Philipp Kirchner

Shadow Banking and the Conduct of Monetary and Macroprudential Policy

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To Lisa, and my parents Elke and Bernd.

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Preface

This monograph represents my cumulative dissertation and was written while I was a PhD student at the Chair for Monetary Economics at the University of Kassel during the years 2015 untill 2020. It would not have been possible to succeed in this project without the help and enduring support of a great number of people.

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Motivation

Since the occurence of the Great Financial Crisis (GFC) in 2007/2008, our understanding of (macro) economics changed fundamentally. The distortions that emanated in the U.S. subprime mortgage market and rapidly developed into a financial and economic crisis of international dimension revealed structural vulnerabilities of the financial system and new insights into the workings and interaction of international financial markets and their nexus with the real economy. Three destinctive points stand out. Firstly, the development of the GFC revealed fundamental changes in the structural composition of financial systems. Over the course of the last few decades, traditional retail banking services, especially in the U.S., shifted progressively into a market-based banking system called the shadow banking system. By providing liquidity and maturity transformation while missing access to public deposit insurances, central bank liquidity and regulatory oversight, shadow banking systems ran bank-like activities without bank-like insurance and stability mechanisms. In the runup to the crisis, these circumstances turned out to be an immense risk to financial stability. Secondly, once disruptions unfolded, the conventional tools of monetary policy were strechted to their limits. In order to overcome the ineffectiveness of conventional monetary policy at the zero lower bound, to expand liquidity and stimulate markets, central banks were forced to reconsider their existing policy toolkit. The answer were unconventional policy measures comprising credit-easing programs, large-scale asset purchases of corporate and government bonds, and multiple other liquidity enhancing and lending measures. Thirdly, the occurences of the GFC unveiled that preserving (international) financial stability requires regulatory policies aimed not only at the micro sphere of financial systems, but in particular at the macro sphere. As it turned out, the faults of financial markets were boosted by large and internationally active banks, associated cross-border financial flows and resulting financial contagion and propagation effects. The regulatory responses were macroprudential measures laid down in the BASEL III-framework geared towards the resilience of the banking sector to adverse financial and economic shocks.

This thesis takes upon the aforementioned issues and contributes to the research on the role of shadow banking for financial intermediation and business cycle fluctuations in general, and for the conduct of monetary and macroprudential policies in particular. In financial systems where shadow banking takes an active part as financial intermediary, the flow of financial capital from investors to the productive sector is separated between both retail and shadow banks. Although this heterogeneity in financial intermediation can eventually increase the equilibrium efficiency of the financial system and the real economy, it constitutes a challenge for policy makers. As shadow banking is largely unregulated, highly leveraged and without access to central bank operations, it changes the transmission and effectiveness of monetary policy measures and constitutes a severe risk to financial stability. In this monograph, we use closed- and open-economy DSGE models to study these repercussions and the possibilities of monetary and regulatory authorities to stabilize the business cycle through conducting unconventional monetary policies and macroprudential regulations.

In particular, two questions are in the focus of interest: What is the optimal unconventional monetary policy intervention to shocks in a closed–economy DSGE-setup where retail and shadow banks interact and both supply financial funds to the productive sector? Since the GFC showed that cross-border financial flows combined with tightly regulated traditional banks and largely unregulated shadow banks leave a gap in financial stability policy, we are then interested in the optimal response of macroprudential regulations in a two-country monetary union setup. In addition to these questions, this monograph contributes to the understanding of the general role of shadow banking in the recent DSGE literature by presenting a structured review and assessment of existing DSGE models with shadow banking alongside retail banking. To answer these questions, the structure of this monograph contains three chapters that are independent research articles. Chapter 1 and 2 are joint research projects with Benjamin Schwanebeck and chapter 3 has been written in single authorship. Note that the structure of this monograph inevitably leads to redundancies and especially the presentation of the models of the different papers can be similar to some extent.

Chapter 1 develops a closed-economy model with shadow banking alongside retail banking as in Gertler et al. (2016) or Meeks et al. (2017). We extend the conventional policy toolkit of the central bank with three different unconventional measures: direct purchases of assets, an intervention policy in the funding process between retail and shadow banks, and liquidity facilities. We then analyze their effectiveness in stabilizing financial markets and the real economy. In a second step, we compute the optimal policy responses to real and financial shocks and calculate the maximum welfare gains from unconventional policies depending on different resource costs. Our analyses allow three major results: firstly, regardless of the shock, unconventional policies stabilize the standard targets output and inflation and improve welfare. Direct asset purchases outperform liquidity facilities in terms of business cycle stabilization, which in turn outperform interbank interventions. A higher shadow banking sector leads to a sharper recession but makes unconventional monetary policy more effective. Secondly, the usefulness of interbank intervention is sensitive to the kind of shock and the size of the shadow banking sector. Thirdly, liquidity facilities are the most appropriate unconventional tool in terms of welfare considerations, closely followed by direct asset purchases.

