterise the dynamics of the economy and thus should be solved simultaneously. As we will see, there are no closed orbit solutions to the system (3.17), so that the variables converge to their respective steady state values and the transversality condition holds. With time approaching infinity, steady state values of consumption and human capital, both per effective worker, are:

$$h^{*} = \left[\frac{\varepsilon(1-\tau)(1-\alpha\xi)\Xi}{\delta+\rho+\theta g}\right]^{\frac{1-\alpha}{1-\alpha-\eta}}, \tag{3.18}$$

$$c^{*} = (1-\tau)(1-\alpha\xi)\Xi h^{*^{\varepsilon}}-(\delta+n+g)h^{*}. \tag{3.19}$$

[1] For a good introduction or reminder about the problem and its solution, see Acemoglu (2009).

3.2.6.1 The transition path

Now we turn to the analysis of the transition path of the variables h and c to their respective steady states. It is ordinary to analyse a path of variables of a system of nonlinear differential equations, using the first order Taylor log-linear approximation and the resulting Jacobian matrix[2]. The corresponding Jacobian matrix of log-linearised system (3.17) around its steady state:

$$\mathbf{J} = \begin{pmatrix} \frac{\rho-n+g(\theta-1)}{f(h^*)} & \frac{\varepsilon(\delta+n+g)-(\delta+\rho+\theta g)}{\varepsilon f(h^*)} \\ \frac{(\varepsilon-1)(\delta+\rho+\theta g)}{\theta} & 0 \end{pmatrix}. \tag{3.20}$$

Here $f(h^*)$ is equation (3.13) evaluated at the steady state h^* and is equal to:

$$f(h^*) \equiv 1 + \frac{\alpha(1-\lambda)(1-\tau)(\delta+\rho+\theta g)}{\frac{r-\phi r^{\omega}}{1-\phi} + \delta - \alpha((n+g)(1-\lambda)+\lambda r+\delta)}\,. \tag{3.21}$$

In this model, there are two possible transition paths: a) saddle b) sink. We rule out closed orbit solutions because $\mathbf{J}$ eigenvalues are all real and not complex.

a) The transition path is saddle stable iff eigenvalues are of opposite sign in the two dimensional system. This is equivalent to conditions: $det(\mathbf{J}) < 0$ and $tr(\mathbf{J}) > 0$. Note that in this particular system $sgn\big(tr(\mathbf{J})\big) = -sgn\big(det(\mathbf{J})\big) = sgn\big(f(h^*)\big)$.

b) The transition path is a sink iff eigenvalues are both negative. This is equivalent to conditions: $det(\mathbf{J}) > 0$ and $tr(\mathbf{J}) < 0$, and $f(h^*) < 0$.

Now it is obvious that the shape of the transition path depends on the sign of $f(h^*)$ and it in turn depends on the magnitude of λ.

[2] $\dot{\mathbf{x}} \approx \mathbf{J}(\mathbf{x}-\mathbf{x}^*)$, where $\mathbf{x}$ is the vector of time-variant variables, $\mathbf{J}$ is the Jacobian matrix of first order partial self- and cross-derivatives of the nonlinear system.

Proposition 1. *The system* (3.17) *converges to the steady state on a: a) saddle path iff* $0 < \lambda < \hat{\lambda} < \bar{\lambda}$ *b) sink path iff* $1 < \hat{\lambda} < \lambda < \bar{\lambda}$*, where*

$$\hat{\lambda} \equiv 1 + \frac{\alpha(r+\delta) - \delta - \frac{r-\phi r^{\omega}}{1-\phi}}{\alpha\big(n+g-r-(1-\tau)(\delta+\rho+\theta g)\big)} > 1.$$

PROOF: See Proof in Appendix C.

According to Proposition 1 part a), $\lambda < \hat{\lambda}$ implies that the eigenvalues of the Jacobian matrix are real and of different sign. Therefore, the path of the economy is a saddle and hence human capital, consumption and output, all per effective worker, monotonically move towards the steady state of the system. In other words, when the indebtedness of households is low, the economy does not experience volatility as it converges to the steady state. In macroprudential policy terms, if there exists a sufficiently strict policy limit, the economy should converge to the steady state in a smooth manner.

Conversely, due to part b) of Proposition 1, when $\lambda > \hat{\lambda}$, the transition of the economy is characterised by boom and bust cycles, a result that was obtained by Pintus (2007, 2011). That is, if the macroprudential limit (λ) is sufficiently loose, the economy will experience volatility when converging, e.g. prolonged periods when human capital and consumption, both per effective worker, exhibit swings.

Suppose, an economy starts with low initial levels of capital and therefore debt. Since borrowing per effective worker is still comparatively high, because of $\lambda > \hat{\lambda} > 1$, stock of capital quickly increases, what makes level of debt and borrowing even higher. The increase in income is also accompanied by increasing consumption per effective worker. There is a point in time when the level of debt and capital become so high, so that the savings become negative, which erodes the level of capital, as well as the level of debt. In other words, debt overhang induces deleveraging process, which is followed by decreasing income. And again, the economy must reach a point, where the levels of debt become sustainable and net savings are positive, so that capital accumulation is plausible. This process continues on as the economy converges to its steady state, while experiencing boom and bust cycles. The latter interpretation resembles Lithuania's path in the 2000's, where we saw a great growth and increase in indebtedness, followed by a bust and a painful deleveraging process, succeeded by further growth and leverage.

Proposition 2. $\hat{\lambda}$ *is an increasing (non-decreasing) function in bargaining power parameter* ϕ*. PROOF: See Proof in Appendix C.*

Proposition 2 tells us that increasing bargaining power ϕ of households, raises threshold $\hat{\lambda}$ and therefore reduces the chance of volatility on a transition to the steady state. In other words, economies that are able to borrow less costly, are more proof to boom and bust cycles. Increased ϕ must raise productivity, what is seen from equation (3.11), which in turn makes every unit of debt and capital more productive. Increased overall productivity raises income at every point of time and reduces the chance that consumption, interest payments and depreciation will be higher than income. If income is always higher than expenditure, capital must accumulate and the economy must move monotonically towards the steady state equilibrium. This implies that economies with higher bargaining power can have relatively high debt to physical capital ratios and enjoy convergence without boom and bust cycles.

3.2.6.2 Rates of convergence on a saddle path

In this subsection we analyse and compare the convergence rates of output on a saddle path transition path. The analysis for the sink-type convergence is not carried out here because the path is non-monotonic and the usual concept of rate of convergence is not applicable.

To compute the rates of convergence, we find eigenvalues of Jacobian matrix (3.20). If the path is a saddle, one eigenvalue is positive and one is negative. The modulus of the negative one will be the rate of convergence that is traditional in the literature of economic growth.

$$\beta = 0.5\left[\frac{(\rho-n+g(\theta-1))^2}{f(h^*)^2}+ +4\left(\frac{\delta+\rho+\theta g}{\varepsilon}-(n+g+\delta)\right)\frac{(1-\varepsilon)(\delta+\rho+\theta g)}{\theta f(h^*)}\right]^{\frac{1}{2}}- -\frac{\rho-n-g(\theta-1)}{2f(h^*)}. \tag{3.22}$$

β in equation (3.22) is the rate of convergence of the system (3.17) on a saddle path. $\beta > 0$ as long as $f(h^*) > 0$ and this is exactly the saddle path condition, when $\lambda < \hat{\lambda}$. The latter coefficient certainly differs from the one of BMS and, in fact, is a generalisation of the latter[3]. The newly introduced parameters into the model, enter the rate of converge β in equation (3.22) through the term $f(h^*)$, where the latter is defined in (3.21). Next, we analyze how these two parameters affect the computed rates of convergence through analyzing derivatives.

Proposition 3. *Suppose $f(h^*) > 0$, i.e. $\lambda < \hat{\lambda}$, and let $2\big(\rho-n+g(\theta-1)\big) < 1$ Then:*

$$\frac{\partial\beta}{\partial\phi} : \begin{cases} >0 & , \text{when } \lambda < 1 \\ <0 & , \text{when } 1 < \lambda \end{cases},$$
$$\frac{\partial\beta}{\partial\lambda} > 0.$$

PROOF: See Proof in Appendix C.

First off, assumptions of Proposition 3 describe that the path of convergence is monotonic, hence $\lambda < \hat{\lambda}$, and that combination $\big(\rho-n+g(\theta-1)\big) < 0.5$, what holds if the parameters are low in magnitude. The latter

[3] $\beta_{BMS} = \frac{1}{2}\Big(\sqrt{(\rho-n+g(\theta-1))^2+4\big(\frac{\delta+\rho+\theta g}{\varepsilon}-(n+g+\delta)\big)\frac{(1-\varepsilon)(\delta+\rho+\theta g)}{\theta}}\Big)-\rho-n-g(\theta-1)\Big)$

is in line with the baseline and alternative calibrations of Barro et al. (1995), which were used for computing speeds of convergence.

The proposition states that increasing bargaining power increases the speed of convergence β, only when $\lambda < 1$, i.e. macroprudential policy is strict. Meanwhile, increasing indebtedness always increases the speed at which an economy converges to its steady state. The latter conclusion is in the direction of the case of infinite speed of convergence. As we discussed earlier, the speed of convergence must be infinite when capital is perfectly mobile. Therefore,when λ is increasing, capital is becoming more mobile, i.e. the country becomes less and less binded by the debt-to-collateral constraint, and can borrow more. This in turn leads to more capital per worker and the country converges faster to the steady state.

If bargaining power increases, holding interest rates fixed, the marginal product of physical capital must decrease accordingly (see equation (3.11)). Increasing capital productivity leads to greater income and thus greater accumulation of capital stock, what implies greater speed of convergence. But when country's indebtedness is high enough, i.e. $\lambda > 1$, an increase in ϕ, via increasing productivity and decreasing physical capital stock (because of diminishing returns; this is not about the dynamics, this is comparative statics), decreases the debt by a *factor greater than unity*. In other words, increased bargaining power decreases debt much more than physical capital. But let us remind that, according to Proposition 3, decreasing indebtedness decreases the rate of convergence. Therefore, the former negative impact of ϕ on debt, can make the economy converge slower, even though capital productivity is higher.

Furthermore, we parameterised our model with the baseline parameter values of BMS and tabulated the computed convergence rates in Table 3.4. The parameter values for computations were $\rho + \theta g = 0.06$, what, according to BMS, is the long-term stock market return in the U.S. $\delta = 0.05$ as in Pintus (2007) or 0.03-0.06 as in Aghion and Durlauf (2005), what usually is interpreted as 5% of physical capital stock depreciates every year. $\alpha = 0.3$ and $\eta = 0.5$ are standard labour and human capital shares of national income in growth models, also backed by the seminal paper of Mankiw et al. (1992). The average population growth for all countries is $n \approx 0,01$, according to Penn World Table 9.0 and our computations. The combination of latter parameter values proved for BMS to produce convergence rates that are consistent with empirical findings of approximately 2% (e.g., see Mankiw et al., 1992):

$$\begin{array}{lll} n = 0.01 & g = 0.02 & \delta = 0.05 \\ \theta = 2 & \rho = 0.02 & \alpha = 0.3 \\ \eta = 0.5 & \phi \in (0,1) & \lambda \in (0,3). \end{array} \tag{3.23}$$

Variation in bargaining power parameter values is in the left-most column of Table 3.4, while variation in debt to capital ratio is in the top row. Different combinations of these parameters produce different rates of convergence, that are in the body of the table. The tabulated values of convergence are the ones of a saddle path, because λ is always below thresholds $\hat{\lambda}$ and $\bar{\lambda}$ for the baseline parameter values in (3.23). For $\lambda = 1$ and any $\phi \in (0,1)$, the rate of convergence is equal to that of BMS: 0.0225. Looking at any row in Table 3.4, one can obviously see that β is increasing with λ. It can increase up to 0.0333 for $\lambda = 3$ and $\phi = 0.05$, which is much faster than the rate of 0.0225. Looking at any column, when $\lambda < 1$, rates of convergence are increasing with bargaining power parameter ϕ. However, they are decreasing, when $\lambda > 1$, what is in line with Proposition 3.

The speed of convergence is less responsive to variation in the bargaining power parameter ϕ, because it changes it only up to third digit (after the decimal), while λ can change it up to second digit (0.02-0.03). This can be founded by the fact that $\partial\beta/\partial\lambda$ is always positive and $\partial\beta/\partial\phi$ can be both positive and negative. Interpreting this, there is some positive effect of bargaining power on β through increasing productivity and there is some negative effect through reduced debt. $\lambda \gtrless 1$ determines which effect outweighs another and therefore the sign of the derivative $\partial\beta/\partial\phi$, so the absolute value of the net effect is not that great.

In this section we have formulated and solved the general model of open economy neoclassical growth with bargaining power. The proved Propositions are empirically testable to what we turn in the next section.

3.3 Empirical tests of propositions

In this section we seek to empirically test Propositions 1, 2 and 3. Firstly, we discuss the available data that we used in our analysis. Secondly, we propose a model (testing framework) for checking Propositions 1 and 2. Lastly, we test Proposition 3 based upon the existing growth regression framework in the literature. In general, our testing procedure relies on a panel model that pools cross-country-time data and utilises variation in growth rates and their volatility, as well as interest rates and indebtedness.

3.3.1 Data and measures of bargaining power

Our data sources are Penn World Table 9.0 (PWT9), which contain the output, human and physical capital, openness, population and price levels, and World Bank (WB) data, including external debt stock, interest rates, inflation, life expectancy, fertility rate. The time span is from 1950 to 2011 and we have 167 countries, but the sample size will be lower because the panels are unbalanced, i.e. some observations for some points in time and space are missing.

Output variable is expenditure-side GDP per capita at chained PPP's ($\log y_{it}$). Human capital measure is an index based on years of schooling and returns to education, i.e. the well known Barro/Lee, Psacharopoulos measure, ($human_{it}$). Openness is measured as country's export plus import ratio to GDP - the more a country trades, the more open it is. The level of physical capital in constant prices is an estimate in PWT9, based on initial level of capital plus cumulative investments minus cumulative depreciation.

External debt, what is owed to creditors outside of a country, with physical capital stock and interest rates will be used to construct measures of debt to capital ratio λ and bargaining power parameter ϕ, respectively. First off, debt ($d \leq \lambda k$) in our theoretical model can be thought of as net external debt, i.e. external debt minus debt which is owed by the citizens of a country to outside world (as interpreted in BMS paper), or gross external debt. Since net external debt stock data is not available, we interpret d as gross external debt. However, one should be aware of possible differences in interpretation. If debt to physical capital relationship is binding, $\lambda = d/k$ and we compute this ratio directly. Before this, we deflate external debt stock, because it is nominal, using price levels from PWT9. Figure 3.12 graphs the distribution of country averages of measures of λ. As one can see, most of the probability mass is when $\lambda < 1$, what means that countries on average tend to have more physical capital than external debt.
It is much more difficult to get a measure of bargaining power of an economy. However, we propose to utilise relationship $r = \phi r^{\omega} + (1 - \phi)(R_K - \delta)$ in Assumption 3 and directly solve for ϕ:

$$\phi = \frac{(R_K - \delta) - r}{(R_K - \delta) - r^{\omega}}. \tag{3.24}$$

As it was said earlier, interest rate on external debt r is a linear combination of world interest rate r^{ω} and internal interest rate (rate of return) $R_K - \delta$. The measure of internal interest rate $R_K - \delta$ is a lending rate charged by banks. External debt interest rate r is measured as average interest rate on new external debt commitments. These two interest rates are the closest in the WB database to our theoretical constructs. It was assumed that the world interest rate equals that of a closed economy steady state interest rate: $r^{\omega} = \rho + \theta g$. Since the world is not in its steady state (it must take an eternity, i.e. $t \to \infty$), we cannot observe this interest rate. However, there are some countries, which are more developed and

their interest rate on external debt is closer to that long-run rate. This insight directly founds the use of the minimum interest rate on external debt in a given year as a proxy for the world interest rate. 97% of the cases interest rate on external debt is lower than the lending rate, and 100% it is greater or equal to the world interest rate. This restricts the bargaining power measure to be in the interval $[0, 1]$, except for 3% of the cases, which we remove. The distribution of country averages of bargaining power is given in Figure 3.13. In contrast to distribution of λ in Figure 3.12, it is left-skewed.
We also considered more interest rates from WB database to construct measures of bargaining power. These included: interest payments on external debt to external debt stock ratio, deposit interest rate, interest rate spread (lending rate minus deposit rate), real interest rate, risk premium on lending (lending rate minus treasury bill). Also, variables reflecting financial development, which lead to higher bargaining power of households (greater availability of resources and suppliers leads to lower prices). These were: number of automated teller machines, borrowers from commercial banks, commercial bank branches, all per capita. Unfortunately, none of these variables were as close to the theoretical construct or behaved as well as our main measure. Next, we turn to the use of the data in testing Propositions 1, 2 and 3.

3.3.2 Indebtedness and volatility

Here we propose a testing procedure for Propositions 1 and 2, and utilise it. To restate the latter propositions in plain language, there exists some debt to capital ratio threshold $\hat{\lambda}$ which is a function of other parameters, as well as bargaining power ϕ. When $\lambda > \hat{\lambda}$, loose macroprudential policy leads to high indebtedness, thus countries should experience volatility, boom-bust cycles when moving towards the steady state equilibrium output. Conversely, if $\lambda < \hat{\lambda}$, countries monotonically converge towards the steady state. As we said, $\hat{\lambda} = f(\phi, \cdot)$ and, according to Proposition 2, $df(\phi, \cdot)/d\phi > 0$. Therefore, having a high bargaining power can help a country reduce the chance of experiencing volatility, while converging. Or in other words, high bargaining power countries can have greater debt to physical capital ratios without experiencing boom and bust cycles.

Figure 3.14 is an example of monotonic and non-monotonic paths of output per worker. The difference between the output per worker and its trend is cyclicality. If this cyclicality is negligible, its mean and variance should be close to zero. According to Proposition 1, we should expect low cyclicality for countries with low indebtedness.

Now we turn to the description of testing procedure and variables involved. First off, we need to filter out business cycle (short-run fluctuations) component from real GDP per capita, since economies tend to fluctuate in the short-run, regardless of general shape of the path, i.e. monotonic or non-monotonic. If we do not filter out the short-run business cycle component, one might draw wrong conclusions about the patterns of convergence which are subject to noise. The filtering can be done by Hodrick-Prescott filter, with the smoothing parameter equal to 6.25 – a standard value for annual data (see Ravn and Uhlig, 2002). After taking the logarithms we detrend the filtered output per capita and collect the residuals. The distribution of country standard deviations of latter residuals is depicted in Figure 3.15. Let $cycl_{it}$ be a 10 year moving standard deviation of these detrended values (cycle component; residuals).