Chapter 2 extends the framework from chapter 1 to a two-country monetary union setup. We model two symmetric countries with standardized productive sectors featuring nominal frictions, and financial systems with heterogeneity in financial intermediation. Retail banks and shadow banks supply credit to domestic firms and only shadow banks are internationally active and able to extend cross-border loans to foreign firms. Following Dedola et al. (2013), the countries are integrated at the real and financial side of the economy. We then evaluate the effectiveness of optimal macroprudential policy. Our results show that monetary policy and macroprudential regulation at the union-level are more effective than country-specific policies. As full real and financial integration via the shadow banking system leads to a harmonization of financial spheres of both countries, business cycles co-move and a supranational regulation intervening symmetrically in both countries can effectively reduce welfare losses among the union members.

In chapter 3, we compile a detailed review of monetary DSGE models featuring shadow banking. To start with, we give a short recap of the evolution of financial frictions and financial intermediation in DSGE modeling to draw attention to why these models did not show sufficient signs of the vulnerability of the financial system prior to the GFC, and what changed afterwards. In the second step, we present the latest progress of DSGE setups considering shadow banking alongside retail banking. We find that, firstly, the models that account shadow banking constitute a well-suited setup for analyzing financial distress that precipitates large-scale downturns in financial intermediation and real economic activity. They are better able to simulate movements in the business cycle of comparable magnitude to the GFC. Secondly, these models allow to study amplification channels between the financial and the real sector that proved to be of importance during times of financial distress. Thirdly, as these models largely miss fully-fledged productive setups with nominal rigidities, they are inappropriate to analyze conventional monetary measures.

Chapter 1

Optimal Unconventional Monetary Policy in the Face of Shadow Banking

1.1 Introduction

Over the past two decades and especially since the onset of the Global Financial Crisis (GFC), the financial system has witnessed a remarkable change in some major advanced economies. Retail banking services such as deposit issuance and loan origination have progressively shifted into a market-based banking system called the shadow banking system. By appearing as an alternative provider of liquidity, shadow banking has certainly supplemented and partly even replaced the services offered by the traditional banking system and contributed to a more efficient allocation of financial assets (International Monetary Fund (IMF) 2014a). Empirical evidence accentuates these developments. In 2007, just before the outbreak of the GFC, only 39% of financial assets in the U.S. were held by traditional banks, 61% accounted for shadow banking. The picture was different in the euro area, where traditional banks held roughly 57%, and shadow banks accumulated only 31 % of financial assets. The remaining assets were held by insurance corporations and pensions funds, institutions normally not considered being shadow like in the euro area. For 2014, the IMF (2014a) indicates decreasing patterns for the former (51% in the US) and an upward trend for the latter (28% in the euro area).

However, while the traditional banking system provides credit, liquidity and maturity transformation under a single roof, backed by public deposit insurance and supported by central bank liquidity, the shadow banking system runs almost the same activities but without being able to resort to the last two mentioned points. Shadow activities are neither backed by deposit insurance nor can the central bank directly intervene in that system. As turned out in the midst of the crisis, these differences comprise immense vulnerabilities and instabilities, hence costs for financial markets that can only be tackled by monetary policy through expanding the conventional interest rate tools by unconventional measures.

In order to consider these changes and challenges, we build a comprehensive

DSGE-model featuring financial intermediation with shadow banking along the lines of Gertler, Kiyotaki and Prestipino (2016) and Meeks, Nelson and Alessandri (2017), henceforth GKP and MNA. This setup enables use to evaluate different unconventional policy measures, their relative effectiveness and the optimal policy intervention. We endow the central bank with three different unconventional measures: direct purchases of assets (purchasing loans to non-financial firms), an intervention policy in the funding process between retail and shadow banks (purchasing interbank loans), and liquidity facilities (placing additional funds on the balance sheet of retail banks). We use these measures to analyze their effectiveness in stabilizing financial markets and the real economy. In a second step, we compute the optimal monetary policy responses to business cycle and financial sector shocks and calculate the maximum welfare gains from unconventional policies depending on different resource costs.

The unconventional measures we implement are based on the attempts of the Fed and ECB to tackle the repercussions of the GFC and to overcome the ineffectiveness of conventional monetary policy at the zero lower bound on nominal interest rates. However, effects, timing, and especially the point of intervention of these measures differed across central banks. Whereas the Fed reacted promptly after the markets collapsed in 2008/2009, the ECB chose a more moderate approach, not least because financial disturbances started much later in Europe.[1] To account for the majority of unconventional measures, we implement three different tools. The central bank can *(a)* directly intervene in the market for non-financial loans, *(b)* intervene in the funding process between retail and shadow banks, or *(c)* provide liquidity directly to retail banks. Direct intervention in the market for non-financial loans requires the central bank to directly purchase loans (assets) from non-financial firms (see e.g. Gertler and Karadi 2011). If the central bank intervenes in the funding process between retail and shadow banks, it essentially purchases loans that retail banks assigned to shadow banks. The third policy option follows Gertler and Kiyotaki (2011) and Dedola et al. (2013) and represents a form of liquidity facility where the central bank provides loans, i.e. liquidity injections directly to retail banks. All three non-standard tools differ in their point of intervention and, accordingly, have different effects.