We propose this panel regression model for testing Propositions 1 and 2:

$$cycl_{it} = \gamma(\lambda_{it} - \hat{\lambda}_{it}) + \varepsilon_{it} \tag{3.25}$$

$$\hat{\lambda}_{it} = \alpha_i + \mu_t + b\phi_{it} - cn_{it} + \nu_{it}, \tag{3.26}$$

where λ_{it} is a 10 year moving average of external debt to physical capital ratio, ϕ_{it} is a 10 year moving average of bargaining power and n_{it}, the 10 year moving average annual population growth. This specification is quite flexible, because cyclicality is higher when $\lambda_{it} > \hat{\lambda}_{it}$, but the increase depends on the magnitude of the difference $\lambda_{it} - \hat{\lambda}_{it}$. The threshold is time and country specific and is parameterised to be a function of bargaining power ϕ_{it} and average population growth n_{it}. It is obvious from Propositions 1 and 2 that λ is an increases with ϕ and a decreases with n. Combining (3.25) with (3.26) we get the reduced form for estimation:

$$cycl_{it} = -\gamma(\alpha_i + \beta_t) + \gamma\lambda_{it} - \gamma \cdot b\phi_{it} + \gamma \cdot cn_{it} + e_{it}, \qquad (3.27)$$

where $e_i \equiv \varepsilon_{it} + \gamma\nu_{it}$. The latter panel regression model can be estimated using fixed effects (within) or any other panel estimator and $\hat{\lambda}_{it}$ can be computed then directly.

Now we turn to the results of our estimations, which are given in Table 3.1. We estimated 4 models: (1) pooled, (2) random effects, (3) fixed effects, (4) fixed two-way effects. Here, as one can see, all signs are correct and all coefficients are statistically significant at conventional levels. Volatility around long-run trend increases with increasing indebtedness λ and decreases with bargaining power ϕ. In the lower panel of Table 3.1, there are implied estimates of parameterised function (3.26). Although, estimated coefficients are extremely similar across all $cycl_{it}$ models in the upper panel, they differ a lot in the lower panel. This in turn implies different average $\hat{\lambda}$ values, which range from 0.73 to 5.39 across models. The (2) random effects model implied average $\hat{\lambda} = 5.39$ is close to the theoretical model equivalent which is equal to 4.98 with $\phi = 0.77$ and $n = 0.01$. Again let us remind the reader that d and therefore λ interpretation directly leads to the selection of (net) external debt stock variable. Therefore, differences may arise naturally among theoretical construct $\hat{\lambda}$ values and its estimates based on various debt measures. Nevertheless, the estimated coefficients are significant and of correct signs, what favours the results of our general theoretical model of neoclassical growth.

Table 3.1: Estimated models of cyclicality and implied $\hat{\lambda}_{it}$ functions.

	Dependent variable:			
	$cycl_{it}$			
	(1)	(2)	(3)	(4)
λ_{it}	0.054^{***}	0.044^{***}	0.037^{**}	0.044^{**}
	(0.011)	(0.015)	(0.017)	(0.018)
ϕ_{it}	-0.220^{***}	-0.345^{***}	-0.427^{***}	-0.413^{***}
	(0.015)	(0.020)	(0.024)	(0.029)
n_{it}	1.102^{***}	1.288^{***}	1.455^{***}	1.338^{**}
	(0.262)	(0.390)	(0.536)	(0.577)
Constant	0.119^{***}	0.214^{***}		
	(0.013)	(0.019)		
Observations	2,334	2,334	2,334	2,334
Adjusted R^2	0.093	0.119	0.132	0.082
Note:				*p<0.1; **p<0.05; ***p<0.01

	Dependent variable:			
	$\hat{\lambda}_{it}$			
	(1)	(2)	(3)	(4)
Average $\alpha_i + \mu_t$	-0.119	-0.214	-7.433	-5.982
ϕ_{it}	4.063	7.869	11.527	9.321
n_{it}	-20.321	-29.401	-39.239	-30.215
Average $\hat{\lambda}$	2.693	5.392	0.839	0.732

3.3.3 Convergence

Here we test Proposition 3, which states that the speed of convergence β increases with increasing debt to capital ratio. Moreover, if debt to capital ratio is less than unity, higher bargaining power makes the economy converge faster. And conversely, if debt to capital ratio is greater than one, higher bargaining power leads to lower speed of convergence. To test this we rely on standard growth regressions, where speeds of convergence can be computed directly:

$$(\log y_{it} - \log y_{it-10})/10 = \alpha_i + \mu_t - \gamma \log y_{it-10} + \delta X_{it} + \varepsilon_{it}, \tag{3.28}$$

$$\gamma = (1 - e^{-10\beta})/10, \tag{3.29}$$

where y_{it} is real per capita GDP, X_{it} is a vector of control variables and β is the speed of convergence. The latter X_{it} includes lagged human capital index, reciprocal of lagged life expectancy at birth, log of lagged fertility rate and 10 year moving average of openness (export and import divided by real GDP). Human capital and openness are expected to positively correlate with growth, while reciprocal of life expectancy and fertility rate negatively, what is a standard result in the growth literature. Note that we use average growth of GDP per capita in a decade, what is sufficient to be a long term, as usual. This is a model of conditional convergence because different economies tend to converge to different steady states, which depend upon their characteristics that are controlled by X_{it}.

Here we are interested to test how external debt to physical capital ratio and bargaining power affect speed of convergence β through γ coefficient. We assume that $\gamma_{it} = \gamma(\lambda_{it}, \phi_{it})$, i.e. time-variant and dependent on bargaining power and debt to capital ratio. This in turn makes speed of convergence β dependent on the former variables and lets us directly test Proposition 3. We parametrise $\gamma(\lambda_{it}, \phi_{it})$ function and combine it with (3.28) and (3.29) to get:

$$(\log y_{it} - \log y_{it-10})/10 = \alpha_i + \mu_t - \gamma_{it} \log y_{it-10} + \delta X_{it} + \varepsilon_{it}, \tag{3.30}$$

$$\gamma_{it} = a_0 + a_1\phi_{it} + a_2\lambda_{it} + a_3\phi_{it}\lambda_{it} + a_4\phi_{it}\mathbb{I}_{\{\lambda_{it}>1\}} + a_5\phi_{it}\mathbb{I}_{\{\lambda_{it}<1\}}, \tag{3.31}$$

$$\beta_{it} = -0.1\log(1 - 10\gamma_{it}). \tag{3.32}$$

Inserting (3.31) into (3.30) produces interactions of $\log y_{it-10}$ with ϕ_{it}, λ_{it} and indicator functions – a reduced form single-equation model for estimation. In estimating this combined panel regression function we use 10 year moving averages of external debt to physical capital stock ratio and bargaining power. These variables are likely to be correlated with the error terms, i.e. higher growth can lead to less or more indebtedness and possibly higher bargaining power. To control for this correlation we use instrumental variables: 5 year moving averages of the latter variables with a 10 year lag, what are standard instruments (e.g., see Acemoglu, 2009). Openness is considered as an exogenous variable, i.e. growth does not make an economy more open, so it serves as an instrument itself.

Although we estimated model (3.30)-(3.31) using pooled, random effects, within, within two-ways instrumental variables estimators, pooled estimates are mostly reliable because other estimators provided too large rates of convergence, ranging even up to 30%. As summarised by Acemoglu (2009), methods that account for heterogeneity (fixed, random) generally tend to provide too large convergence rates. Noting the caveat that some heterogeneity is unaccounted for, we tabulate only pooled (using instruments) estimates in Table 3.2. All control variables are significant and of expected signs, except for (1) regression, where human capital's coefficient is negative. Model (1) does not include any debt ratio or bargaining power variables, so the speed of convergence β is constant and equal to 1.3% (see Table 3.5), what is closer to closed economy estimates. Models (2)-(4) contain ϕ_{it}, λ_{it} and indicator functions, what makes R squared higher than in (1).

Table 3.2: Pooled growth regression estimates.

	Dependent variable:			
	$(\log y_{it} - \log y_{it-10})/10$			
	(1)	(2)	(3)	(4)
$\log y_{it-10}$	-0.012^{***}	-0.017^{***}	-0.016^{***}	-0.018^{***}
	(0.001)	(0.002)	(0.002)	(0.002)
$human_{it-10}$	-0.004^{***}	0.015^{***}	0.018^{***}	0.020^{***}
	(0.001)	(0.003)	(0.003)	(0.003)
$1/life_{it-10}$	-2.516^{***}	-2.569^{***}	-2.601^{***}	-2.121^{***}
	(0.185)	(0.387)	(0.427)	(0.396)
$\log fertility_{it-10}$	-0.028^{***}	-0.024^{***}	-0.023^{***}	-0.023^{***}
	(0.002)	(0.003)	(0.003)	(0.003)
$openness_{it}$	0.010^{***}	0.013^{***}	0.015^{***}	0.014^{***}
	(0.002)	(0.005)	(0.005)	(0.005)
$\log y_{it-10} \cdot \lambda_{it}$			-0.009^{**}	-0.007^{***}
			(0.004)	(0.001)
$\log y_{it-10} \cdot \phi_{it}$			-0.005^{***}	
			(0.001)	
$\log y_{it-10} \cdot \lambda_{it} \cdot \phi_{it}$		-0.002^{***}	0.009^{*}	
		(0.0004)	(0.005)	
$\log y_{it-10} \cdot \phi_{it} \cdot \mathbb{I}_{\{\lambda_{it}>1\}}$				0.017^{***}
				(0.005)
$\log y_{it-10} \cdot \phi_{it} \cdot \mathbb{I}_{\{\lambda_{it}<1\}}$				-0.004^{***}
				(0.001)
Constant	0.209^{***}	0.196^{***}	0.215^{***}	0.221^{***}
	(0.009)	(0.018)	(0.019)	(0.019)
Observations	4,302	1,147	1,147	1,147
Adjusted R^2	0.161	0.279	0.282	0.290
Note:		*p<0.1; **p<0.05; ***p<0.01		

Model (2) is restrictive because it allows bargaining power to significantly increase γ_{it} and therefore increase β_{it}, regardless of the value of λ_{it}. Table 3.5 contains estimated speeds of convergence for different λ_{it} and ϕ_{it} combinations at their respective 10%, 25%, 50%, 75%, 99.5% quantiles and sample means. (2) model's implied speeds range from 1.8% to 2.4%, which are closer to parameterised values of theoretical model in Table 3.4.

Model (3) specification is flexible, as it allows to compute the thresholds when λ_{it} and ϕ_{it} raise β_{it}. More precisely, here $d\beta_{it}/d\lambda_{it} > 0$, when $\phi_{it} < 1$, i.e. always; and $d\beta_{it}/d\phi_{it} > 0$, when $\lambda_{it} < 0.5$. The latter concludes that the correct threshold for bargaining power to increase speed of convergence is $\lambda < 0.5$ - point estimate. As we have already discussed theoretical model's debt d and our used external debt stock might be not the same and therefore this 0.5 estimate differs from unity. However, we carried out Wald test with the null hypothesis that this threshold is equal to unity and did not manage to reject it at all levels, what points in the direction of our theoretical model[4]. Model (3) implies speeds of convergence ranging from 2% to 4%, where the upper value is with implied by high λ and low ϕ_{it}, as our theory predicts. Estimated $\beta = 2.273\%$ at means of $\phi = 0.75$ and $\lambda = 0.24$ is remarkably close to the theoretical model's counterpart of 2.167%.

The last model (4) includes λ_{it} threshold 1 directly via indicator functions. It is clear that the estimated model implies that λ_{it} always increases the speed of convergence, while ϕ_{it} does it only when $\lambda_{it} < 1$, what supports our theory. The computed speeds of convergence β_{it} are ranging from 2.2% to 4.2% - values close to the ones in Table 3.4.

We also checked other values for the threshold instead of 1, and we were able to get that the sum of squared residuals minimizing value was 1.05 - an estimate which is very close to unity. The differences in the

[4]To be more precise, we tested the estimated model versus the restricted model, where $-a_1 = a_3$ and were not able to reject the latter hypothesis with p-value 0.67 from the χ^2 distribution.

estimated coefficients of all models in Table 3.2 and the former (with 1.05 threshold) are negligible. What is more, λ, as in the theoretical model, seems to influence speeds of convergence more than ϕ.

Carried out empirical testing, though not perfect due to the lack of good data on interest rates and external debt, points in the direction of our theoretical model. The empirical speeds of convergence are extremely close to parametrised model's ones and Propositions 1 to 3 are supported by the data.

3.4 Final thoughts

In this chapter we generalised the small open-economy neoclassical model of growth (Barro et al., 1995; Pintus, 2011) to include macroprudential policy limits on indebtedness and endogenous interest rates. The model allows to draw some qualitative conclusions that are relevant to macroprudential policy setting in Lithuania, as well as other policies that affect indebtedness and interest rate levels.

The general model implies that economies, such as Lithuania's, can experience volatility while converging to their respective steady state, if macroprudential policies are too loose or absent. This result is a reminder of an almost mechanistic boom and bust cycle experienced by Lithuania in the 2000's, when indebtedness and economic activity were quickly expanding, then came to a halt, and deleveraging followed (see discussion in Introduction). On the other hand, if macroprudential policies are present and binding, such as the LTV ratio on household mortgages, it can produce substantial benefits in the reduction of volatility. What is more, the ability of economic agents to borrow less costly, due to inherent high bargaining power or higher banking competition, can raise upper limits on debt levels and let the country enjoy fast growth without experiencing volatility.

The findings can be associated with some policy implications. Governing the level of indebtedness can be achieved by some healthy macroprudential policy limits. These 'healthy' regulations should not discourage lending and borrowing to an extent that it could hinder economic performance. Instead, they should be limiting economy's volatility by targeting some ratio of indebtedness, such as the LTV ratio. The problem with these ratio targets is that they are unknown, however, they could be calibrated using some macro model or micro-level data on loans.

As higher bargaining power reduces the chance of falling into a volatile growth trajectory, policies that decrease the price of borrowing can be stabilising. For example, better access to financial markets or greater competition in the financial industry. However, while competition can put downward pressure on interest rates and promote stability, the banking competition-stability literature suggests that the relationship is less straightforward. For instance, great competition among banks may lower interest rates, but can also induce risk-seeking behaviour, which can in turn hinder overall stability, as was the case in Lithuania in 2000's. It is exactly the weakness of our presented model that it omits the risk (which was modelled in Chapter 2) factor. This is a potential line for future research, which could look into how competition among institutions induces risk-taking behaviour and affects growth in the long term.

Conclusions

The doctoral research agenda covered topics including bank money creation, macroprudential policy and its impact on economic activity, as well as on long-term growth and volatility. We finalise this dissertation by itemising the following conclusions.

- The institutional ability for banks to create credit and money out of thin air is an undeniable accounting fact, which empowers the banking sector to greatly influence the monetary system and the real economy. However, money creation is limited by market forces such as profitability and credit risk. In addition to, bank regulation, such as macroprudential policy tools, including capital and liquidity requirements, can act as a backstop on balance sheet expansion and limit money creation.
- The developed DSGE model for Lithuania, that contains banking sector, has money creation features. By inducing a positive credit supply shock, we showed that such model could generate model responses that fit the money-creationist view of banking. According to the model results, bank credit expansion that was caused by the supply shock can be almost entirely self-financed with the simultaneous creation of deposits that also serve as money. In the real or non-monetary version of the model, i.e. with fixed prices, banks have to rely on external resources to be able to lend them out in the form of credit.

- Our DSGE model for Lithuania is quite simple, yet it features money creation, which is important for any macroeconomic analysis of the banking sector. As a contribution to the literature on bank money creation, on the basis of our model, we propose four prerequisites that must be maintained by any macroeconomic model in order to be compatible with money creation. First, the model must be a stock-flow consistent system with endogenous determination of money supply. Second, and very importantly, stocks of loans and deposits must not be predetermined and they must be controlled simultaneously by all relevant agents. Third, it must have some level of heterogeneity between sectors, and banks with double entry bookkeeping balance sheets. Fourth, the model must be nominal in the sense there should be prices and not perfectly rigid price mechanism that clears the markets.

- In essence, our contribution is that our proposed prerequisites rectify the ingredients, that are necessary for money creation, that were outlined by Jakab and Kumhof (2015). As our prerequisites are not binding for most of the DSGE models that contain banking, we conclude that the number of models that have money creation is greater than described by Jakab and Kumhof (2015, 2019).

- We extend the DSGE model with money creation to include housing, mortgages and credit risk, and recalibrate it using Lithuanian data. The model contains three macroprudential policy tools – bank capital requirements, risk weights, and an LTV cap on mortgages. We simulate the model and assess the economic impact of tightening of the three measures. Model calculations imply that an early announcement of changes in macroprudential policy produces the smallest losses in welfare, because economic agents have more time to adjust. However, this does not imply that policy authorities should always announce early, especially in situations where decisive action is warranted, i.e. fast build-up of a bubble.

- Higher capital requirements and risk weights are passed on to higher interest rates, thus reduce the credit flows and economic activity in Lithuania. Specifically, an increase in bank capital requirements by 1 p.p. increases interest rates on corporate lending by 0.12 p.p. and on mortgages by 0.03 p.p. The impact on general lending is only -0.2%, however, corporate lending tends to be cut more in the short-term. This result stems from the fact that loans to businesses tend to carry higher risk weights, and is consistent with other studies (such as Budrys et al., 2017; Mayordomo and Rodriguez-Moreno, 2018). As per increased regulation of risk weights by 5% (or 2.5 p.p.), mortgage interests rates rise by 0.04 p.p. as in Glancy and Kurtzman (2018) and lending decreases by 0.1%, while the impact on economic activity is minuscule.

- A 1 p.p. tightening in the Lithuanian mortgage LTV requirement reduces housing interest rates by a rather large 0.3 p.p. due to an expansion of credit supply which exacerbates the effect of reduced loan demand. The impact on mortgage lending is around -0.5%, and -0.1% on GDP – similar to estimates of Richter et al. (2018) and Reichenbachas (2020).

- Since broad-based capital requirements have a tendency to decrease corporate lending by a greater extent, they are the least suitable of all three macroprudential policy measures for reducing cyclical pressures in the housing market. The tightening of LTV limit seems to be the most promising, because it is directly related to mortgages.

- The developed neoclassical model of small-open economy growth with indebtedness and endogenous interest rates shows that macroprudential limits may reduce Lithuania's long-term speeds of convergence. Nonetheless, macroprudential policy can also stabilise the economy's long-term growth. Otherwise, if there were no tools in place, the economy could experience a volatile path of convergence, characterised by boom-and-bust cycles, similar to the ones experienced by Lithuania in the 2000's.

- Promotion of competition in the financial industry of Lithuania could increase the economy's bargaining power for lower interest rates, thus lower debt service costs, and therefore decrease the chance of having boom-and-bust periods. However, one has to bear in mind that the model highlights only the interest rate channel of competition, without taking into account the possible negative effects on financial stability through the risk-taking channel.

Limitations of research and future directions

While the models presented in this dissertation are useful and enhance our understanding, they are not limitless. In essence, general equilibrium models, be they DSGE or of Ramsey type, are quite theoretical and rigid structures. Loan-level data from the credit register, such as the Lithuanian PRBD database, and longer time series of banking and macroeconomic data could be used to assess the impact of macroprudential policy in a purely empirical manner, to complement the findings of this dissertation.

The analysis carried out in this body of work exploits impulse-response functions and convergence rates, thus essentially focuses on the first moments of distributions of macrofinancial variables. Additional empirical analyses, such as the growth-at-risk approach (e.g. Suarez, 2021), could provide an additional dimension and look into the impact of macroprudential policy on the whole distribution of variables like GDP growth. This dimension enables a researcher to quantify not only the short-run cost of macroprudential policy measures but also the long-term benefits, in terms of reduced variability of GDP growth.

Lastly, modelling frameworks need not be entirely structural or reduced-form empirical models, but can be combined into semi-structural models (e.g. Budnik et al., 2020). Although such framework can be cumbersome, it may be used to calibrate macroprudential measures, such as the LTV ratio, in some optimal sense. We believe that the semi-structural approach is a good candidate line for future research.

Bibliography

Acemoglu, D. (2009). *Introduction to Modern Economic Growth*. Princeton University Press.

Aghion, P., Bacchetta, P., and Banerjee, A. (2004). Financial development and the instability of open economies. *Journal of Monetary Economics*, 51(6):1077–1106.

Aghion, P. and Durlauf, S., editors (2005). *Handbook of Economic Growth*, volume 1. Elsevier, 1 edition.

Aghion, P. and Durlauf, S., editors (2014). *Handbook of Economic Growth*, volume 2. Elsevier, 1 edition.

Angelini, P., Neri, S., and Panetta, F. (2014). The interaction between capital requirements and monetary policy. *Journal of Money, Credit and Banking*, 46(6):1073–1112.

Aoki, K., Benigno, G., and Kiyotaki, N. (2018). Monetary and financial policies in emerging markets. Manuscript available.

Barro, R. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics*, 106(2):407–443.

Barro, R., Mankiw, N. G., and Sala-i Martin, X. (1995). Capital mobility in neoclassical models of growth. *American Economic Review*, 85(1):103–15.

Barro, R. J. and Sala-i Martin, X. (2004). *Economic Growth*. MIT Press, 2nd edition.

Bekiros, S. D., Nilavongse, R., and Uddin, G. S. (2017). Mortgage defaults, expectation-driven house prices and monetary policy. Economics Working Papers ECO 2017/09, European University Institute.

Beneš, J. and Kumhof, M. (2012). The Chicago plan revisited. IMF Working Papers 12/202, International Monetary Fund.

Beneš, J., Kumhof, M., and Laxton, D. (2014a). Financial Crises in DSGE Models; A Prototype Model. IMF Working Papers 14/57, International Monetary Fund.

Beneš, J., Kumhof, M., and Laxton, D. (2014b). Financial Crises in DSGE Models; Selected Applications of MAPMOD. IMF Working Papers 14/56, International Monetary Fund.

Bernanke, B., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In Taylor, J. B. and Woodford, M., editors, *Handbook of Macroeconomics*, volume 1, Part C, chapter 21, pages 1341–1393. Elsevier.

Borio, C. (2011). Rediscovering the macroeconomic roots of financial stability policy: journey, challenges and a way forward. BIS Working Papers 354, Bank for International Settlements.

Bruno, B., Nocera, G., and Resti, A. (2017). The impact of risk-based capital requirements on corporate lending: Evidence from Europe. Discussion paper DP12007, Centre for Economic Policy Research.

Brzoza-Brzezina, M. (2014). Financial frictions and macroprudential policy. *International Journal of Central Banking*, 10(2):249–261.

Brzoza-Brzezina, M., Gelain, P., and Kolasa, M. (2014). Monetary and macroprudential policy with multiperiod loans. NBP Working Papers 192, Narodowy Bank Polski, Economic Research Department.

Budnik, K., Balatti, M., Dimitrov, I., Groß, J., Kleemann, M., Reichenbachas, T., Sanna, F., Sarychev, A., Siņenko, N., and Volk, M. (2020). Banking euro area stress test model. Working Paper Series 2469, European Central Bank.

Budrys, Z., Cappelletti, G., Marques, A. P., and Varraso, P. (2017). Macroprudential policy, O-SII bank capital buffers and their effects: Evidence from the euro area experiments.

Chen, J. and Columba, F. (2016). Macroprudential and monetary policy interactions in a DSGE model for Sweden. IMF Working Papers 16/74, International Monetary Fund.

Christiano, L. J., Eichenbaum, M. S., and Trabandt, M. (2018). On dsge models. *Journal of Economic Perspectives*, 32(3):113–40.

Claessens, S., Kose, M. A., and Terrones, M. E. (2009). What happens during recessions, crunches and busts? *Economic Policy*, 24(60):653–700.

Clancy, D. and Merola, R. (2017). Countercyclical capital rules for small open economies. *Journal of Macroeconomics*, 54(PB):332–351.

Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suarez, J., and Vardoulakis, A. P. (2015). Capital regulation in a macroeconomic model with three layers of default. *International Journal of Central Banking*, 15(3):9–63.

Cohen, D. and Sachs, J. (1986). Growth and external debt under risk of debt repudiation. *European Economic Review*, 30(3):529–560.

Crowe, C., Dell'Ariccia, G., Igan, D., and Rabanal, P. (2013). How to deal with real estate booms: Lessons from country experiences. *Journal of Financial Stability*, 9(3):300–319.

Darracq Pariès, M., Kok Sørensen, C., and Rodriguez-Palenzuela, D. (2011). Macroeconomic propagation under different regulatory regimes: Evidence from an estimated DSGE model for the Euro Area. *International Journal of Central Banking*, 7(4):49–113.

de Walque, G., Pierrard, O., and Rouabah, A. (2010). Financial (in)stability, supervision and liquidity injections: A dynamic general equilibrium approach. *The Economic Journal*, 120(549):1234–1261.

Decker, F. and Goodhart, C. (2018). Credit Mechanics – A Precursor to the Current Money Supply Debate. CEPR Discussion Paper 13233.

Dejong, D. N. and Dave, C. (2007). *Structural Macroeconometrics*. Princeton University Press, Princeton, New Jersey.

Dellas, H., Diba, B., and Loisel, O. (2010). Financial shocks and optimal policy. Working papers, Banque de France.

Duczynski, P. (1999). Adjustment costs in a two-capital growth model. CERGE-EI Working Papers wp144, The Center for Economic Research and Graduate Education - Economics Institute, Prague.

Fell, J., Grodzicki, M., Krušec, D., Martin, R., and O'Brien, E. (2017).

Overcoming non-performing loan market failures with transaction platforms. In *Financial Stability Review*, pages 130–144. European Central Bank.

Forlati, C. and Lambertini, L. (2011). Risky mortgages in a DSGE model. *International Journal of Central Banking*, 7(1):285–335.

Furfine, C. (2001). Bank portfolio allocation: The impact of capital requirements, regulatory monitoring, and economic conditions. *Journal of Financial Services Research*, 20(1):33–56.

Gelain, P., Lansing, K. J., and Natvik, G. J. (2015). Leaning against the credit cycle. Working Paper 2015/04, Norges Bank.

Gelain, P., Lansing, K. J., and Natvik, G. J. (2018). Leaning against the credit cycle. *Journal of the European Economic Association*, 16(5):1350–1393.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking*, 42(S1):107–141.

Gertler, M. and Kiyotaki, N. (2015). Banking, liquidity, and bank runs in an infinite horizon economy. *American Economic Review*, 105(7):2011–43.

Glancy, D. P. and Kurtzman, R. J. (2018). How do capital requirements affect loan rates? Evidence from high volatility commercial real estate. Finance and Economics Discussion Series 2018-079, Board of Governors of the Federal Reserve System (US).

González, L., Durán Santomil, P., Lado Sestayo, R., and Búa, M. (2016). The impact of loan-to-value on the default rate of residential mortgage-backed securities. *The Journal of Credit Risk*, 12:1–13.

Goodfriend, M. and McCallum, B. T. (2007). Banking and interest rates in monetary policy analysis: A quantitative exploration. *Journal of Monetary Economics*, 54(5):1480–1507.

Goodhart, C., Tsomocos, D., and Shubik, M. (2013). Macro-Modelling, Default and Money. FMG Special Papers sp224, Financial Markets Group.

Goodhart, C. A. E. and Tsomocos, D. (2011). The role of default in macroeconomics. IMES Discussion Paper Series 11-E-23, Institute for Monetary and Economic Studies, Bank of Japan.

Guerrieri, L. and Iacoviello, M. (2017). Collateral constraints and macroeconomic asymmetries. *Journal of Monetary Economics*, 90(C):28–49.

Hoon Lim, C., Costa, A., Columba, F., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T., and Wu, X. (2011). Macroprudential Policy; What Instruments and How to Use them? Lessons From Country Experiences. IMF Working Papers 11/238, International Monetary Fund.

Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. *American Economic Review*, 95(3):739–764.

Iacoviello, M. (2015). Financial Business Cycles. *Review of Economic Dynamics*, 18(1):140–164.

Iacoviello, M. and Neri, S. (2010). Housing market spillovers: Evidence from an estimated DSGE model. *American Economic Journal: Macroeconomics*, 2(2):125–64.

Jakab, Z. and Kumhof, M. (2015). Banks are not intermediaries of loanable funds – and why this matters. Bank of England working papers 529.

Jakab, Z. and Kumhof, M. (2019). Banks are not intermediaries of loanable funds — facts, theory and evidence. Bank of England working papers 761.

Jakučionytė, E. (2018). Output and welfare gains from non-recourse mortgages: The role of general equilibrium effects.

Jordà, O., Schularick, M., and Taylor, A. M. (2013). When credit bites back. *Journal of Money, Credit and Banking*, 45(s2):3–28.

Jordà, O., Schularick, M., and Taylor, A. M. (2017). Macrofinancial history and the new business cycle facts. *NBER Macroeconomics Annual*, 31(1):213 – 263.

Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2015). Credit supply and the housing boom. NBER Working Papers 20874, National Bureau of Economic Research.

Kaldor, N. (1957). A model of economic growth. *The Economic Journal*, 67(268):591–624.

Kanngiesser, D., Martin, R., Maurin, L., and Moccero, D. (2017). Estimating the impact of shocks to bank capital in the euro area. Working Paper Series 2077, European Central Bank.

Karmelavičius, J. (2021). Risky Mortgages and Macroprudential Policy: A Calibrated DSGE Model for Lithuania. *Ekonomika*, 100(2):6–39.

Karmelavičius, J. and Ramanauskas, T. (2019). Bank credit and money creation in a DSGE model of a small open economy. *Baltic Journal of Economics*, 19(2):296–333.

Karpavičius, S. (2008). Calibrated DSGE model for the Lithuanian economy. *Pinigų studijos (Monetary Studies)*, Nr. 2:22–46.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2):211–248.

Kumhof, M. and Wang, X. (2020). Banks, Money, and the Zero Lower Bound on Deposit Rates. Tinbergen institute discussion papers.

Kuodis, R. and Ramanauskas, T. (2009). From boom to bust: lessons from Lithuania. *Pinigų studijos (Monetary Studies)*, Nr. 1:96–104.

Kvedaras, V. (2013). Exogenous growth dynamics with a binding macroeconomic borrowing constraint: the case of a constant savings rate.

Lozej, M., Onorante, L., and Rannenberg, A. (2017). Countercyclical capital regulation in a small open economy dsge model. Research Technical Papers 03/RT/17, Central Bank of Ireland.

Mankiw, N. G. (2007). *Macroeconomics*. Worth Publishers, New York, 6th edition.

Mankiw, N. G., Romer, D., and Weil, D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, 107(2):407–437.

Mayordomo, S. and Rodriguez-Moreno, M. (2018). How do european banks cope with macroprudential capital requirements?

McLeay, M., Radia, A., and Thomas, R. (2014). Money creation in the modern economy. Quarterly bulletin, Bank of England.

Mendoza, E. G. and Terrones, M. E. (2008). An anatomy of credit booms: Evidence from macro aggregates and micro data. NBER Working

Papers 14049, National Bureau of Economic Research, Inc.

Mihai, I., Popa, R., and Banu, E. (2018). The probability of default for private individuals using microeconomic data. What is the role played by macroprudential measures?

Nookhwun, N. and Tsomocos, D. (2017). Mortgage default, financial disintermediation and macroprudential policies.

Noss, J. and Toffano, P. (2016). Estimating the impact of changes in aggregate bank capital requirements on lending and growth during an upswing. *Journal of Banking & Finance*, 62(C):15–27.

Pedersen, J. (2016). An estimated DSGE-model for Denmark with housing, banking, and financial frictions. *Danmarks Nationalbank Working Paper No. 108*.

Pintus, P. (2007). Procyclical international capital flows, debt overhang and volatility. Working papers, HAL.

Pintus, P. (2011). International capital flows, debt overhang and volatility. *International Journal of Economic Theory*, 7.

Proškutė, A. (2012). Business cycle drivers in Lithuania. *Pinigų studijos (Monetary Studies)*, Nr. 1:5–29.

Pušinskaitė, R. (2014). Essays on macroeconomics and financial intermediation. Doctoral dissertation, Wolfgang Goethe-University Frankfurt am Main.

Quint, D. and Rabanal, P. (2014). Monetary and macroprudential policy in an estimated DSGE model of the Euro Area. *International Journal of Central Banking*, 10(2):169–236.

Ramanauskas, T. (2005). Bankų kredito didėjimas makroekonominiu požiūriu. *Pinigų studijos (Monetary Studies)*, Nr. 3:78–97.

Ramanauskas, T. (2011). What caused the recent boom-and-bust cycle in Lithuania? Evidence from a macromodel with the financial sector. Bank of Lithuania Working Paper Series 10, Bank of Lithuania.

Ramanauskas, T. (2017). Understanding bank credit: why it is crucial for sound economic analysis. Presentation given to the staff of the Bank of Lithuania.

Ramanauskas, T. and Karmelavičius, J. (2018). Bank credit and money creation in a DSGE model of a small open economy. Bank of Lithuania Working Paper Series 52, Bank of Lithuania.

Ramanauskas, T., Matkėnaitė, S., and Rutkauskas, V. (2016a). Application of the integrated accounts framework for empirical investigation of the economic and financial cycle in Lithuania. *Pinigų studijos (Monetary Studies)*, Nr. 1:61–79.

Ramanauskas, T., Matkėnaitė, S., and Rutkauskas, V. (2016b). Credit and money creation from the integrated accounts perspective. *Pinigų studijos (Monetary Studies)*, Nr. 1:5–29.

Ramanauskas, T., Matkėnaitė, S., and Rutkauskas, V. (2018). Application of the integrated accounts framework for empirical investigation of the economic and financial cycle in Lithuania. Occasional Paper Series 20, Bank of Lithuania.

Ravn, M. O. and Uhlig, H. (2002). On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations. *The Review of Economics and Statistics*, 84(2):371–376.

Reichenbachas, T. (2020). Assessing the impact of macroprudential measures: The case of the LTV limit in Lithuania. Working Paper Series 80, Bank of Lithuania.

Richter, B., Schularick, M., and Shim, I. (2018). The costs of macroprudential policy. Working paper 24989, National Bureau of Economic Research.

Romer, D. (2012). *Advanced Macroeconomics*. McGraw-Hill, New York, 4th edition.

Romer, P. (1987). Crazy explanations for the productivity slowdown. In *NBER Macroeconomics Annual 1987, Volume 2*, pages 163–210. National Bureau of Economic Research, Inc.

Rubio, M. and Comunale, M. (2016). Lithuania in the Euro Area: Monetary Transmission and Macroprudential Policies. Working Paper Series 34, Bank of Lithuania.

Schmitt-Grohé, S. and Uribe, M. (2003). Closing small open economy models. *Journal of International Economics*, 61(1):163–185.

Solow, R. (1956). A contribution to the theory of economic growth. *The*

Quarterly Journal of Economics, 70(1):65–94.

Suarez, J. (2021). Growth-at-risk and macroprudential policy design JEL Classification: G01, G20, G28. Occasional Paper Series 19, European Systemic Risk Board.

Townsend, R. M. (1979). Optimal contracts and competitive markets with costly state verification. *Journal of Economic Theory*, 21(2):265–293.

Vītola, K. and Ajevskis, V. (2011). Housing and banking in a small open economy DSGE model. Working Papers 2011/03, Latvijas Banka.

Vlcek, J. and Roger, S. (2012). Macrofinancial Modeling At Central Banks; Recent Developments and Future Directions. IMF Working Papers 12/21, International Monetary Fund.

Werner, R. A. (2014). Can banks individually create money out of nothing? — the theories and the empirical evidence. *International Review of Financial Analysis*, 36:1 – 19.

Appendix A

Appendix to Chapter 1.

All equations

Here we state all equations of the baseline model.

$$W_t L_t + Div_t + \left(1 + r_{D_{t-1}}\right) D_{H_{t-1}} = P_t C_t + D_{H_t}$$
$$\beta \mathbb{E}_t \left[\frac{\nu_{t+1}}{\nu_t} \frac{(1 + r_{D_t}) P_t}{P_{t+1}} C_{t+1}^{-\theta_C} \right] = C_t^{-\theta_C}$$
$$\sigma_L L_t^{\theta_L} = \frac{C_t^{-\theta_C} W_t}{P_t}$$

$$Y_t = A_t K_{t-1}^{\alpha} L_t^{1-\alpha}$$
$$K_t = K_{t-1}(1 - \delta) + I_t$$
$$P_t K_t = L_{F_t} + \Pi_t$$
$$\Pi_t = \Pi_{t-1} - Div_t + \pi_t$$
$$\pi_t = P_t Y_t - W_t L_t - P_t \delta K_{t-1} - r_{L_{t-1}} L_{F_{t-1}} - \Omega_t^I - \Omega_t^P + K_{t-1} \Delta P_t$$
$$\Omega_t^P = \frac{\psi_P}{2} \left(\frac{P_t}{P_{t-1}} - 1 \right)^2 P_t Y_t$$
$$\Omega_t^I = \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 P_t I_t$$

$$\frac{\partial \Omega_t^I}{\partial I_t} = \frac{\psi_I}{2} P_t \left(1 + 3\left(\frac{I_t}{I_{t-1}}\right)^2 - 4\left(\frac{I_t}{I_{t-1}}\right)\right)$$

$$\frac{\partial \Omega_{t+1}^I}{\partial I_t} = -\psi_I P_{t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 \left(\frac{I_{t+1}}{I_t} - 1\right)$$

$$\frac{\partial \Omega_t^P}{\partial P_t} = \psi_P Y_t \left(\frac{P_t}{P_{t-1}} - 1\right)$$

$$\frac{\partial \Omega_{t+1}^P}{\partial P_t} = -\psi_P Y_{t+1} \left(\frac{P_{t+1}}{P_t}\right)^2 \left(\frac{P_{t+1}}{P_t} - 1\right)$$

$$\frac{\partial \Omega_t^P}{\partial L_t} = \frac{(1-\alpha)}{L_t} \Omega_t^P$$

$$\frac{\partial \Omega_{t+1}^P}{\partial K_t} = \frac{\alpha}{K_t} \Omega_{t+1}^P$$

$$\lambda_{1,t} = -\frac{1}{P_t}$$

$$\lambda_{2,t} = -\frac{1}{P_t} + \beta_F \mathbb{E}_t \left[\frac{1}{P_{t+1}}\right]$$

$$\lambda_{3,t} = -\frac{1}{P_t} + \beta_F \left(1 + r_{L,t}\right) \mathbb{E}_t \left[\frac{1}{P_{t+1}}\right]$$

$$\lambda_{4,t} = -\frac{1}{P_t} \frac{\partial \Omega_t^I}{\partial I_t} - \beta_F \mathbb{E}_t \left[\frac{1}{P_{t+1}} \frac{\partial \Omega_{t+1}^I}{\partial I_t}\right]$$

$$\lambda_{5,t} = \frac{L_t}{(1-\alpha) P_t Y_t} \left(W_t + \frac{\partial \Omega_t^P}{\partial L_t}\right) - 1$$

$$Y_t \left(1 + \varepsilon \lambda_{5,t}\right) = \frac{\partial \Omega_t^P}{\partial P_t} + \beta_F \mathbb{E}_t \left[\frac{P_t}{P_{t+1}} \frac{\partial \Omega_{t+1}^P}{\partial P_t}\right]$$

$$\begin{aligned}(\eta_K P_t \lambda_{3,t} - P_t \lambda_{2,t} - \lambda_{4,t}) = \beta_F \mathbb{E}_t \Bigg[& \alpha \frac{Y_{t+1}}{K_t} \left(1 + \lambda_{5,t+1}\right) + 1 - \delta - \frac{P_t}{P_{t+1}} - \\ & - \lambda_{4,t+1} \left(1 - \delta\right) - \frac{1}{P_{t+1}} \frac{\partial \Omega_{t+1}^P}{\partial K_t} \Bigg]\end{aligned}$$

$$\lambda_{3,t} \left(L_{F_t} - \eta_K P_t K_t\right) = 0$$

$$
\begin{aligned}
&L_{F_t} = D_{H_t} + F_t + E_t \\
&E_t = E_{t-1} - DivB_t + \pi_t^B \\
&\pi_t^B = r_{L_{t-1}} L_{F_{t-1}} - r_{D_{t-1}} D_{H_{t-1}} - r_{F_{t-1}} F_{t-1} + \gamma \log\left(\frac{E_{t-1}}{\omega L_{F_{t-1}}} - \mu_{t-1}\right) L_{F_{t-1}} \\
&r_{F_t} = r_t^*(\phi_0 + \phi_1 \frac{F_t}{P_t Y_t}) \\
&\frac{1}{DivB_t} = \beta_B \mathbb{E}_t\left[\frac{1}{DivB_{t+1}}\right]\left(1 + r_{D_t} + \gamma \frac{L_{F_t}}{E_t - \mu_t \omega L_{F_t}}\right) \\
&r_{L_t} - r_{D_t} = \gamma\left(\frac{E_t}{E_t - \omega \mu_t L_{F_t}} - \log\left(\frac{E_t}{\omega L_{F_t}} - \mu_t\right)\right) \\
&F_t = P_t Y_t \frac{r_{D_t} - \phi_0 r_t^*}{2\phi_1 r_t^*}
\end{aligned}
$$

$$
\begin{aligned}
&P_t NX_t = DivB_t + r_{F_{t-1}} F_{t-1} - \Delta F_t \\
&NX_t = n_1 P_t^{-n_2} - n_0 C_t
\end{aligned}
$$

There are 33 equations and 33 endogenous variables. The exogenous variables are: A_t, μ_t, r_t^*, ν_t.