The model we set up combines elements from Gertler and Karadi (2011) com-

[1] To better stabilize financial markets and to extend the basic liquidity providing programs, the Fed launched different Credit Easing-programs (QE I, II, III) and intervened in markets for agency mortgage backed securities, agency debts and Treasury securities. The aim was to bring down long term interest rates through directly purchasing financial assets within these markets. In contrast, the ECB started with activities focussed on avoiding liquidity shortages in the interbank market and implemented unconventional measures in the sense of Quantitative Easing relatively late. The initial programs aimed at unrestricted lending to the banking sector (such as the FRFA-program) and were mainly liquidity providing measures. However, with the most recent "Corporate Sector Purchase Programme" introduced in June 2016, the ECB started to directly purchase corporate sector bonds in the primary and secondary market to "... further strengthen the pass-through of Eurosystem's asset purchases to the financing condition of the real economy" (Doyle et al. 2016).

bined with elements from GKP and MNA. In following the perception of GKP, we model shadow banks as intermediaries that can make non-financial loans to firms but are almost exclusively dependent on funds from their sponsors, retail banks, to finance their activities. A common funding market (virtually speaking an interbank market) is the direct link between retail and shadow banks and merges their liquidity positions. The latter act solely as borrowers and the former appear solely as lenders. Management of financial capital comes at a cost, giving shadow banks an advantage over retail banks in making non-financial loans. Since we consider shadow banks to be highly leveraged and dependent on funding from retail banks, exogenous shocks to the business cycle lead to disturbances in the funding process and let shadow intermediation collapse.

We can draw three major results from the analyses: first, regardless of the shock, unconventional policy measures stabilize the standard targets output and inflation and improve welfare. Hereby, direct asset purchases outperform liquidity facilities in terms of business cycle stabilization, which in turn outperform interbank interventions. A higher shadow banking sector leads to a sharper recession but also makes unconventional monetary policy more effective. Second, the usefulness of interbank intervention is highly sensitive to the kind of shock and the size of the shadow banking sector. Third, our welfare analysis shows that liquidity facilities seem to be the most appropriate unconventional policy tool closely followed by direct asset purchases. However, that finding is conditional on several aspects, e.g. the financial structure of the economy, reasonable assumptions for the resource costs of interventions and a foreseeable exit. Hence, there is no one-size-fits-all solution for unconventional monetary policy.

We want to make the reader aware of what we do not do in this paper. The recent financial crisis has not only spawned changes in the framework of monetary policy, it has also changed thinking about regulation and macroprudential oversight with several new measures being put into place (see e.g. Levine and Lima (2015) or Palek and Schwanebeck (2019)). Although macroprudential tools could be easily implemented into our framework, within this paper we do not account for these changes in the regulatory framework and, in a first step, focus rather on the effects of unconventional monetary policy. Another point worth mentioning in the process of shadow credit intermediation is the importance of securitization and the decoupling into different steps that are carried out along a chain of different entities.[2] We do not explicitly account for that process, but nonetheless incorporate the direct effects of securitization, namely the higher collateral value of interbank debt ascribable to the reduction of idiosyncratic risk inherent in the process of securitization. While the recent unconventional measures are designed for extraordinary times of crisis,

[2] These entities comprise, among others, money market mutual funds, and special purpose vehicles. For a more detailed explanation of the entities involved in the shadow banking system and the process of securitization, we refer to Pozsar et al. (2013). A comprehensive literature review of shadow banking has been put in place by Adrian and Ashcraft (2012).

it remains an open debate of how and when monetary policy should actively exit. Although our analysis points to a tapering process that can be interpreted as an exit, we do not explicitly model an active exit from unconventional policies in the sense of Foerster (2015).

The remainder of the paper is structured as follows. In section 1.2, we introduce our model economy. Section 1.3 starts with the calibration of the model and an analysis of the shocks without influence of unconventional policies and with different shadow banking magnitudes. Thereafter, we run several experiments and let the central bank react with unconventional measures. The optimal monetary policy reaction and the implications for welfare are studied as well in section 1.3. Section 1.4 concludes with final remarks.

1.2 The Basic Model

Our core framework is a standard monetary DSGE model with nominal rigidities and financial intermediation as in Gertler and Karadi (2011), extended by a shadow banking sector along the lines of GKP and MNA. The model consists of the following agents: households, intermediate goods firms, capital goods firms, retailers, and financial intermediaries, segmented into a retail bank and a wholesale (shadow) bank. Although both intermediaries can make non-financial loans to intermediate goods firms, their balance sheet structure differs. Only the retail bank is able to obtain deposits from households, shadow banks have to rely on funding from retail banks to finance their loans to firms. Moreover, both intermediaries face an agency problem; retail banks towards households, and shadow banks towards retail banks. This restricts the ability of intermediaries to obtain funds from their financiers due to their incentive of diverting a fraction of their balance sheet for personal use. In order to simplify the analysis and focus on the financial sector, we abstract from explicitly modelling agency frictions between financial intermediaries and non-financial firms. The focal point of our paper is the implementation and the effect of optimal unconventional monetary policy. Thus, we incorporate several measures into the model. They comprise central bank purchases of assets, i.e. credit policies, central bank intervention in the funding market between retail and shadow banks and liquidity facilities. In the following, we describe the model setup.