Steady state

Noting that in the the steady state price and investment adjustment costs, as well as their respective partial derivatives, are equal to zero and normalising total factor productivity A to unity, we can recursively derive steady state expressions for model variables.

$$
\begin{aligned}
&r_D = \frac{1}{\beta} - 1 \\
&\frac{E}{L_F} = \mu\omega + \frac{\gamma}{\frac{1}{\beta_B} - \frac{1}{\beta}} \\
&r_L = r_D + \gamma\left(\frac{E/L_F}{E/L_F - \mu\omega} - \log\left(\frac{1}{\omega}\frac{E}{L_F} - \mu\right)\right)
\end{aligned}
$$

$$
\begin{aligned}
\frac{F}{PY} &= \frac{r_D - \phi_0 r^*}{2\phi_1 r^*} \\
r_F &= r^* \left(\phi_0 + \phi_1 \frac{F}{PY} \right) \\
\frac{Y}{K} &= \frac{1}{\alpha} \left(\frac{\varepsilon}{\varepsilon - 1} \right) \left((1 - \eta_K) \left(\frac{1}{\beta_F} - 1 \right) + \eta_K r_L + \delta \right) \\
\frac{Y}{L} &= \left(\frac{Y}{K} \right)^{\alpha/(\alpha-1)} \\
\frac{W}{P} &= (1-\alpha) \frac{Y}{L} \left(\frac{\varepsilon - 1}{\varepsilon} \right) \\
\frac{L_F}{PY} &= \eta_K \left(\frac{Y}{K} \right)^{-1} \\
\frac{D_H}{PY} &= \left(1 - \frac{E}{L_F} \right) \frac{L_F}{PY} - \frac{F}{PY} \\
\frac{C}{Y} &= 1 - \delta \frac{K}{Y} - r_L \frac{L_F}{PY} + r_D \frac{D_H}{PY} \\
L &= \left(\left(\frac{1-\alpha}{\sigma_L} \right) \left(\frac{\varepsilon - 1}{\varepsilon} \right) \left(\frac{Y}{L} \right)^{1-\theta_C} \left(\frac{C}{Y} \right)^{-\theta_C} \right)^{\frac{1}{\theta_L + \theta_C}} \\
Y &= \left(\frac{Y}{L} \right) L
\end{aligned}
$$

Now that we have the expression for output, we move on to express the price level.

$$
\begin{aligned}
\frac{\pi^B}{PY} &= r_L \frac{L_F}{PY} - r_D \frac{D_H}{PY} - r_F \frac{F}{PY} + \gamma \log \left(\frac{E}{L_F} \frac{1}{\omega} - \mu \right) \frac{L_F}{PY} \\
NX &= \left(\frac{\pi^B}{PY} + r_F \frac{F}{PY} \right) Y \\
C &= \left(\frac{C}{Y} \right) Y \\
P &= \left(\frac{n_1}{NX + n_0 C} \right)^{\frac{1}{n_2}}
\end{aligned}
$$

Utilising the expressions for ratios above, we can obtain the steady state expressions for the following variables: L_F, E, F, K, W, D_H, and π^B. We can use these to obtain the rest of the variables.

$$
\begin{aligned}
\lambda_1 &= -\frac{1}{P} \\
\lambda_2 &= \frac{\beta_F - 1}{P} \\
\lambda_3 &= \frac{\beta_F(1 + r_L) - 1}{P} \\
\lambda_4 &= 0 \\
\lambda_5 &= \frac{WL}{(1-\alpha)PY} - 1 \\
I &= \delta K \\
\pi &= PY - WL - P\delta K - r_L L_F \\
\Pi &= PK - L_F \\
Div &= \pi \\
DivB &= \pi^B
\end{aligned}
$$

Figures

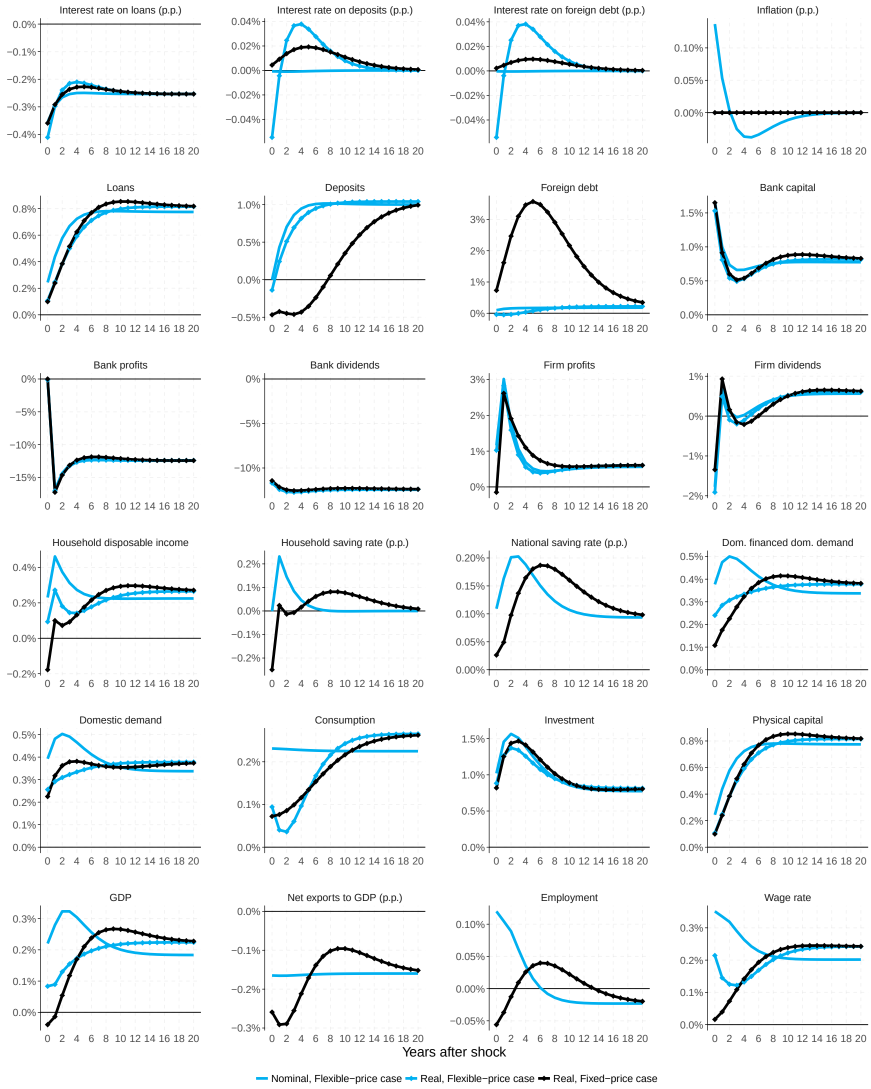


Figure 3.1: Responses to an unexpected increase in banker's willingness to lend.

Appendix B

Appendix to Chapter 2.

Tables

Table 3.3: Welfare gain of tightening of LTV cap, capital requirements (Cap. req.) and risk weights (RW) over instant scenario.

	Route	Impatient	Patient	Total
LTV	Future	0.0020	0.0004	0.0024
	Gradual	0.0016	0.0003	0.0019
Cap. req.	Future	0.0017	-0.0003	0.0014
	Gradual	0.0014	-0.0002	0.0012
RW	Future	0.0164	-0.0026	0.0138
	Gradual	0.0145	-0.0020	0.0125

Figures

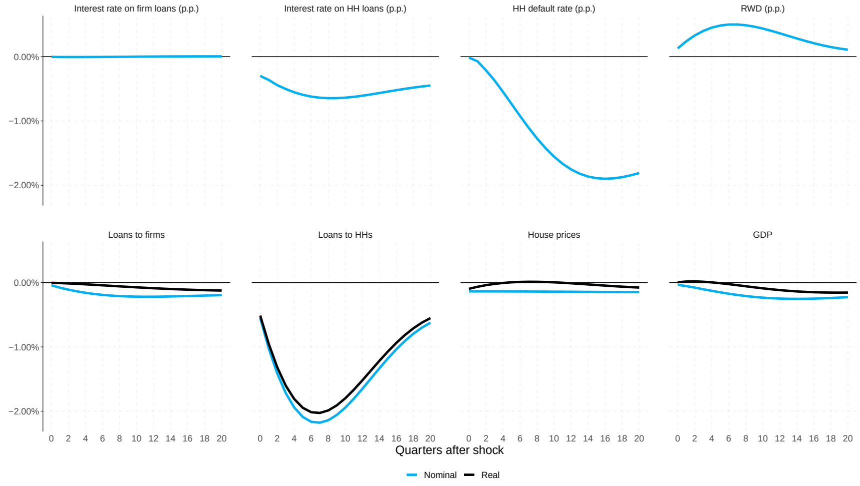


Figure 3.2: Responses to an unexpected and permanent rise tightening of LTV constraint by 1 p.p.

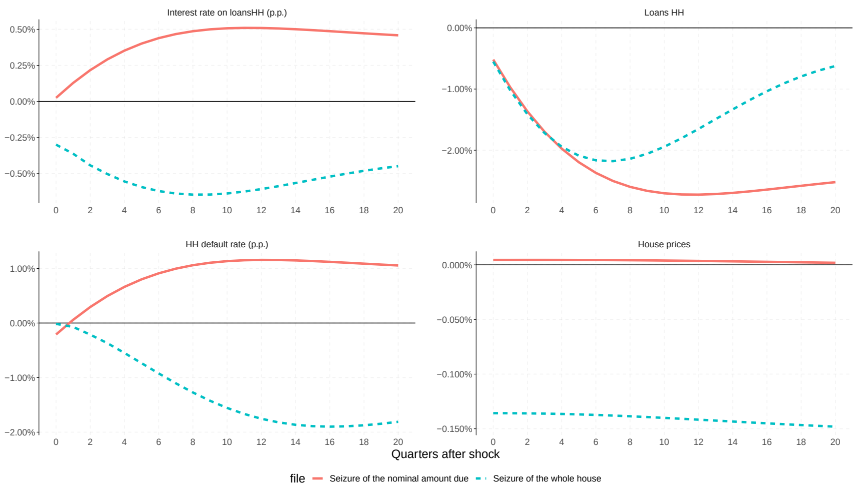


Figure 3.3: Comparison of responses to an unexpected and permanent rise tightening of LTV constraint by 1 p.p.

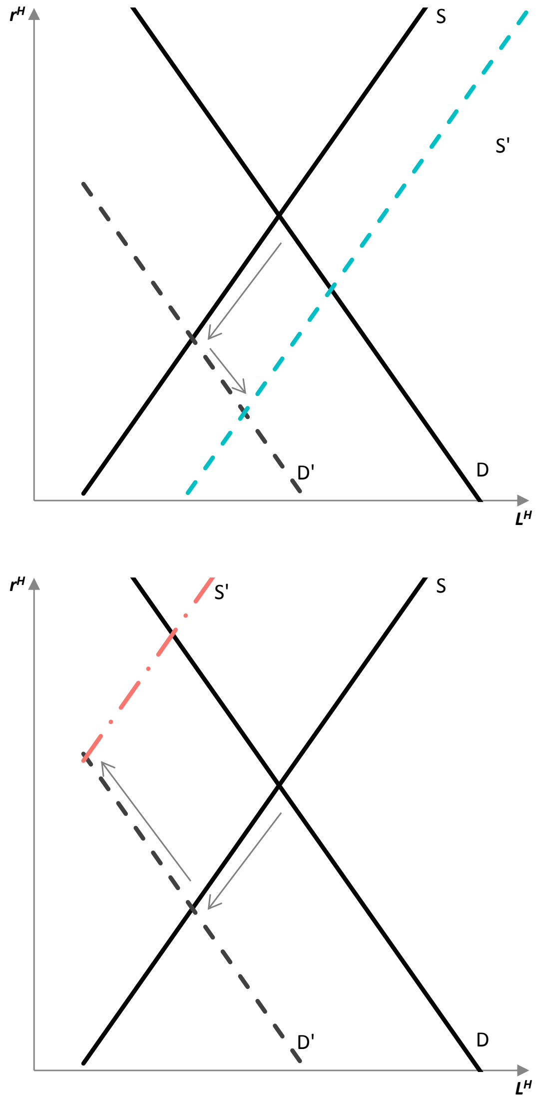


Figure 3.4: Stylised depiction of changes in credit supply and demand after LTV tightening occurs. Under the assumption of seizure of whole house (upper), and bank recovery of the whole amount defaulted (lower).

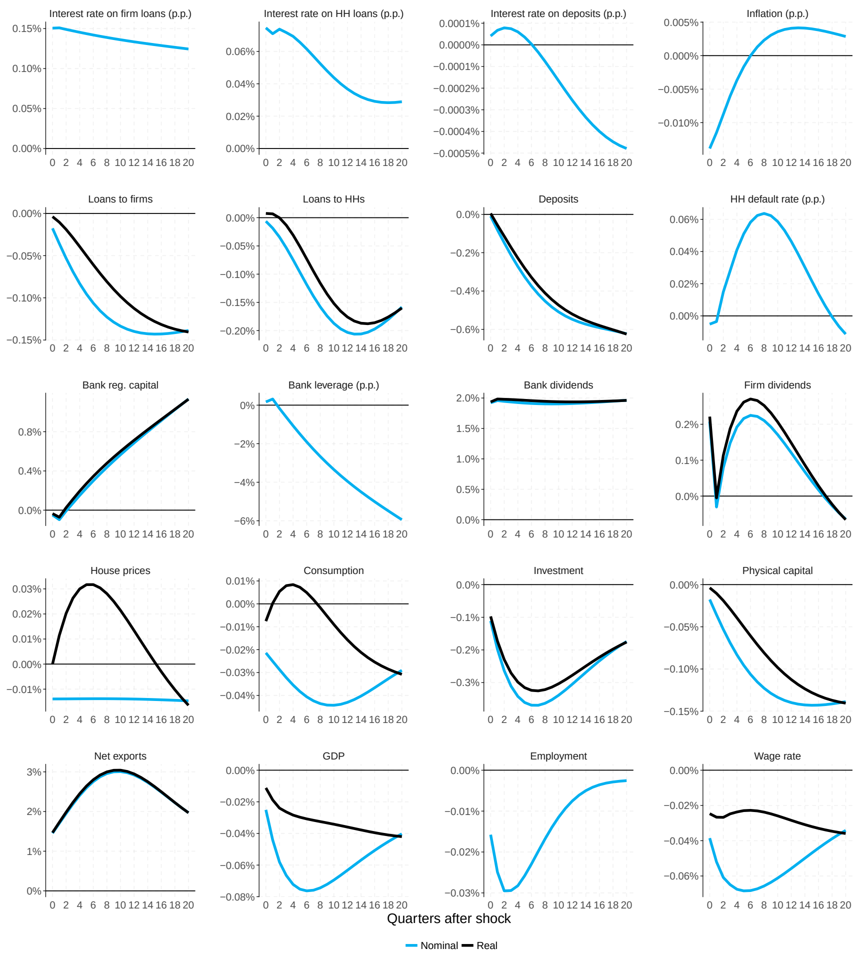


Figure 3.5: Responses to an unexpected and permanent rise in bank capital requirement by 1 p.p.

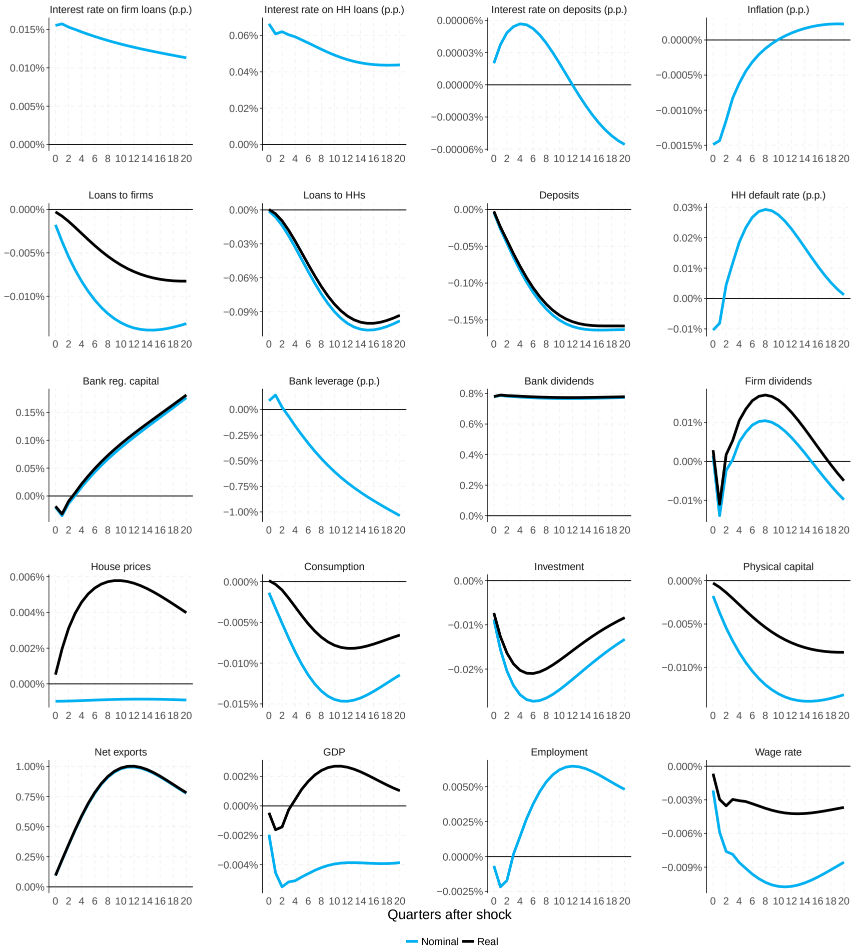


Figure 3.6: Responses to an unexpected and permanent rise in risk weight on mortgages by 5% (2.5 p.p. under baseline calibration).

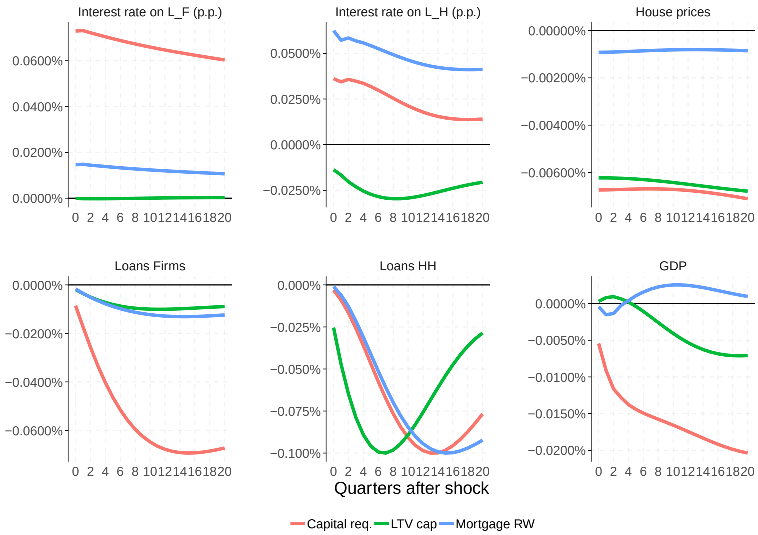


Figure 3.7: Main variable respones to *equivalised* three prudential policy tightenings: capital requirements, cap on LTV ratio and mortgage risk weight.

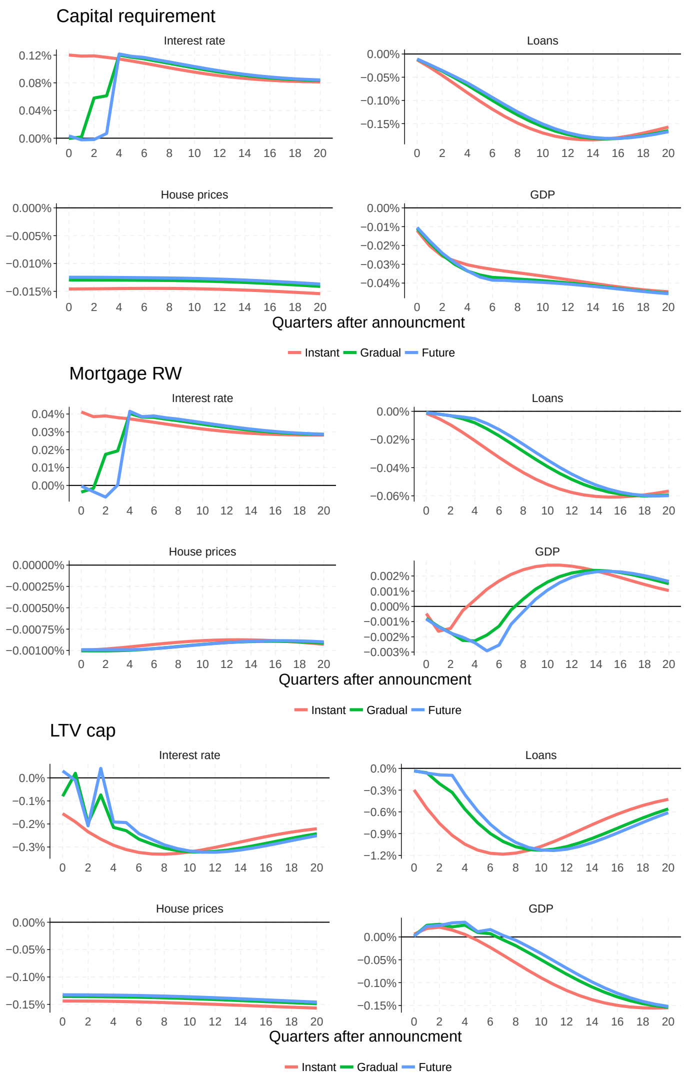
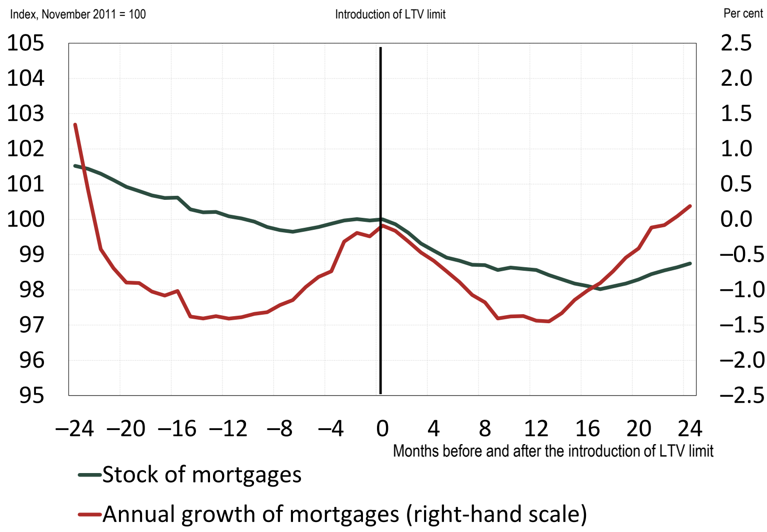


Figure 3.8: Main variable respones to prudential policy tightenings under different scenarios: *instant*, *gradual*, *future*



Source: Bank of Lithuania calculations.

Figure 3.9: Stock of mortgage loans before and after introduction of LTV requirement of 85% in Lithuania.

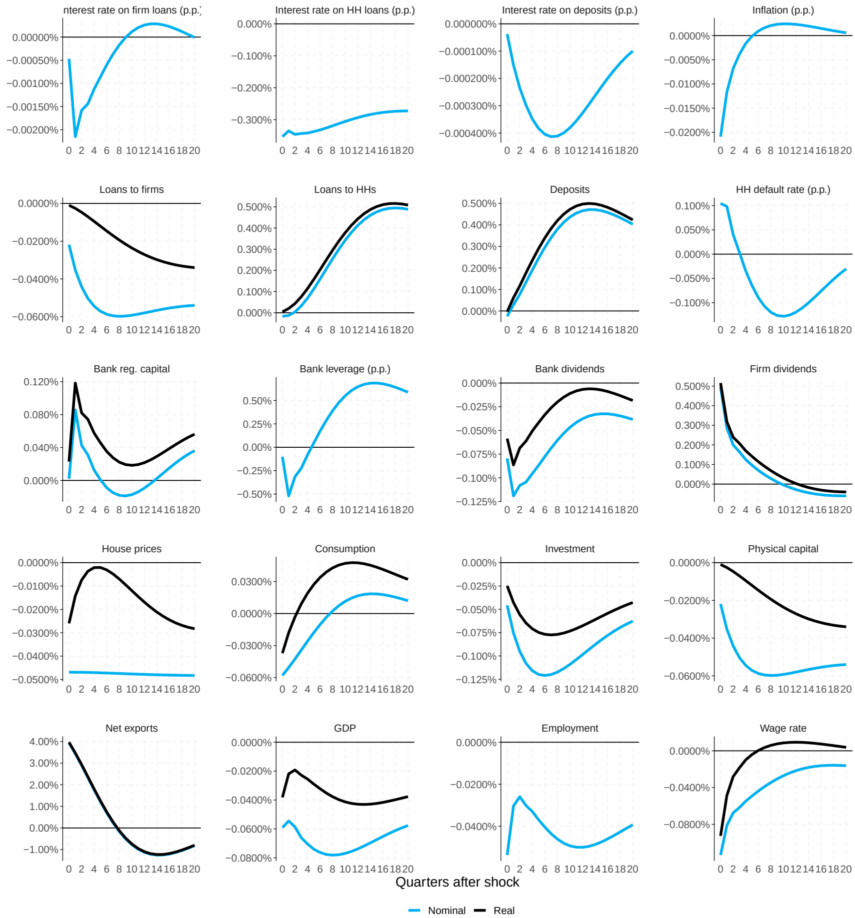


Figure 3.10: Main variable responses to a permanent reduction in bank mortgage monitoring/adminstritative costs o by 10 %.

Equation list

Here we state all equations of the baseline model.

Patient household (4 equations)

$$W_t^P L_t^P + Div_t + r_{t-1}^D D_{t-1} = P_t C_t^P + \Delta D_t + P_t^H \left(H_t^P - H_{t-1}^P\right)$$

$$\beta_P \left(1 + r_t^D\right) \mathbb{E}_t \left[\frac{1}{P_{t+1} C_{t+1}^P}\right] = \frac{1}{P_t C_t^P}$$

$$\sigma_L L_t^P = \frac{W_t^P}{P_t C_t^P}$$

$$\frac{\sigma_{H,t}}{H_t^P} + \beta_P \mathbb{E}_t \left[\frac{P_{t+1}^H}{P_{t+1} C_{t+1}^P}\right] = \frac{P_t^H}{P_t C_t^P}$$

Impatient household (6 equations)

$$W_t^I L_t^I + L_t^H = P_t C_t^I + \left(1 + r_{t-1}^H - \chi_t^H\right) L_{t-1}^H + P_t^H \left(H_t^I - H_{t-1}^I\right) + \\ + P_t^H \chi_{t-1}^H H_{t-2}^I + \frac{\psi_D}{2} \left(\chi_{t-1}^H L_{t-2}^H\right)^2$$

$$\lambda_{2,t}^I \left(L_t^H - \rho L_{t-1}^H - (1-\rho) \eta_{H,t} P_t^H H_t^I\right) = 0$$

$$\beta_I \mathbb{E}_t \left[\frac{1}{P_{t+1} C_{t+1}^I} \left(1 + r_t^H - \chi_{t+1}^H\right) + \rho \lambda_{2,t+1}^I + \beta_I \psi_D \left(\chi_{t+1}^H\right)^2 \frac{L_t^H}{P_{t+2} C_{t+2}^I}\right] = \frac{1}{P_t C_t^I} + \lambda_{2,t}^I$$

$$\frac{\sigma_{H,t}}{H_t^I} - (1-\rho) \eta_{H,t} \lambda_{2,t}^I P_t^H + \beta_I \mathbb{E}_t \left[\frac{P_{t+1}^H}{P_{t+1} C_{t+1}^I}\right] = \frac{P_t^H}{P_t C_t^I} + \beta_I^2 \mathbb{E}_t \left[\chi_{t+1}^H \frac{P_{t+2}^H}{P_{t+2} C_{t+2}^I}\right]$$

$$\sigma_L L_t^I = \frac{W_t^I}{P_t C_t^I}$$

$$\frac{L_{t-1}^H}{P_t C_t^I} = \beta_I \mathbb{E}_t \left[\frac{1}{P_{t+1} C_{t+1}^I} \left(P_{t+1}^H H_{t-1}^I + \psi_D \chi_t^H \left(L_{t-1}^H\right)^2\right)\right]$$

Firms (15 equations)

$$Y_t = A_t K_{t-1}^{\alpha} L_t^{1-\alpha}$$

$$K_t = K_{t-1}(1-\delta) + I_t$$

$$P_t K_t = L_t^F + \Pi_t$$

$$\Pi_t = \Pi_{t-1} - Div_t + \pi_t$$

$$\pi_t = P_t Y_t - W_t L_t - P_t \delta K_{t-1} - r_{t-1}^L L_{t-1}^F - \Omega_t^I - \Omega_t^P + K_{t-1} \Delta P_t$$

$$\lambda^F_{2,t} = -\frac{1}{P_t} + \beta_F \mathbb{E}_t\left[\frac{1}{P_{t+1}}\right]$$

$$\lambda^F_{3,t} = -\frac{1}{P_t} + \beta_F\left(1+r^L_t\right)\mathbb{E}_t\left[\frac{1}{P_{t+1}}\right]$$

$$\lambda^F_{4,t} = -\frac{1}{P_t}\frac{\partial\Omega^I_t}{\partial I_t} - \beta_F \mathbb{E}_t\left[\frac{1}{P_{t+1}}\frac{\partial\Omega^I_{t+1}}{\partial I_t}\right]$$

$$\lambda^F_{5,t} = \frac{L_t}{(1-\alpha)P_t Y_t}\left(W_t + \frac{\partial\Omega^P_t}{\partial L_t}\right) - 1$$

$$Y_t\left(1+\varepsilon\lambda^F_{5,t}\right) = \frac{\partial\Omega^P_t}{\partial P_t} + \beta_F \mathbb{E}_t\left[\frac{P_t}{P_{t+1}}\frac{\partial\Omega^P_{t+1}}{\partial P_t}\right]$$

$$\left(\eta_K P_t\lambda^F_{3,t} - P_t\lambda^F_{2,t} - \lambda^F_{4,t}\right) = \beta_F \mathbb{E}_t\left[\alpha\frac{Y_{t+1}}{K_t}\left(1+\lambda^F_{5,t+1}\right) + 1 - \delta - \frac{P_t}{P_{t+1}} - \right.$$
$$\left. - \lambda^F_{4,t+1}(1-\delta) - \frac{1}{P_{t+1}}\frac{\partial\Omega^P_{t+1}}{\partial K_t}\right]$$

$$\lambda^F_{3,t}\left(L^F_t - \eta_K P_t K_t\right) = 0$$

$$L = \left(L^P\right)^\nu \left(L^I\right)^{1-\nu}$$

$$W^P L^P = \nu W L$$

$$W^I L^I = (1-\nu) W L$$

Banks (10 equations)

$$L^H_t + L^F_t = D_t + F_t + \pi^B_t + \Pi^B_t$$

$$\Pi^B_t = \Pi^B_{t-1} - DivB_t + \pi^B_{t-1}$$

$$\pi^B_t = \left(r^H_{t-1} - \chi^H_t\right)L^H_{t-1} + r^L_{t-1}L^F_{t-1} - r^D_{t-1}D_{t-1} - r^F_{t-1}F_{t-1} + (1-o)\chi^H_{t-1}P^H_t H^I_{t-2}$$

$$\lambda^B_{1,t} = \lambda^B_{2,t}\left(1 - \frac{\gamma}{a + CR_t - \mu_t}\right)$$

$$\lambda^B_{2,t} = -\frac{1}{DivB + \Omega^B_t}$$

$$\lambda^B_{1,t} = \beta_B\left[\lambda^B_{2,t} r^D_t + \lambda^B_{2,t+1}\right]$$

$$\beta_B \mathbb{E}_t\left[\lambda^B_{1,t+1}\left(r^H_t - \chi^H_{t+1} - r^D_t\right) + \lambda^B_{1,t+2}\beta_B\frac{(1-o)}{(1-\rho)}\frac{\chi^H_{t+1}}{\eta_{H,t}}\frac{P^H_{t+2}}{P^H_t} - \right.$$
$$\left. - \lambda^B_{1,t+3}\rho\beta_B^2\frac{(1-o)}{(1-\rho)}\frac{\chi^H_{t+2}}{\eta_{H,t+1}}\frac{P^H_{t+3}}{P^H_{t+1}}\right] = \gamma\omega_{H,t}\lambda^B_{2,t}\mathscr{L}_t$$

$$\beta_B \mathbb{E}_t \left[\lambda^B_{1,t+1} \left(r^L_t - r^D_t \right) \right] = \gamma \omega_{F,t} \lambda^B_{2,t} \mathscr{L}_t$$

$$F_t = P_t Y_t \left(\frac{r^D_t - r^*_t}{\phi} \right)$$

$$r_{F_t} = r^*_t + \phi \frac{F_t}{P_t Y_t}$$

Closing equations (6)

$$P_t NX_t - DivB_t - r^F_{t-1} F_{t-1} = -\Delta F_t$$

$$NX_t = EX_t - IM_t$$

$$IM_t = n_0 \left(C^P_t + C^I_t \right)$$

$$EX_t = n_1 P_t^{-n_2}$$

$$H^P_t + H^I_t = 1$$

Auxiliary equations (14)

$$\Omega^P_t = \frac{\psi_P}{2} \left(\frac{P_t}{P_{t-1}} - 1 \right)^2 P_t Y_t$$

$$\Omega^I_t = \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 P_t I_t$$

$$\frac{\partial \Omega^I_t}{\partial I_t} = \frac{\psi_I}{2} P_t \left(1 + 3 \left(\frac{I_t}{I_{t-1}} \right)^2 - 4 \left(\frac{I_t}{I_{t-1}} \right) \right)$$

$$\frac{\partial \Omega^I_{t+1}}{\partial I_t} = -\psi_I P_{t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 \left(\frac{I_{t+1}}{I_t} - 1 \right)$$

$$\frac{\partial \Omega^P_t}{\partial P_t} = \psi_P Y_t \left(\frac{P_t}{P_{t-1}} - 1 \right)$$

$$\frac{\partial \Omega^P_{t+1}}{\partial P_t} = -\psi_P Y_{t+1} \left(\frac{P_{t+1}}{P_t} \right)^2 \left(\frac{P_{t+1}}{P_t} - 1 \right)$$

$$\frac{\partial \Omega^P_t}{\partial L_t} = \frac{(1-\alpha)}{L_t} \Omega^P_t$$

$$\frac{\partial \Omega^P_{t+1}}{\partial K_t} = \frac{\alpha}{K_t} \Omega^P_{t+1}$$

$$\lambda^F_{1,t} = -\frac{1}{P_t}$$

$$\Omega^B_t = \gamma \log \left(a + CR_t - \mu_t \right) \frac{RWA_t}{P^*_t}$$

$$RWA_t = \omega_{H,t} L_t^H + \omega_{F,t} L_t^F$$

$$CR_t = \frac{\Pi_t^B}{RWA_t}$$

$$\mathscr{Z}_t = \left(\frac{CR_t}{a + CR_t - \mu_t} - \log(a + CR_t - \mu_t) \right)$$

$$NBVP_t = P_t(C_t^P + C_t^I + I_t + NX_t) + \Omega_t^H + o\chi_{t-1}^H P_t^H H_{t-2}^I$$

Steady state

In the the steady state price and investment adjustment costs, as well as their respective partial derivatives, are equal to zero, and total factor productivity A is normalised to unity. Analytical derivation of the steady state is non-trivial because in the full model the interest rates on mortgages r^H depend on household default rate χ^H and vice versa. This creates a simultaneity issue that is hard to tackle algebraically. Hence, we do steady state derivation and calibration of the default rate simultaneously. First off, we assume a given quarterly default rate $\chi^H = 0.0125$. Secondly, we recursively derive steady state expressions for model variables. Lastly, we choose a value of ψ_D so that the χ^H is consistent with annual default rate of 5%.