1.2.1 Households

There is a continuum of representative infinitely-lived households that consume, save and supply labor. Within each household exist three types of members, one worker and two bankers. Both bankers manage financial intermediaries, however, they are split up into a retail banker (i.e. managing a retail bank) and a shadow banker (i.e. managing an entity within the shadow banking sector). Through managing their financial intermediaries, both types of bankers accumulate net worth and transfer retained earnings back to their household once they have to shut down their intermediary and exit the banking sector. Following Gertler and Karadi (2011), this mechanism prevents bankers from accumulating enough net worth to independently fund all their investments. Simultaneously, workers supply labor to goods producers and return their earnings back to the household. After each period, the fraction of bankers who exit the industry become workers. In order to keep the family members constant over time, a corresponding fraction of workers become new bankers who are endowed with startup funds from their respective household. To guarantee the assumption of the representative agent framework, we assume perfect consumption insurance among household members.

The representative infinitely-lived household maximizes its utility function

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} U(C_\tau - hC_{\tau-1}, L_\tau) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\log(C_\tau - hC_{\tau-1}) - \chi \frac{L_\tau^{1+\varphi}}{1+\varphi} \right], \quad (1.1)$$

consisting of consumption C_t with h as the parameter to allow for habit formation in consumption and labor L_τ. The households discount factor is β, φ is the inverse Frisch elasticity and χ a weight on labor utility. Households are the ultimate savers of the economy, thus they deposit funds D_t at banks other than the ones they own and may acquire government debt $B_{g,t}$. Both deposits and government debt are one-period riskless assets that pay the real riskless rate R_t and can be thought of as noncontingent short-term bonds. Besides, households obtain real wage income W_t from supplying labor L_t to goods producers and they receive net earnings Π_t arising out of bank returns and profits from providing management services plus the profits generated from the ownership of capital producers and retailers reduced by startup funds for new bankers. T_t represents lump sum taxes. Accordingly, the flow of funds of the household can be written as

$$C_t + D_t + B_{g,t} = W_t L_t + R_t D_{t-1} + R_t B_{g,t-1} + \Pi_t - T_t. \quad (1.2)$$

By maximizing the households utility function (1.1) subject to the flow of funds constraint we get the first-order conditions for labor supply and consumption/savings

$$U_{C_t} W_t = \chi L_t^{\varphi} \quad (1.3)$$

$$E_t \Lambda_{t,t+1} R_{t+1} = 1 \quad (1.4)$$

with the marginal utility of consumption defined as

$$U_{C_t} = (C_t - hC_{t-1})^{-1} - \beta h E_t (C_{t+1} - hC_t)^{-1}$$

and the households stochastic discount factor written as

$$\Lambda_{t,\tau} = \beta^{\tau-t} \frac{U_{C_\tau}}{U_{C_t}}.$$

1.2.2 Intermediate goods firms

Competitive intermediate goods firms employ the constant-returns-to-scale Cobb-Douglas production function given by

$$Y_{m,t} = (\psi_t K_t)^{\alpha} L_t^{1-\alpha} \tag{1.5}$$

using the input factors capital K_t and labor L_t to produce intermediate output $Y_{m,t}$, that is afterwards sold to retailers and then used to produce the final output. ψ_t reflects a shock to the quality of capital. Prior to use, capital for production in the subsequent period $t+1$ needs to be purchased from capital producers in period t. In order to obtain loans to finance the acquisition of capital, intermediate firms issue claims S_t to financial intermediaries. These claims equal the amount of acquired capital and are priced with Q_t , reflecting the real price of a unit of capital. It follows that

$$Q_t K_{t+1} = Q_t S_t \tag{1.6}$$

which states that the value of capital acquired equals the value of claims issued, with the evolution of the capital stock K_{t+1} following the law of motion given by

$$K_{t+1} = (1-\delta)\psi_t K_t + I_t. \tag{1.7}$$

Capital for period $t+1$ is the sum of current investment I_t and existing undepreciated capital subject to the shock to capital quality. The term $\psi_t K_t$ denotes the effective quantity of capital at t. It is best to think of this shock as a negative event triggering a sudden depreciation of the already installed capital, thereby causing a devaluation of the balance sheets of banks (e.g. describing the circumstances after the bursting of the US housing bubble in 07/08). As will be clear later, banks use capital as collateral in their balance sheet. Consequently, sudden changes in the value of capital affect the asset side of banks and thus their overall financing structure.