$$r_D = \frac{1}{\beta} - 1$$

$$CR = \mu - a + \frac{\gamma(1 - \beta_B r^D)}{1 - \beta_B r^D - \beta_B}$$

$$\mathscr{M} = \frac{\gamma}{\beta_B} \left(\frac{CR}{(a + CR - \mu)} - \log(a + CR - \mu) \right) \frac{(a + CR - \mu)}{(a + CR - \mu - \gamma)}$$

$$r^L = r^D + \omega_F \mathscr{M}$$

$$r^H = r^D + \omega_H \mathscr{M} + \chi^H \left\{ 1 - \frac{\beta_B(1-o)(1-\beta_B\rho)}{(1-\rho)\eta_H} \right\}$$

$$r_F = r^D$$

$$\frac{F}{PY} = \frac{r^D - r^*}{\phi}$$

$$\frac{Y}{K} = \frac{1}{\alpha}\left(\frac{\varepsilon}{\varepsilon - 1}\right)\left((1-\eta_K)\left(\frac{1}{\beta_F} - 1\right) + \eta_K r_L + \delta\right)$$

$$\frac{Y}{L} = \left(\frac{Y}{K}\right)^{\alpha/(\alpha-1)}$$

$$\frac{W}{P} = (1-\alpha)\left(\frac{Y}{L}\right)\left(\frac{\varepsilon - 1}{\varepsilon}\right)$$

$$\frac{L_F}{PY} = \eta_K \left(\frac{Y}{K}\right)^{-1}$$

$$\frac{PC^I}{P^H H^I} = \frac{1}{\sigma_H}\left(1 - \beta_I + \eta_H\left(\frac{1-\rho}{1-\beta_I\rho}\right)\left(\beta_I\left(1+r^H\right) - 1\right) + \beta_I^2 \chi^H \rho\left(\frac{1-\beta_I}{1-\rho\beta_I}\right)\right)$$

$$\frac{W^I L^I}{P^H H^I} = r^H \eta_H + \left(\frac{PC^I}{P^H H^I}\right) + \chi^H\left(0.5 + \eta_H\left(\frac{0.5}{\beta_I} - 1\right)\right)$$

$$\frac{L^H}{PY} = \eta_H (1-\nu)(1-\alpha)\left(\frac{\varepsilon-1}{\varepsilon}\right)\left(\frac{W^I L^I}{P^H H^I}\right)^{-1}$$

$$\frac{F}{L^H} = \left(\frac{F}{PY}\right)\left(\frac{L^H}{PY}\right)^{-1}$$

$$\frac{L^F}{L^H} = \left(\frac{L^F}{PY}\right)\left(\frac{L^H}{PY}\right)^{-1}$$

$$\frac{D^H}{L^H} = \frac{1}{1-r^D}\Big\{1 - r^H + \chi^H\left(1 - \frac{(1-o)}{\eta_H}\right) - \omega_H CR -$$

$$- \left(1 - r^F\right)\left(\frac{F}{L^H}\right) + \left(1 - r^L - \omega_F CR\right)\left(\frac{L^F}{L^H}\right)\Big\}$$

$$\frac{PC^P}{P^H H^I} = \left\{\frac{1}{(1-\nu)(1-\alpha)}\left(\frac{\varepsilon-1}{\varepsilon}\right) - 1\right\}\left(\frac{W^I L^I}{P^H H^I}\right) -$$

$$-\eta_H\left(r^L + \frac{\delta}{\eta_K}\right)\left(\frac{L^F}{L^H}\right) + r^D \eta_H \left(\frac{D^H}{L^H}\right)$$

$$H^I = \frac{(1-\beta_P)}{\left(1 - \beta_P + \sigma_H\left(\frac{PC^P}{P^H H^I}\right)\right)}$$

$$L^P = \sqrt{\frac{\nu}{\sigma_L(1-\nu)}\left(\frac{W^I L^I}{P^H H^I}\right)\left(\frac{PC^P}{P^H H^I}\right)^{-1}}$$

$$L^I = \sqrt{\frac{1}{\sigma_L}\left(\frac{W^I L^I}{P^H H^I}\right)\left(\frac{PC^I}{P^H H^I}\right)^{-1}}$$

$$L = \left(L^P\right)^{\nu}\left(L^I\right)^{(1-\nu)}$$

$$Y = \left(\frac{Y}{L}\right)L$$

$$K = L\left(\frac{Y}{K}\right)^{\frac{1}{\alpha-1}}$$

$$C^I = \frac{(1-\nu)(1-\alpha)(\varepsilon-1)}{\varepsilon\sigma_L}Y\left(L^I\right)^{-2}$$

$$C^P = \frac{\nu(1-\alpha)(\varepsilon-1)}{\varepsilon\sigma_L}Y\left(L^P\right)^{-2}$$

$$C = C^P + C^I$$

$$\frac{\pi^B}{PY} = \left(\frac{L^F}{PY}\right)r^L + \left(\frac{L^H}{PY}\right)\left(r^H - \chi^H\left(1-\frac{1-o}{\eta_H}\right) - r^D\left(\frac{D^H}{L^H}\right)\right) - r^F\left(\frac{F}{PY}\right)$$

$$NX = \left(\frac{\pi^B}{PY} + r_F\frac{F}{PY}\right)Y$$

$$IM = n_0 C$$

$$EX = NX + IM$$

$$P = \left(\frac{n_1}{EX}\right)^{(1/n_2)}$$

$$L^H = \left(\frac{L^H}{PY}\right)PY$$

After finding the expressions for nominal value of mortgages, we calibrate ψ_D so that it is consistent with the target share of defaults χ^H:

$$\psi_D = \frac{1}{\chi^H L^H}\left(\frac{1}{\beta_I} - \frac{1}{\eta_H}\right)$$

Utilising the expressions for ratios above, we can obtain the steady state expressions for the following variables: $F\ K\ W$, L_F, F, K, W, P^H, D_H, and

π^B, Π^B. We can use these to obtain the rest of the variables.

$$\lambda_1^F = -\frac{1}{P}$$

$$\lambda_2^F = \frac{1}{P}\left(\beta_F - 1\right)$$

$$\lambda_3^F = \frac{1}{P}\left(\beta_F\left(1 + r^L\right) - 1\right)$$

$$\lambda_4^F = 0$$

$$\lambda_5^F = -\frac{1}{\varepsilon}$$

$$I = \delta K$$

$$W^P = \nu \frac{WL}{L^P}$$

$$W^I = (1-\nu)\frac{WL}{L^I}$$

$$H^P = 1 - H^I$$

$$\pi = PY - WL - P\delta K - r_L L_F$$

$$\Pi = PK - L_F$$

$$Div = \pi$$

$$DivB = \pi^B$$

Alternative asset seizure

Here we describe the alternative first order conditions for impatient household and bank, when the bank is able to recover the whole amount defaulted. Under this setting asset seizure at time t is:

$$S_t = \chi^H_{t-1} L^H_{t-2}.$$

After plugging this into the impatient household's budget constraint and solving the optimisation problem, the first-order conditions (2.11)-(2.13) respectively become:

$$\beta_I \mathbb{E}_t \Bigg[\frac{1}{P_{t+1} C^I_{t+1}} \left(1 + r^H_t - \chi^H_{t+1}\right) + \rho \lambda^I_{2,t+1} + \\ + \beta_I \frac{1}{P_{t+2} C^I_{t+2}} \left(\psi_D \left(\chi^H_{t+1}\right)^2 L^H_t + \chi^H_{t+1} \right) \Bigg] = \frac{1}{P_t C^I_t} + \lambda^I_{2,t},$$

$$\frac{\sigma_{H,t}}{H^I_t} - (1-\rho)\eta_{H,t} \lambda^I_{2,t} P^H_t + \beta_I \mathbb{E}_t \left[\frac{P^H_{t+1}}{P_{t+1} C^I_{t+1}} \right] = \frac{P^H_t}{P_t C^I_t},$$

$$\frac{L^H_{t-1}}{P_t C^I_t} = \beta_I \mathbb{E}_t \left[\frac{1}{P_{t+1} C^I_{t+1}} \left(L^H_{t-1} + \psi_D \chi^H_t \left(L^H_{t-1}\right)^2 \right) \right]$$

Using this alternative asset seizure setting, the bank's profit equation (2.18) becomes:

$$\pi^B_t = \left(r^H_{t-1} - \chi^H_t\right) L^H_{t-1} + r^L_{t-1} L^F_{t-1} - r^D_{t-1} D_{t-1} - r^F_{t-1} F_{t-1} + (1-o)\chi^H_{t-1} L^H_{t-2}.$$

The first-order (mortgage supply) condition (2.26) is now:

$$\beta_B \mathbb{E}_t \left[\lambda^B_{1,t+1} \left(r^H_t - \chi^H_{t+1} - r^D_t\right) + \lambda^B_{1,t+2} \beta_B (1-o) \chi^H_{t+1} \right] = \gamma \omega_{H,t} \lambda^B_{2,t} \mathscr{L}_t,$$

Appendix C

Appendix to Chapter 3.

Figures and tables

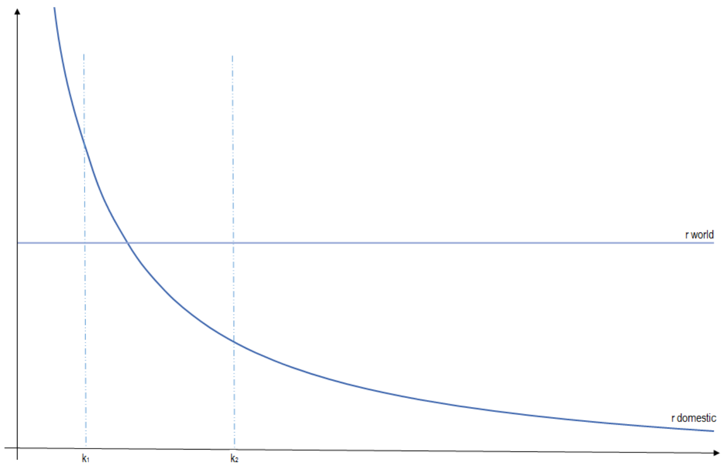


Figure 3.11: Interest rate determination in capital markets.

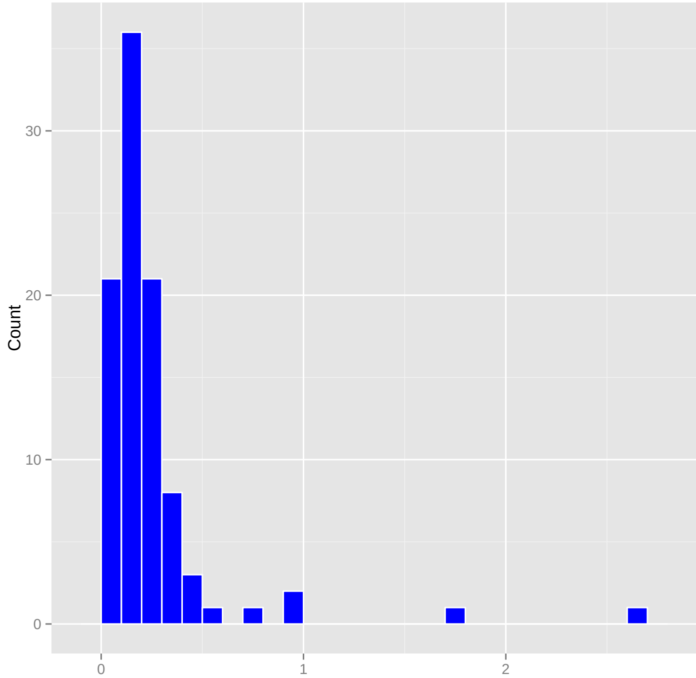


Figure 3.12: Country averages of empirical measure of debt to capital ratio λ.

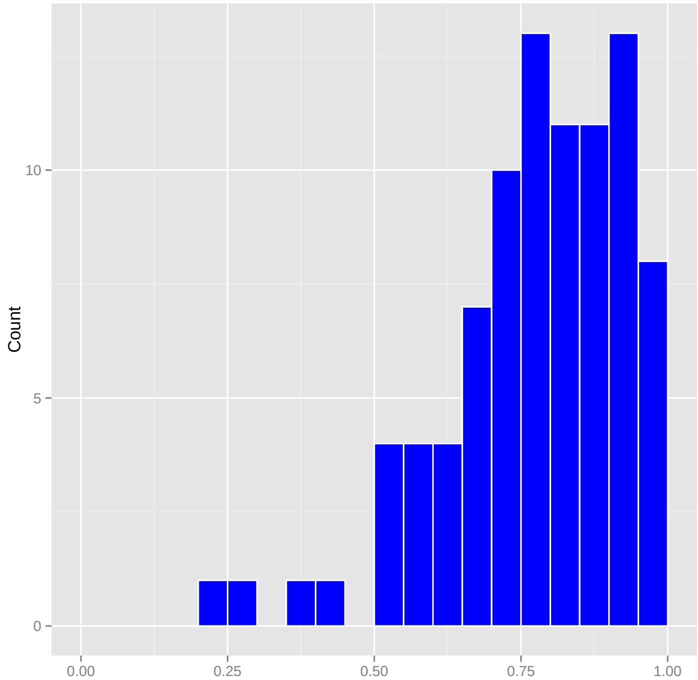


Figure 3.13: Country averages of empirical measure of bargaining power ϕ.

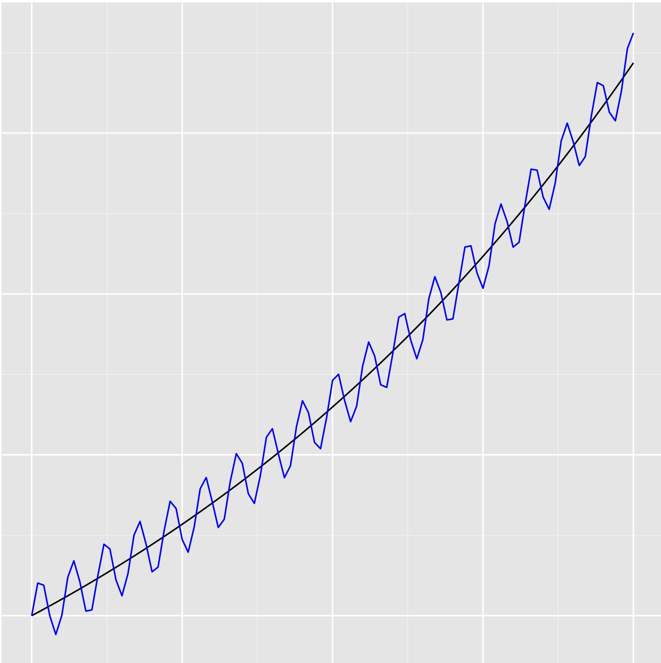


Figure 3.14: Example of monotonic and non-monotonic growth of output per worker.

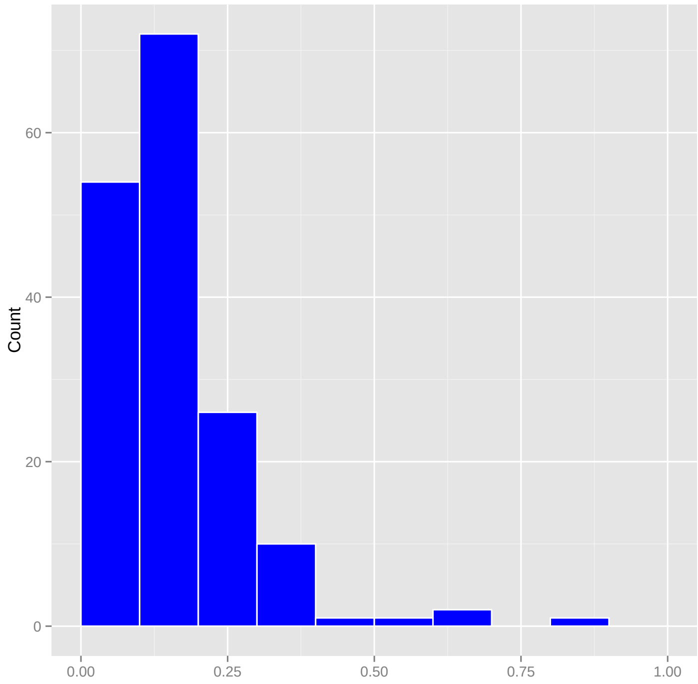


Figure 3.15: Distribution of country standard deviation of detrended logarithm of real GDP per capita.

Table 3.4: β rates of convergence. Here $\lambda < \hat{\lambda}(\phi, \cdot), \forall \phi \in (0,1)$.

ϕ, λ	0.25	0.5	0.75	1	1.25	1.5	1.75	2
0.05	0.0211	0.0214	0.0218	0.0223	0.0228	0.0234	0.0241	0.0250
0.15	0.0211	0.0214	0.0218	0.0223	0.0228	0.0233	0.0241	0.0249
0.25	0.0211	0.0215	0.0218	0.0223	0.0227	0.0233	0.0240	0.0248
0.35	0.0212	0.0215	0.0219	0.0223	0.0227	0.0233	0.0239	0.0247
0.45	0.0212	0.0215	0.0219	0.0223	0.0227	0.0232	0.0238	0.0245
0.55	0.0213	0.0216	0.0219	0.0223	0.0227	0.0231	0.0237	0.0243
0.65	0.0214	0.0216	0.0219	0.0223	0.0226	0.0230	0.0235	0.0240
0.75	0.0215	0.0217	0.0220	0.0223	0.0226	0.0229	0.0233	0.0237
0.85	0.0217	0.0219	0.0220	0.0223	0.0225	0.0227	0.0230	0.0233
0.95	0.0220	0.0221	0.0222	0.0223	0.0223	0.0224	0.0225	0.0227

Table 3.5: Estimated speeds of convergence from growth regressions.