Profit maximization of the intermediate goods firms lead to the first-order conditions for labor input

$$W_t = P_{m,t}(1-\alpha)\frac{Y_t}{L_t}, \tag{1.8}$$

where $P_{m,t}$ is the relative price of the intermediate good. The gross profits per unit of capital can be expressed as the marginal product of capital:

$$Z_t = P_{m,t}\alpha\frac{Y_{m,t}}{K_t}. \tag{1.9}$$

Following GKP, we assume that the funding process between intermediate firms and the corresponding financial intermediaries includes management costs which arise as costs for supervising contracting parties as well as complying with regulatory guidelines. Retail bankers make loans subject to management costs in form of $F_r = \iota(S_{r,t})^2/2$ while shadow banks do not face these costs ($\iota_w \to 0$), households on the other hand, are excluded from directly lending to firms ($\iota_h \to \infty$). However, households receive profits ($F_r' S_{r,t} - F_r$) from providing management services to retail banks by bearing the management costs F_r while demanding the price $F_r' = \iota S_{r,t}$ per managed unit $S_{r,t}$.

As a result, shadow banks have a cost advantage over retail banks which results in different rates of return on non-financial loans:

$$R_{wk,t} = \frac{Z_t + (1-\delta)\psi_t Q_t}{Q_{t-1}}, \ R_{rk,t} = \frac{Z_t + (1-\delta)\psi_t Q_t}{Q_{t-1} + \iota S_{r,t-1}}. \tag{1.10}$$

1.2.3 Capital goods firms

Competitive capital goods firms produce new capital goods and sell the capital to intermediate goods producers at the price Q_t. Production of capital goods utilizes final output from retailers as input and is subject to investment adjustment costs following the functional form

$$f_i\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{1.11}$$

satisfying $f(1) = f'(1) = 0$ and $f''(1) > 0$. By choosing investment I_t, capital producers maximize their profits according to the objective function

$$\max E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f_i\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\}. \tag{1.12}$$

Profit maximization leads to the first-order condition for the marginal cost of investment

$$Q_t = 1 + f_i\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f_i'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 f_i'\left(\frac{I_{t+1}}{I_t}\right) \tag{1.13}$$

which equals the price Q_t of a capital good. Since capital producers are owned by households, they return all profits back to their household.

1.2.4 Retailers

Monopolistically competitive retailers produce the final good by using the intermediate good as input and label it at no cost. Thus, final output Y_t as a CES aggregate of a continuum of retail output is given by

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{1.14}$$

where Y_{it} denotes the output of retailer i and ε is the elasticity of substitution between goods. Cost minimization leads to

$$Y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\varepsilon} Y_t, \; P_t = \left[\int_0^1 P_{it}^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}. \tag{1.15}$$

To introduce nominal rigidities, we follow Christiano et al. (2005) and assume that only the fraction $1-\zeta$ of retailers is able to adjust their prices each period, whereas the fraction ζ of retailers can only index their prices to lagged inflation according to $P_{it} = \pi_{t-1}^{\zeta_P} P_{it-1}$ with $\pi_t = P_t/P_{t-1}$ and ζ_P as a measure of price indexation. The retailers optimization problem boils down to choose the optimal price P_t^* in order to maximize profits following

$$\max E_t \sum_{\tau=t}^{\infty} \zeta^{\tau-t} \Lambda_{t,\tau} \left[\frac{P_t^*}{P_\tau} \prod_{j=1}^{\tau-t} \pi_{t+j-1}^{\zeta_P} - P_{m,\tau}\right] Y_{i\tau}. \tag{1.16}$$

The first-order condition is given by

$$E_t \sum_{\tau=t}^{\infty} \zeta^{\tau-t} \Lambda_{t,\tau} \left[\frac{P_t^*}{P_\tau} \prod_{j=1}^{\tau-t} \pi_{t+j-1}^{\zeta_P} - \frac{\varepsilon}{\varepsilon-1} P_{m,\tau}\right] Y_{i\tau} = 0 \tag{1.17}$$

and the aggregate price index evolves according to

$$P_t = \left[(1-\zeta)(P_t^*)^{1-\varepsilon} + \zeta(\pi_{t-1}^{\zeta_P} P_{t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{1.18}$$

1.2.5 Financial intermediaries

The financial system is responsible for channeling funds from savers (households) to investors (non-financial firms) and comprises two types of financial intermediaries, retail banks and shadow banks. Both intermediaries can make non-financial loans to intermediate goods firms and both have access to a common funding market. This funding market represents the direct link between retail and shadow banks, where shadow banks act solely as borrowers and retail banks appear solely as lenders. For the sake of simplicity, when we later mention the process of funding between retail and shadow banks we will refer to it as the interbank market. Furthermore, shadow banks have no direct access to retail financial markets (i.e. household deposits) and, besides accumulated net worth, have to rely on funding (loans) from retail banks to make non-financial loans. Hence, we consider shadow banks to be highly leveraged and dependent on funding from retail banks. This structure of interaction between retail banks and shadow banks closely follows GKP. Here, in general both intermediaries would be able to obtain deposits from households and to borrow as well as lend in the interbank market. However, the authors focus their attention on the most realistic case where retail banks obtain deposits from households, lend funds to non-financial firms as well as shadow banks, and shadow banks exclusively rely on interbank borrowing from retail banks. Two pivotal assumptions guarantee this flow of funds: on the one hand, management of financial capital is subject to costs, and on the other hand, intermediaries differ in their ability to make use of the interbank market. We will elaborate on these parameters later on when we introduce the incentive constraints of retail and shadow banks.