ϕ	λ	(1)	(2)	(3)	(4)
0.44022	0.02562	0.01292	0.01820	0.02023	0.02231
0.44022	0.06972	0.01292	0.01824	0.02051	0.02269
0.44022	0.14410	0.01292	0.01830	0.02097	0.02333
0.44022	0.26023	0.01292	0.01839	0.02171	0.02434
0.44022	3.36337	0.01292	0.02093	0.04358	0.04139
0.44022	0.23925	0.01292	0.01837	0.02157	0.02415
0.65296	0.02562	0.01292	0.01821	0.02152	0.02332
0.65296	0.06972	0.01292	0.01826	0.02169	0.02370
0.65296	0.14410	0.01292	0.01835	0.02198	0.02435
0.65296	0.26023	0.01292	0.01849	0.02244	0.02537
0.65296	3.36337	0.01292	0.02229	0.03552	0.03620
0.65296	0.23925	0.01292	0.01847	0.02236	0.02518
0.80106	0.02562	0.01292	0.01822	0.02242	0.02403
0.80106	0.06972	0.01292	0.01828	0.02252	0.02441
0.80106	0.14410	0.01292	0.01839	0.02269	0.02507
0.80106	0.26023	0.01292	0.01856	0.02296	0.02609
0.80106	3.36337	0.01292	0.02325	0.03027	0.03274
0.80106	0.23925	0.01292	0.01853	0.02291	0.02591
0.92242	0.02562	0.01292	0.01822	0.02317	0.02461
0.92242	0.06972	0.01292	0.01830	0.02321	0.02500
0.92242	0.14410	0.01292	0.01842	0.02328	0.02566
0.92242	0.26023	0.01292	0.01862	0.02338	0.02669
0.92242	3.36337	0.01292	0.02404	0.02616	0.02999
0.92242	0.23925	0.01292	0.01859	0.02336	0.02650
0.99088	0.02562	0.01292	0.01823	0.02360	0.02495
0.99088	0.06972	0.01292	0.01831	0.02360	0.02533
0.99088	0.14410	0.01292	0.01844	0.02361	0.02599
0.99088	0.26023	0.01292	0.01865	0.02362	0.02703
0.99088	3.36337	0.01292	0.02449	0.02392	0.02847
0.99088	0.23925	0.01292	0.01862	0.02362	0.02684
0.75412	0.02562	0.01292	0.01822	0.02214	0.02380
0.75412	0.06972	0.01292	0.01828	0.02226	0.02419
0.75412	0.14410	0.01292	0.01838	0.02247	0.02484
0.75412	0.26023	0.01292	0.01854	0.02279	0.02586
0.75412	3.36337	0.01292	0.02294	0.03190	0.03382
0.75412	0.23925	0.01292	0.01851	0.02273	0.02568

Proofs

Proof of Proposition 1 The condition for b) sink path convergence is

$$0 > 1 + \frac{\alpha(1-\lambda)(1-\tau)(\delta+\rho+\theta g)}{\frac{r-\phi r^{\omega}}{1-\phi} + \delta - \alpha((n+g)(1-\lambda)+\lambda r+\delta)} \equiv f(h^{*})$$

$$-1 > \frac{\alpha(1-\lambda)(1-\tau)(\delta+\rho+\theta g)}{\frac{r-\phi r^{\omega}}{1-\phi} + \delta - \alpha((n+g)(1-\lambda)+\lambda r+\delta)}$$

, where the denominator in the last inequality is equal to $1-\alpha\xi > 0$, because of Assumption 4. Therefore, the nominator must be negative, for the fraction to be positive, which is equivalent to condition $\lambda > 1$. Multiplying both sides of the inequality by the denominator, does not change the sign ($>$). After tedious manipulation, one should arrive at the conclusion of Proposition 1 part b). Proof for part a) is just the opposite of part b).

Proof of Proposition 2

$$\frac{\partial\hat{\lambda}}{\partial\phi} = \frac{r^{\omega}-r}{\alpha[n+g-r-(1-\tau)(\delta+\rho+\theta g)]} > 0$$

, which is supported by the fact that $r > n+g$, what is the direct consequence of Assumptions 2 and 3.

Proof of Proposition 3 The derivative of β with respect to both parameters (ϕ, λ):

$$\frac{\partial\beta}{\partial j} = \frac{\partial f(h^{*})}{\partial j}\left[\frac{2\Psi\sqrt{\Psi^{2}+Cf(h^{*})}-(\Psi^{2}+Cf(h^{*}))}{2\sqrt{\Psi^{2}+Cf(h^{*})}}\right]\frac{1}{2f(h^{*})^{2}},\ j\in\{\phi,\ \lambda\},$$

where $\Psi \equiv \rho - n + g(\theta-1) > 0$ and $C \equiv 4(1-\varepsilon)(\delta+\rho+\theta g-\varepsilon(n+g+\delta))(\delta+\rho+\theta g)/(\varepsilon\theta) > 0$. If $2\big(\rho-n+g(\theta-1)\big) \equiv 2\Psi < 1$, and $2\Psi\sqrt{\Psi^{2}+Cf(h^{*})} < \Psi^{2}+Cf(h^{*})$.

Therefore, $sgn(\partial\beta/\partial j) = -sgn(\partial f(h^{*})/\partial j)$. Moving to the latter derivative:

$$\frac{\partial f(h^*)}{\partial \phi} = \frac{(\lambda-1)\alpha(1-\tau)(\delta+\rho+\theta g)(r-r^{\omega})}{(1-\alpha\xi)[(\frac{r-\phi r^{\omega}}{1-\phi}+\delta)(1-\phi)]^2} : \begin{cases} <0 & \text{, when } \lambda < 1 \\ >0 & \text{, when } 1 < \lambda \end{cases}$$

, because $1-\alpha\xi > 0$.

$$\frac{\partial f(h^*)}{\partial \lambda} = \frac{\alpha(1-\tau)(\delta+\rho+\theta g)}{[(1-\alpha\xi)(\frac{r-\phi r^{\omega}}{1-\phi}+\delta)]^2}\left[\alpha(r+\delta) - \frac{r-\phi r^{\omega}}{1-\phi} - \delta\right] < 0\,.$$

The last inequality is founded by the assumption that $r > r^{\omega}$.

Combining all these results, we get:

$$sgn(\frac{\partial \beta}{\partial j}) = -sgn(\frac{\partial f(h^*)}{\partial j}) : \begin{cases} >0 & \text{, when } \lambda < 1, \text{ for } j = \phi \\ <0 & \text{, when } 1 < \lambda, \text{ for } j = \phi \\ >0 & \text{, for } j = \lambda \end{cases}$$

, what proves Proposition 3.

Publications by the Author

1. Karmelavičius, J. and Ramanauskas, T. (2019). Bank Credit and Money Creation in a DSGE Model of a Small Open Economy, *Baltic Journal of Economics*, 19:2, 296-333.
2. Karmelavičius, J. (2021). Risky Mortgages and Macroprudential Policy: a Calibrated DSGE Model for Lithuania, *Ekonomika*, 2021, vol. 100(2), pp. 6–39.

Conference presentations

1. On the Costs of Three Macroprudential Policy Instruments: a DSGE Model for Lithuania. 2nd Baltic Economic Conference, Stockholm School of Economics in Riga, Latvia, 10-11th of June, 2019.
2. On the Costs of Three Macroprudential Policy Instruments: a DSGE Model for Lithuania. Challenges of Europe: Growth, Competitiveness, Innovation and Well-being, Bol, Croatia, 22-24th of May, 2019.
3. Bank Credit and Money Creation in a Simple DSGE Model. Inaugural Baltic Economic Conference, Martynas Mažvydas library, Vilnius, Lithuania, 11-12th of June, 2018.
4. A DSGE Model of Lithuanian Economy with Housing and Financial Frictions. Applications of DSGE Models in Central Banking, National Bank of Ukraine, Kyiv, Ukraine, 15-16th of November, 2018.
5. Capital Mobility, Bargaining Power and Economic Growth.
4th Lithuanian Conference on Economic Research, Vytautas Magnus University, Kaunas, Lithuania, 15th of August, 2015.

Santrauka

Tyrimo kontekstas ir aktualumas

XXI a. 1-ajame dešimtmetyje laisva monetarinė politika, mažėjęs finansinis reguliavimas, išaugęs skolinimas ir įsiskolinimas pakurstė įvairių turto klasių kainų augimą, įskaitant akcijas, nekilnojamąjį turtą ir išvestinius produktus. Vėliau kilo pasaulinė finansų krizė, kuri pasižymėjo turto kainų griūtimi, neveiksniomis paskolomis ir bankų bankrotais tiek JAV, tiek Europoje ir kitur. Ši finansų krizė buvo didžiausia pasaulyje nuo Didžiosios depresijos laikų. Jordà et al. (2017) pateikė naujuosius verslo ciklų faktus (angl. *new business cycle facts*), kurie nusakė, kad pasaulio ekonomika pasidarė vis labiau priklausoma nuo finansų sistemos, o verslo ir finansų ciklai tapo vis labiau susieti. Tyrimai (Claessens et al., 2009; Crowe et al., 2013; Jordà et al., 2013, 2017) rodo, kad ekonomikos bumai, kurie pasižymi greitu kredito augimu, gali vėliau sukelti gilias ir ilgai vykstančias krizes. Be to, finansų krizės gali būti itin skausmingos, jeigu krizės metu sumažėja kreditavimas.

Panašus pakilimų ir nuosmukių ciklas (angl. *boom-and-bust cycle*) įvyko ir Lietuvoje. Tarp 2003 ir 2007 m. kreditas privačiam finansų sektoriui kasmet augo vidutiniškai po 51 proc. Šis augimas buvo finansuojamas pastoviu einamosios sąskaitos deficitu ir "karštais ir trumpais" pinigų srautais, kurie buvo gaunami iš Skandinavijos bankų sektoriaus per Lietuvoje veikusius dukterinius bankus – taip prisidedant prie ekonomikos vidaus ir išorės skolos augimo. Pastarasis procesas ženkliai prisidėjo prie būsto kainų patrigubėjimo ir statybų bei nekilnojamojo turto vystymo sektorių augimo, taip paskatindamas ir visą likusią ekonomiką – 2000-2007 m. nominalusis BVP kasmet vidutiniškai augo po 8 proc. Taip jau atsitiko, kad ekonomikos bumas laike sutapo su finansų sektoriaus brandos didėjimu (angl. *financial deepening*), todėl politikos formuotojai ir ekonomikos analitikai neretai manė, kad šis spartus augimas yra natūralus Lietuvos ekonomikos konvergencijos procesas (žr. *ex post* analizę Kuodis ir Ramanauskas, 2009), nors pasitaikė ir įspėjimų (pvz. Ramanauskas, 2005).

Vis dėlto šie procesai sustojo 2008 m., kada kreditas pradėjo mažėti, o būsto kainos nuo savo aukščiausio taško krito apie 25 proc. Nors Lietuvoje nė vienas bankas nebankrutavo, bankų sektorius 2009-2010 m. patyrė didžiulius nuostolius – apie 1,14 mlrd. eurų. Kredito rizikos materializacija ir neigiami ateities lūkesčiai sukėlė visišką užsienio finansavimo atitraukimą ir vietinio skolinimo sustojimą. Nuo 4 iki 16 proc. padidėjęs nedarbo lygis ir tarpbankinių palūkanų normų (Vilibor), kurios buvo naudojamos kaip bazinė kintamųjų palūkanų normų dalis, šuolis ženkliai pablogino namų ūkių ir įmonių finansinę padėtį, taip prisidėjo prie ekonominės suirutės. Išsamiau apie šį prieš-krizinį ir krizinį periodą Lietuvoje rašė Kuodis ir Ramanauskas (2009) ir Ramanauskas (2011).

Didžiosios finansų krizės ištakos ir pobūdis parodė, kad bankai yra modernios ekonomikos epicentras. Dėl to jie susilaukė papildomo dėmesio iš politikos formuotojų ir ekonomistų tiek per pačią krizę, tiek ir po jos. Išties, bankai yra specialios institucijos, kurios gali leisti privačius pinigus, neskaitant centrinio banko išleidžiamų rezervinių pinigų (monetarinės bazės). Tai, kad bankai gali sukurti pinigus, lemia keletas priežasčių. Pirma, bankai gali priimti indėlius, kurie yra visuotinai pripažinta atsiskaitymo priemonė, tinkama vertės matavimui ir išsaugojimui, t. y. , indėliai tenkina pinigų savybes, todėl gali funkcionuoti kaip pinigai. Valstybinis indėlių draudimas užtikrina indėlininkų ir visos visuomenės pasitikėjimą bankų indėliais, todėl yra labai svarbus mechanizmas, įgalinantis bankus kurti pinigus. Antra, remiantis dvigubo įrašo principu, taikomu apskaitoje (angl. *double-entry bookkeeping principle*), bankas tuo pačiu metu sukuria paskolos įrašą balanso turto pusėje ir sukuria indėlio įrašą įsipareigojimų pusėje. Taip skolinimo metu sukuriamas indėlis – nauji pinigai, kurie yra banko įsipareigojimas. Šio proceso metu pinigai sukuriami "iš oro", tad nėra jokio poreikio turėti iš anksto sukauptus resursus ar rezervus – visiškai priešingai negu paplitęs mitas apie pinigų "perskolinimą". Ši bankų savybė įgalina bankų sistemą daryti itaką visai finansų sistemai, o taip pat ir realiajai ekonomikai – būtent tai, kas buvo matyti XXI a. 1-ajame dešimtmetyje Lietuvoje ir kitur pasaulyje.

Prieš 2008-2009 m. finansų krizę pasaulyje, įskaitant ir Lietuvą, bankų sektoriaus priežiūra buvo pernelyg orientuota į pavienes įstaigas, arba mikro-priežiūrą. Po krizės atsirado įrankiai, kurie buvo buvo orientuoti į sistemiškumą ir skirti mažinti sisteminės rizikos formavimąsi, taip pat stiprinti finansų rinkų, institucijų ir bendros ekonomikos atsparumą. Tokių įrankių visuma dabar vadinama makroprudencine politika, nors kai kurie šios politikos elementai dar egzistavo ir buvo žinomi jau XX a. Beveik visi makroprudencinės politikos instrumentai yra nukreipti į bankų sektorių, kadangi, kaip jau anksčiau minėta, šis sektorius buvo pastarosios krizės epicentre, netgi ją pagilino. Pagal Hoon Lim et al. (2011) politikos priemonės gali būti suskaidytos į tris pagrindines grupes. Pirma grupė apima likvidumo reikalavimus, kaip likvidaus padengimo koeficiento (angl. *liquidity coverage ratio*) normatyvas. Antrajai grupei priklauso instrumentai, kurie yra susiję su bankų turtu, pvz., paskolos ir užstato vertės santykio (LTV, angl. *loan to value*), skolininkų skolos ir pajamų santykio ribojimai ir kt. Trečioje grupėje yra kapitalo reikalavimai ir susijusios taisyklės, nusakantys, kiek kredito institucija turi turėti "atsidėjusi" kapitalo nuostoliams padengti, kaip turi reikiamą kapitalo kiekį skaičiuoti. Plačiąja prasme, makroprudencinės politikos priemonės gali būti suprantamos kaip bankų pinigų kūrimą ribojančios priemonės.

Makroprudencinė politika iš esmės buvo pradėta įgyvendinti, kai Europos Sąjunga ir Lietuva pritaikė Bazelio III sąrangą. 2011 m. Lietuvos bankas išleido Atsakingojo skolinimo nuostatus, kurie reguliuoja paskolų būstui įsigyti ir vartojimo paskolų išdavimą. Nuostatai numatė būsto paskolos pradinio įnašo minimalų reikalavimą, lygų 15 proc., arba kitaip 85 proc. maksimalų LTV rodiklį. Be to, paskolą imančio namų ūkio skolos aptarnavimo sąnaudų ir pajamų santykis (DSTI, angl. *debt service to income*) negali būti didesnis nei 40 proc., o maksimali būsto paskolos trukmė buvo – 40 metų. 2014 m. rugsėjo mėn. LR Seimas Lietuvos bankui suteikė makroprudencinės politikos mandatą, kuris centriniam bankui leido vykdyti makroprudencinę politiką.

Lietuvoje 2015 m. atsirado du papildomi kapitalo rezervų reikalavimai – anticiklinis kapitalo rezervas (CCyB, angl. *counter-cyclical capital buffer*) ir kapitalo apsaugos rezervas (CCB, angl. *capital conservation buffer*). Taip pat tų pačių metų lapkričio mėn. buvo atlikti svarbūs Atsakingojo skolinimo nuostatų pakeitimai. Maksimali būsto paskolos trukmė buvo sutrumpinta iki 30 metų. Taip pat, dėl mažų palūkanų normų aplinkos, atsirado palūkanų testas, kuris numato, kad skolininkui būsto paskola gali būti išduota tik tuo atveju, jei DSTI santykis, esant palūkanų normai lygiai 5 proc., neviršija 50 proc. Makroprudencinės politikos priemonių sąrangos atsiradimas žymi naujos griežtesnės ir galimai saugesnės finansinės aplinkos pradžią ne tik Lietuvoje, bet ir pasaulyje.

Tyrimo problema

Nors makroprudencinė politika atrodo kaip daug žadanti sritis, nes galimai leidžia politikos formuotojams stabilizuoti finansų sistemą ir ekonomiką, vis dėlto ji dar tebėra vystoma. Vis dar nėra iki galo aišku, kaip politikos priemonės ar jų pasikeitimai gali paveikti finansų sistemą, taip pat ekonomiką. Kai kurios mokslinės studijos remiasi laiko eilučių metodais (pvz. Noss ir Toffano, 2016; Kanngiesser et al., 2017; Richter et al., 2018) arba mikro-duomenimis (pvz. Gonzalez et al., 2016; Glancy ir

Kurtzman, 2016; Mihai et al., 2018), tačiau politikos sąranga atsirado palyginti neseniai arba vis dar yra plėtojama, pvz. Europos Sąjungoje. Tai apsunkina bet kokius tyrimus, kurie siekia išmatuoti politikos poveikį, naudojant istorinius duomenis.

Makroprudencinė politika Lietuvoje atsirado nuo 2011 m., tačiau jos poveikis beveik nėra ištirtas. Egzistuoja tik keletas straipsnių (pvz. Rubio ir Comunale, 2016; Reichenbachas, 2020), kurie tiria šios politikos priemones Lietuvos kontekste. Makroprudencinės politikos priemonės buvo įgyvendintos vienu metu, todėl yra pakankamai sunku atskirti, kur yra kurios konkrečios priemonės poveikis. Bendrosios pusiausvyros makroekonominiai modeliai gali būti alternatyva aukščiau minėtiems laiko eilučių ar mikro-duomenų ekonometriniams metodams, ypač kai trūksta tokių duomenų arba jie yra prastos kokybės. Pavyzdžiui, dinaminiai stochastiniai bendrosios pusiausvyros (DSGE, angl. *dynamic stochastic general equilibrium*) modeliai yra pakankamai dažnai naudojami tiriant makroprudencinės politikos poveikį ir jos sąveiką su realia makroekonomika. Šio modeliavimo būdo privalumas yra tas, kad jis leidžia įvertinti atskirų instrumentų poveikį, taip pat atlikti įvairias simuliacijas ir eksperimentus apie hipotetines priemones ar jų taisykles.

Makroekonominiai modeliai, tarp jų ir DSGE, nenuspėjo būsimos krizės, taip pat neatskleidė pačios krizės pobūdžio ir masto, todėl modelius reikėjo išplėsti ir adaptuoti, įtraukiant bankus, finansinius trikdžius (angl. *financial frictions*) ir gyvenamojo būstą rinką. Tokio pobūdžio mokslinė literatūra apie finansinius trikdžius ir jų sąveiką su ekonomika rėmėsi Kiyotaki ir Moore (1997), Bernanke et al. (1999) ir Iacoviello (2005) straipsniais, ir vėliau suklestėjo. Tarp didelio kiekio straipsnių galima išskirti, pvz., Iacoviello ir Neri (2010), Iacoviello (2015), Gerali et al. (2010), Gertler ir Kiyotaki (2015). Paprastai tiriami finansiniai trukdžiai, kuriuos patiria skolininkas arba skolintojas, arbu abu. Šioje akademinėje literatūroje naudojami modeliai leidžia įvertinti makroprudencinės politikos priemonių ir jų skirtingų dizainų poveikį (žr. Angelini et al., 2014; Quint ir Rabanal, 2014; Chen ir Columba, 2016; Lozej et al., 2017).