Retail banks

At the beginning of the period t, an individual retail banker obtains deposits d_t from households and accumulates net worth $n_{r,t}$ from retained earnings, in order to allocate non-financial loans $s_{r,t}$ priced at Q_t to intermediate goods firms (including management services) and funds (loans) $b_{r,t}$ to shadow banks. The balance sheet identity during period t can be written as follows:

$$\left(Q_t + \iota s_{r,t}\right) s_{r,t} + b_{r,t} = d_t + n_{r,t} + m_t, \tag{1.19}$$

where m_t reflects one out of three possibilities of unconventional monetary policy by the central bank. Following Gertler and Kiyotaki (2011) and Dedola et al. (2013), the central bank conducts liquidity facilities in the sense of the ECB, i.e. allocating loans directly to retail banks at the noncontingent interest rate $R_{g,t}$.

Net worth $n_{r,t}$ at period t evolves as the difference between earnings on non-financial loans $s_{r,t-1}$ from $t-1$ to t and funds to shadow banks $b_{r,t-1}$ from $t-1$ to t at the interbank lending rate $R_{b,t}$ net of payments on deposits d_{t-1} at the non-contingent riskless rate R_t and payments on liquidity facilities at the penalty rate $R_{g,t}$. Accordingly, we can express the evolution of net worth as

$$\begin{aligned} n_{r,t} &= \left(Z_t + (1-\delta)\psi_t Q_t\right) s_{r,t-1} + R_{b,t} b_{r,t-1} - R_t d_{t-1} - R_{g,t} m_{t-1} \\ n_{r,t} &= \left(R_{rk,t} - R_t\right)\left(Q_{t-1} + \iota s_{r,t-1}\right) s_{r,t-1} + (R_{b,t} - R_t) b_{r,t-1} \\ &\quad + R_t n_{r,t-1} - (R_{g,t} - R_t) m_{t-1}. \end{aligned} \tag{1.20}$$

Given a positive spread for retail bankers it is worth increasing their loan holdings indefinitely by raising new deposits until they have to exit the industry and become a worker. Accordingly, the objective of the retail banker is to maximize the expected terminal value of his net worth at the end of period t given by the value function

$$V_{r,t} = E_t\left[\sum_{\tau=t+1}^{\infty} (1-\sigma)\sigma^{\tau-t-1} \Lambda_{t,\tau} n_{r,\tau}\right], \tag{1.21}$$

with the surviving probability σ and the stochastic discount factor $\Lambda_{t,\tau}$, which equals that of households since retail bankers are members of the same. Since retail bankers would try to expand their assets indefinitely by raising new deposits, we set up a moral hazard problem between them (Gertler and Karadi 2011). Still in period t but after raising new funds from households, the banker can decide to behave corrupt instead of maximizing the terminal value of net worth. Being corrupt means to divert the fraction θ_t of the balance sheet that is funded by retained earnings and deposits and return them back to the respective household. Since the remaining households are only able to recover the fraction $1 - \theta_t$, they force the retail banker into bankruptcy at the beginning of the next period. It follows that households are only willing to supply additional funds to retail banks, if the latter have an incentive to remain in business and supply further loans, i.e. if the present discounted value of future payouts exceeds or is at least equal to the gain from absconding with the divertable fraction θ_t. This relation can be expressed with the following incentive constraint

$$V_{r,t} \geq \theta_t \left[\left(Q_t + \iota s_{r,t} \right) s_{r,t} + \gamma_t b_{r,t} - \lambda m_t \right], \tag{1.22}$$

where the weight of an asset is inversely related to its collateral value (see MNA). Remaining in doing business implies that the franchise value $V_{r,t}$ of the bank must exceed, or is at least equal to, the gain from absconding with the divertable fraction θ_t of assets. However, the possibility to divert funds is not evenly distributed among assets. Whereas retail bankers can divert the fraction θ_t $(0 < \theta_t < 1)$ of non-financial loans, they are only able to divert the fraction $\theta_t \gamma_t$ of interbank loans, with $0 < \gamma_t < 1$, and the fraction $\theta_t \lambda$, with λ $(0 < \lambda < 1)$, of loans allocated by the central bank. Thus, non-financial loans are easier to divert compared to interbank loans and governmental loans. This fact is motivated by the assumption that loans granted within the interbank market are easier to monitor and to evaluate for third parties (i.e. households) compared to loans from retail banks to non-financial firms. As argued by GKP, and MNA, mutual interbank lending largely destroys the idiosyncratic features inherent in such loans thereby making them a safer asset and more pledgeable. Accordingly, γ_t influences the composition of assets of retail banks and, particularly, the size of the shadow banking sector. Suppose a decrease in γ_t. The more the parameter shrinks, the less easy it is to divert interbank loans, and the higher is the incentive for retail banks to precipitate a relaxation of their incentive constraint by increasing interbank loans to shadow banks compared to non-financial loans. Subsequently, shadow banks are endowed with more funds leading to an increased intermediation activity of the very same, i.e. lending to non-financial firms. There may be exogenous shocks ϵ_t^θ and ϵ_t^γ to the diversion parameters θ_t and γ_t that are assumed to follow AR(1) processes. One could think of these shocks as a sudden loss of confidence in the banking sector and a loss of pledgeability of interbank loans that are manifest in an increase in the attractiveness of diverting assets. This leads to a tightening of the incentive constraint and thereby triggers a credit crunch (see e.g. MNA and Dedola et al., 2013).

Turning now to the optimization problem of the retail banker, we begin by writing the value function (1.21) recursively as the Bellman equation and get

$$V_{r,t-1} = E_{t-1} \Lambda_{t-1,t} \left[(1-\sigma) n_{r,t} + \sigma V_{r,t} \right]. \tag{1.23}$$

The retail banker maximizes (1.23) by choosing $\{s_{r,t}, b_{r,t}, m_t\}$ subject to (1.20) and (1.22). To solve the maximization problem, we guess and later verify that (1.23) can be stated by the following expression

$$V_{r,t} = \mu_{rs,t}\left(Q_t + \iota s_{r,t}\right) s_{r,t} + \mu_{rb,t} b_{r,t} + \nu_{r,t} n_{r,t} - \mu_{g,t} m_t, \tag{1.24}$$

where $\mu_{rs,t}$ is the excess return of non-financial loans over deposits, $\mu_{rb,t}$ is the excess return of interbank loans over deposits and $\nu_{r,t}$ is the marginal value of net worth while $\mu_{g,t}$ shows the excess cost of liquidity facilities. Now, the optimization problem of the retail banker can be solved by maximizing (1.24) subject to (1.22).

By rearranging the first-order conditions, we obtain

$$\mu_{rs,t} = \frac{1}{\gamma_t}\mu_{rb,t} \tag{1.25a}$$

$$\mu_{rs,t} = \frac{1}{\lambda}\mu_{g,t}. \tag{1.25b}$$

From (1.25a) we see that the excess return for the retail bank of assigning another unit of interbank loan is twofold. On the one hand, it is the excess return $\mu_{rb,t}$ resulting from that unit and, on the other hand, it is the relaxation of the incentive constraint governed by γ_t and the resulting increased willingness of households to supply further deposits. Accordingly, the retail banker accepts a lower excess return on interbank loans if the relaxation effect via γ_t is strong enough The same holds for governmental loans, i.e. liquidity facilities, as shown by (1.25b): the retail banker is willing to accept the excess cost $\mu_{g,t}$ due to the incentive-relaxing effect via λ.

By using (1.25a) and (1.25b), we can combine (1.24) and (1.22) to obtain an equation defining the leverage ratio $\phi_{r,t}$:

$$\phi_{r,t} = \frac{\left(Q_t + \iota s_{r,t}\right) s_{r,t} + \gamma_t b_{r,t}}{n_{r,t}} = \frac{\nu_{r,t}}{\theta_t - \mu_{rs,t}} + \lambda \frac{m_t}{n_{r,t}}. \tag{1.26}$$

Now, by combining the guess (1.24), the Bellman equation (1.23), the incentive constraint (1.22), the leverage ratio (1.26), and the evolution of net worth (1.20), the value function of the retail banker can be rewritten as

$$V_{r,t} = E_t \Omega_{r,t+1} \left[\begin{array}{c} \left(R_{rk,t+1} - R_{t+1}\right)\left(Q_t + \iota s_{r,t}\right) s_{r,t} + (R_{b,t+1} - R_{t+1}) b_{r,t} \\ + R_{t+1} n_{r,t} - (R_{g,t+1} - R_{t+1}) m_t \end{array} \right], \tag{1.27}$$

where

$$\Omega_{r,t+1} = \Lambda_{t,t+1}\left[1 - \sigma + \sigma(\nu_{r,t+1} + \mu_{rs,t+1}\phi_{r,t+1})\right].$$

Since retail banks face a binding financial friction, their stochastic discount factor Ω_{rt+1} differs from that of households.