Kaip aukščiau buvo diskutuota, pinigų kūrimas yra nepaneigiamas apskaitos dėsnis – fundamentalus šiuolaikinei bankininkystei (žr. McLeay et al., 2014; Werner, 2014), tačiau vis dar nėra aišku, ar makroekonominiai modeliai, tokie kai DSGE, yra suderinti su pinigų kūrimo idėja. Borio (2011) teigia, kad makroekonominiai modeliai, kurie turi tik realius dydžius, negali atskleisti sąryšių tarp finansų sistemos ir ekonomikos. Remiantis Jakab ir Kumhof (2015), beveik visi po finansų krizės sukurti modeliai remiasi banko – finansų tarpininko, kuris perskolina resursus, idėja, tuo tarpu pinigų kūrimu pasižyminčių modelių yra tik saujelė. Tarp ekonomistų vyrauja požiūris, ir tai matyti jų modeliuose, kad bankai yra tik finansiniai tarpininkai, kurie surenka santaupas ir jas paskirsto paskolų forma, todėl nekuria pinigų. Goodhart et al. (2013) netgi teigia, kad literatūroje nėra nė vieno dėmesio verto bankininkystės teorinio modelio. Ši mokslinės literatūros sritis teigia, kad norint turėti ekonomikai analizuoti tinkamą modelį su bankais, jame privalo būti pinigų kūrimas. Remiantis šiuo požiūriu, šioje disertacijoje atliekamas makroprudencinės politikos vertinimas turi būti suderintas su bankų pinigų kūrimo idėja.

Nors tarptautinėje literatūroje paprastai tiriamas makroprudencinės politikos poveikis ekonomikai ir jos stabilumui, autoriai paprastai nežvelgia į politikos poveikį ilgojo laikotarpio ekonomikos augimui ir konvergencijai. Pavyzdžiui, ekonomikos augimo literatūroje yra žinoma, kad įsiskolinimas gali turėti poveikį ekonomikai ilguoju laikotarpiu (Pintus, 2007, 2011), tačiau tai nėra tiriama makroprudencinės politikos kontekste. Iš tiesų, bet kokios ekonomikos įsiskolinimą ribojančios priemonės, pvz. makroprudencinė politika, gali daryti įtaką ekonomikos konvergavimui ir stabilumui. Lietuva jau kurį laiką turi makroprudencinę sąrangą, tačiau vis dar nėra aišku, koks šių priemonių poveikis ilguoju laikotarpiu.

Tikslas ir uždaviniai

Disertacijos tikslas yra įvertinti makroprudencinės politikos priemonių poveikį Lietuvos ekonomikai. Šiuo tikslu yra siekiama prisidėti prie vietos literatūros apie makroprudencinę politiką ir pateikti vertinimus, kurie būtų naudingi praktiniu požiūriu. Kadangi šiam tikslui įvykdyti disertacijoje yra kuriami ir plėtojami makroekonominiai modeliai mažai-atvirai ekonomikai, tuo pačiu siekiama prisidėti prie tarptautinės mokslinės literatūros apie makro-finansų modeliavimą.

Disertacijos tikslui pasiekti ir įnešti indėlį į mokslinę literatūrą, disertacinis darbas yra suskaidomas į šiuos tyrimo uždavinius:

1. Aptarti tarptautinę literatūrą apie bankų pinigų kūrimo savybę bei jos svarbą makroekonominiuose modeliuose.
2. Sukurti stilizuotą DSGE modelį Lietuvai, kuris pasižymėtų bankų pinigų kūrimu.
3. Nurodyti būtinąsias sąlygas, kurioms esant bet koks makroekonominis modelis pasižymėtų pinigų kūrimo savybėmis.
4. Išplėsti DSGE modelį, į jį įtraukiant gyvenamąjį būstą, būsto paskolas ir kredito riziką, taip pat modelį kalibruoti Lietuvos duomenims.
5. Naudojantis išplėsta modeliavimo sąranga, įvertinti makroprudencinės politikos priemonių griežtinimo poveikį Lietuvos ekonomikai.
6. Išplėtoti neoklasikinį mažos-atviros ekonomikos augimo modelį, kuriame būtų skola, makroprudencinė politika ir endogeninės palūkanų normos.
7. Įvertinti makroprudencinės politikos poveikį įsiskolinimui ir ilgojo laikotarpio augimui bei konvergencijai.

Tyrimo metodai

Disertacinis darbas remiasi makroekonominių sistemų matematiniu modeliavimu, didelį dėmesį skiriant bendrosios pusiausvyros modeliams. Iš esmės, disertaciją galima padalinti į dvi dalis, kur pirmoji nagrinėja trumpąjį ir vidutinį laikotarpius, o antroji dalis – ilgąjį laikotarpį.

Pirmojoje dalyje (1 ir 2 skyriai) sudarinėjami DSGE tipo modeliai, kuriais remiantis studijuojama diskretaus laiko ir begalinio horizonto dinaminė sistema. Kiekvieną institucinį sektorių atspindi tam tikras reprezentatyvus agentas, kuris turi savo biudžetinį apribojimą bei maksimizuoja savo tarplaikinę tikslo funkciją. Šios optimizavimo problemos sprendžiamos naudojantis dinaminio programavimo principais ir Lagranžo daugiklių metodu. Išsprendus kiekvieno agento uždavinį, pirmos eilės sąlygos, kurios apibūdina agentų elgseną, yra sujungiamos ir taip modelis išsprendžiamas – gaunama bendroji pusiausvyra, kurią apibūdina kainos ir kiekiai. Siekiant analizuoti rūpimus klausimus, pvz. koks makroprudencinės politikos poveikis, naudojamas impulso-atsako funkcijų (IRF, angl. *impulse-response functions*) metodas. Metodinė literatūra apie DSGE modelius yra pakankamai plati, tačiau Romer (2012) ir Dejong ir Dave (2007) gali būti naudojama kaip gera įžanga. Šioje disertacijoje naudojami DSGE modeliai remiasi labiau specializuotais finansinių trikdžių literatūros straipsniais ir modeliais, kaip pvz. Iacoviello (2005, 2015), Gerali et al. (2010), de Walque et al. (2010), Jakab ir Kumhof (2015, 2019).

Antrojoje dalyje (3 skyrius) taip pat naudojama bendrosios pusiausvyros koncepcija, tačiau modeliuojant daroma prielaida, kad laikas yra tolydus, todėl naudojamos diferencialinės lygtys – ne skirtuminės. Suformuluojamas begalinio laiko horizonto Ramsey-tipo uždavinys, kuris sprendžiamas naudojantis Pontriagino maksimumo principu. Vartotojo ir firmos elgseną optimizuojančios lygtys kartu sudaro sistemos bendrąją pusiausvyrą. Kadangi šią ekonomiką aprašo netiesinių diferencialinių lygčių sistema, modelio analitinės savybės nagrinėjamos pasitelkiant sistemos Jacobi matricą, įvertintą pusiausvyrinio taško mažoje aplinkoje. Bendrieji modeliavimo metodai yra gerai aprašyti Barro ir Sala-i-Martin (2004) ir Acemoglu (2009). Šioje disertacijoje naudojamas modelis konkrečiai remiasi Barro et al. (1995) ir Pintus (2011). Empiriniam modelio išvadų testavimui sudaromi panelinių duomenų ekonometriniai modeliai, remiantis Mankiw et al. (1992) ir Barro ir Sala-i-Martin (2004).

Mokslinis naujumas

Disertacinis tyrimas yra naujoviškas keletu aspektų. Pirmiausia, šis darbas papildo Lietuvos literatūrą apie makroprudencinę politika, kur yra tik du viešai žinomi straipsniai Rubio ir Comunale (2016) ir Reichenbachas (2020). Pastarieji autoriai tiria tik būsto paskolų LTV limito aspektus, tuo tarpu šiame darbe nagrinėjamos trys makroprudencinės politikos priemonės: LTV limitas, kapitalo reikalavimai ir paskolų rizikos svoriai. Disertacijoje pateikiami makroprudencinių priemonių griežtinimo poveikio įverčiai gali turėti praktinės reikšmės tiek politikos formuotojams, tiek analitikams. Šiame darbe sukurti DSGE modeliai yra vieni iš nedaugelio specialiai Lietuvai sukurtų modelių (pvz. Karpavičius, 2008; Proškutė, 2012; Pušinskaitė, 2014; Rubio ir Comunale, 2016). Daktaro disertacijoje pateikiamas modelis išsiskiria iš kitų minėtų tuo, kad jis pasižymi pinigų kūrimo savybėmis, taip pat prielaidomis apie būsto paskolas ir jų kredito riziką bei makroprudencinę politiką.

Negana to, disertacinis tyrimas įdeda įnašą į tarptautinę mokslinę literatūrą, nes darbe pabrėžiamas bankų pinigų kūrimo vaidmuo – vienas iš nedaugelio darbų, kur pateikiamas DSGE modelis su pinigų kūrimu. Darbe suformuluojamos Jakab ir Kumhof (2015) teiginius (ingredientus) patikslinančios būtinosios sąlygos, kad makroekonominis modelis būtų suderintas su pinigų kūrimu. Taip pat darbas pasižymi tam tikromis naujovėmis, susijusiomis su finansinių trikdžių modeliavimo niuansais. Kredito rizikos komponentė yra modeliuojama remiantis de Walque et al. (2010), idant būtų geriau atskleidžiama namų ūkių finansų daugiadimensiškumo problema – priešingai nei paplitusi Bernanke et al. (1999) modeliavimo sąranga. Disertacijoje pristatomas modelis yra vienas iš nedaugelio, kur modeliuojama kartu ir daugiaperiodinės paskolos (naudojantis LTV ribojančia dinamine lygtimi), ir kredito rizikos komponentė. Verta paminėti, kad, skirtingai nuo kitų autorių straipsnių, šioje disertacijoje daroma prielaida, kad bankai optimizuodami taip pat atsižvelgia į skolininkų LTV apribojimą. Dėl to šis instrumentas turi ne tik tiesioginį poveikį kredito paklausai, bet ir netiesioginį – kredito pasiūlai.

Disertacinis tyrimas taip pat atkreipia literatūros dėmesį į makroprudencinės politikos poveikį ilgojo laikotarpio ekonomikos augimui ir jo stabilumui. Disertacijoje pateikiamas modelis yra (Barro et al., 1995; Pintus, 2007, 2011) autorių modelių apibendrinimas, kuris įtraukia tiek makroprudencinę politiką, tiek endogenines palūkanų normas. Ankstesni straipsniai rėmėsi prielaida, kad palūkanų normos yra egzogeninės ir statiškos, t. y., lygios žemai pasaulinei palūkanų normai. Šios disertacijos atveju yra tariama, kad skolinimosi palūkanų norma yra tarp žemos pasaulinės ir aukštos vietinės kapitalo grąžos, o tiksliai kur priklauso nuo skolininkų derybinės galios. Kadangi derybinė galia ir paskolų kainodara yra glaudžiai susijusios su finansų rinkos koncentracija ir konkurencija, šio tyrimo įžvalgos apie makroprudencinę politiką taip pat papildo ir literatūrą, tiriančią konkurencijos įtaką finansiniam stabilumui.

Išvados

Šiame disertaciniame darbe (1-3 skyriuose) pateikiami rezultatai atskleidžia pinigų kūrimo, makroprudencinės politikos tyrimų problemiką, remiantis aukščiau aptartais metodais. Tyrimo rezultatų pagrindu suformuluotos išvados, kurios gali būti laikomos ir kaip darbo ginamieji teiginiai:

- Tai, kad bankai gali kurti kreditą ir pinigus yra paprastas apskaitos faktas, leidžiantis bankų sektoriui daryti įtaką monetarinei sistemai ir visai ekonomikai. Vis dėlto pinigų kūrimas gali būti ribojamas įvairių rinkos veiksnių, kaip antai pelningumas arba kredito rizika. Be to, bankinis reguliavimas, makroprudencinės politikos priemonės, kaip kapitalo ir likvidumo reikalavimai, taip pat gali turėti įtakos pinigų kūrimo procesams ir pristabdyti bankų balansų plėtrą.

- Disertacijoje pateiktas DSGE modelis Lietuvai pasižymi bankų pinigų kūrimo savybėmis. Modeliavimo rezultatai rodo, kad po teigiamo kredito pasiūlos šoko, kintamųjų reakcija primena kredito kūrimą. Tai yra, plečiantis banko paskolų dydžiui, tuo pačiu metu didėja ir indėlių kiekis, kas primena banko savi-finansavimą pinigų kūrimu. Remiantis ne monetarine, o realiais dydžiais paremta modelio versija, matyti, kad bankų sektorius siekdamas išplėsti savo skolinimą turi pritraukti resursus iš išorės, pvz. užsienio, kad galėtų juos išskolinti paskolų forma.

- Šios disertacijos indėlis į atitinkamą literatūrą yra tai, kad pasiūlomi keturi ingredientai, kuriems esant bet koks makroekonominis modelis galėtų būti suderintas su pinigų kūrimo idėja. Pirma, modelis turi būti apskaitos lygčių prasme suderinta sistema (angl. *stock-flow consistent*), kurioje pinigai yra endogeniniai. Antra, paskolos ir pinigai yra apsprendžiami vienu metu, remiantis dvigubo įrašo apskaitos principu. Trečia, modelis turi turėti tam tikrą heterogeniškumą, t. y., skirtingus agentus, kurių vieni taupo ar skolina, kiti skolinasi. Ketvirta, modelis turi būti nominalus, kas reiškia, kad kainos turi būti išreikštos indėliais (pinigais), taip pat jos turi galėti keistis, nors ir netolygiai.

- Aukščiau pateikti ingredientai patikslina išdėstytus Jakab ir Kumhof (2015). Kadangi šiame darbe pateiktos būtinosios pinigų kūrimo sąlygos yra ne tokios griežtos, galima daryti išvadą, kad modelių, kurie pasižymi pinigų kūrimu, yra kur kas daugiau nei nurodė Jakab ir Kumhof (2015, 2019).

- Išplėstas DSGE modelis yra naudojamas įvertinti trijų makroprudencinės politikos priemonių griežtinimo poveikį. Modelio rezultatai rodo, kad ankstyvas paskelbimas apie būsimą priemonių įgyvendinimą turi mažesnius gerovės nuostolius, palyginus su netikėtu paskelbimu, kadangi agentai turi daugiau laiko prisitaikyti. Vis dėlto dar nereiškia, kad politikos formuotojai visur ir visada privalo iš anksto paskelbti apie ateities politikos pasikeitimus. Netikėtas politikos priemonių įgyvendinimas, be išankstinio paskelbimo, kartais gali būti itin reikalingas, pvz. siekiant suvaldyti greitai besipučiantį kredito ir būsto kainų burbulą.

- Aukštesni kapitalo reikalavimai ir rizikos svoriai yra perduodami skolininkams per didesnes palūkanų normas, kurios sumažina kredito srautus bei Lietuvos ekonominį aktyvumą. Konkrečiau, kapitalo reikalavimų padidinimas 1 proc. p. įmonių paskolų palūkanas padidina per 0,12 proc. p., o būsto paskolų – per 0,03 proc. p. Bendras paskolų portfelis dėl tokio reguliavimo susitrauktų apie 0,2 proc., tačiau trumpuoju laikotarpiu poveikis įmonių skolinimui būtų juntamesnis. Pastarasis rezultatas yra susijęs su faktu, kad įmonių paskolos paprastai turi didesnį rizikos svorį, tad yra labiau jautrios kapitalo reikalavimų didinimui (panašiai nustatė ir Budrys et al., 2017; Mayordomo ir Rodriguez-Moreno, 2018). Tuo tarpu, būsto paskolų rizikos svorių padidinimas 5 proc. (arba 2,5 proc. p.) būsto paskolų palūkanas padidintų per 0,04 proc. p. (kaip ir Glancy ir Kurtzman, 2018), paskolų portfelį sumažintų per 0,1 proc., tačiau poveikis bendrai ekonomikai būtų ribotas.

- Remiantis modeliu, LTV limito padidinimas 1 proc. p. sumažintų būsto paskolų palūkanas 0,3 proc. p. – sąlyginai daug, kadangi sumažėtų paskolų paklausa, tačiau padidėtų pasiūla. Poveikis būsto kreditui būtų lygus apie -0,5 proc., BVP – -0,1 proc. – panašiai kaip suskaičiavo Richter et al. (2018) arba Reichenbachas (2020).

- Kadangi bendrųjų kapitalo reikalavimų didinimas labiau paveikia skolinimą įmonių sektoriui ir ekonomiką, ši priemonė mažiausiai tinka iš trijų, siekiant užkardyti rizikas, kylančias būsto kredito rinkoje. LTV santykio ribojimas yra pranašiausias, nes ši priemonė yra tiesiogiai orientuota į būsto paskolas.

- Nors makroprudencinė politika turi nedidelį neigiamą poveikį ekonomikos augimui trumpuoju ir ilguoju laikotarpiais, tačiau ji gali veikti stabilizuojančiai. Kitu atveju, jeigu makroprudencinės politikos nebūtų arba ji būta pernelyg laisva, Lietuvos ekonomika galėtų patirti pakilimų ir nuosmukių laikotarpius, kaip 2005-2009 m.

- Konkurencijos Lietuvos finansų sektoriuje skatinimas galėtų didinti skolininkų derybinę galią dėl mažesnių palūkanų normų, taip mažinti skolos aptarnavimo sąnaudas. Tuo atveju didesnė konkurencija mažintų tikimybę, kad ekonomika pasižymės dideliu kintamumu – net ir su pakankamai negriežtais makroprudenciniais reikalavimais. Vis dėlto reikia atkreipti dėmesį, kad disertacijoje pateiktas ilgojo laikotarpio augimo modelis neatsižvelgia į galimą konkurencijos poveikį bankų rizikos prisiėmimui, kuris ekonomiką gali veikti destabilizuojančiai.

Tyrimo apribojimai ir ateities perspektyvos

Šioje disertacijoje pateikti modeliai yra naudingi, nes padidina supratimą apie makroprudencinę politiką, tačiau jie nėra beribiai. Iš esmės, bendrosios pusiausvyros modeliai yra gana didelės teorinės struktūros. Paskolų lygmens informacija iš kredito registro arba ilgos bankų ir makroekonominių duomenų laiko eilutės galėtų būti naudojamos papildomiems tyrimams, taip papildyti šios disertacijos įžvalgas.

Disertaciniame darbe atlikta analizė remiasi impulso-atsako funkcijomis bei konvergavimo greičiais, taigi daugiausiai kreipiamas dėmesys į makro-finansinių kintamųjų skirstinių pirmuosius momentus – vidurkius. Papildoma empirinė analizė, pvz. Suarez (2021) *growth-at-risk* idėjos, galėtų įnešti papildomos informacijos apie politikos priemonių poveikį visam kintamojo, tokio kaip BVP augimas, pasiskirstymui. Tyrėjas naudodamas tokią metodiką galėtų kvantifikuoti ne tik trumpalaikius politikos kaštus, bet ir įvertinti kylančią naudą dėl sumažėjusio ekonomikos kintamumo.

Galiausiai, modeliavimo sąrangos neturi būti nei visiškai struktūrinės, nei būtinai redukuotos formos empiriniai modeliai – galimas ir pusiau struktūrinis kompromisas (pvz. Budnik et al., 2020). Nors ir pusiau struktūriniai modeliai gali būti itin sudėtingi, jie gali būti panaudojami makroprudencinių priemonių kalibravimui, optimizuojant tam tikrą tikslo funkciją. Dėl šios priežasties pusiau struktūriniai modeliai yra pakankamai perspektyvūs metodai makroprudencinės politikos tyrimų ateityje.

Trumpos žinios apie disertantą

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Disertantas 2014-2017 m. dirbo duomenų analitiku tarptautinėje įmonėje Euromonitor International, o nuo 2017 m. dirba Lietuvos banko Finansinio stabilumo departamente.

Moksliniai interesai: taikomoji ekonometrija, finansinis stabilumas ir bankininkystė, makroekonomika.

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