In order to verify the initial guess of the Bellman equation, the coefficients of (1.24) have to satisfy

$$\mu_{rs,t} = E_t \Omega_{r,t+1}(R_{rk,t+1} - R_{t+1}) \tag{1.28a}$$

$$\mu_{rb,t} = E_t \Omega_{r,t+1}(R_{b,t+1} - R_{t+1}) \tag{1.28b}$$

$$\nu_{r,t} = E_t \Omega_{r,t+1} R_{t+1} \tag{1.28c}$$

$$\mu_{g,t} = E_t \Omega_{r,t+1}(R_{g,t+1} - R_{t+1}). \tag{1.28d}$$

Let us emphasize the important features inherent in the intermediation process of retail banks. The leverage ratio $\phi_{r,t}$ retail bankers must comply with in order for households to be willing to supply deposits limits the total amount of assets. Thus, under the assumption of a binding incentive constraint, the total amount of loans that a retail banker can allocate depends on his net worth. The more net worth a retail banker accumulates, the smaller (1.26) gets and the more loans can be provided. Furthermore, it is straightforward to see that $\phi_{r,t}$ is increasing in $\mu_{rs,t}$ and $\nu_{r,t}$, and decreasing in θ_t. The impact of $\mu_{r,st}$ and $\nu_{r,t}$ is as follows. Suppose an increase in the marginal gain from allocating another loan to non-financial firms. What follows is an increase in the franchise value of the retail bank and, due to a higher incentive to continue operating the bank, a relaxation of the retail bankers' incentive constraint. Now, the willingness of a household to supply deposits to retail banks is increasing. The same holds true for an increase in the marginal value of net worth. By contrast, an increase in θ_t makes diversion of assets simpler, and households more skeptical of bankers. This process tightens the incentive constraint of the retail bankers and translates into the need to deleverage, i.e. a reduction of loans (and thus deposits), to meet the leverage ratio. Finally, the unconventional monetary policy of allocating loans directly to retail banks improve their ability to provide loans.

Shadow banks

Unlike retail banks, shadow banks do not have direct access to financial retail markets and, consequently, are not able to raise deposits from households as a source of funding. In order to make non-financial loans $Q_t s_{w,t}$ to firms, an individual shadow bank has instead to rely on funding (interbank borrowing) $b_{w,t}$ from retail banks and accumulated net worth $n_{w,t}$. Thus, the balance sheet identity is given by

$$Q_t s_{w,t} = b_{w,t} + n_{w,t}. \tag{1.29}$$

Net worth $n_{w,t}$ at the beginning of period t is composed of earnings on non-financial loans $s_{w,t-1}$ less interest payments on interbank loans $b_{w,t-1}$ at $R_{b,t}$:

$$\begin{aligned} n_{w,t} &= (Z_t + (1-\delta)\psi_t Q_t)\, s_{w,t-1} - R_{b,t} b_{w,t-1} \\ n_{w,t} &= (R_{wk,t} - R_{bt}) Q_{t-1} s_{w,t-1} + R_{b,t} n_{w,t-1}. \end{aligned} \tag{1.30}$$

The evolution of net worth of shadow banks is dependent on the spread between the return on non-financial loans and the cost of borrowing. Given a positive spread, i.e. $R_{wk,t} - R_{b,t} > 0$, shadow bankers will want to increase lending indefinitely by borrowing additional funds from retail banks and retain all earnings until the time they exit. It follows that the objective of a shadow bank is to maximize the expected terminal value of net worth given by the value function

$$V_{w,t} = E_t \left[\sum_{\tau=t+1}^{\infty} (1-\sigma)\sigma^{\tau-t-1} \Lambda_{t,\tau} n_{w,\tau} \right]. \tag{1.31}$$

As with retail banks and households, a similar moral hazard problem limits the ability of shadow banks to obtain funds from their creditor (retail) banks. What follows is that retail banks are only willing to supply funds (interbank loans) to shadow banks, if the latter have an incentive to continue doing business. This is only the case, if the following incentive constraint holds:

$$V_{w,t} \geq \theta_t [Q_t s_{w,t} - b_{w,t} + \omega b_{w,t}]. \tag{1.32}$$

The left side of the inequality represents the gain from remaining in business, namely the franchise value $V_{w,t}$. The right side reflects the gain from diverting assets, and, as a consequence, being forced into bankruptcy. It is straightforward to see that shadow bankers can divert the fraction θ_t of non-financial loans that are financed by net worth ($Q_t s_{w,t} - b_{w,t} = n_{w,t}$), but only the fraction $\theta_t \omega$ of non-financial loans financed by interbank borrowing $b_{w,t}$, with $0 < \omega < 1$. Following GKP and MNA, banks lending in the interbank market are better able to monitor as well as evaluate the quality of their counterparts. Hence, interbank loans that are used as funds for non-financial loans are harder to divert and thereby more pledgeable. Suppose a reduction in the ability to divert interbank loans $b_{w,t}$, what we express by reducing the value of ω. Now, interbank funding grows in attractiveness since the pledgeability of $b_{w,t}$ rises. As a consequence, shadow banks may want to increase interbank borrowing in order to relax their incentive constraint. The interbank market and thus the shadow banking sector grow in size.

Now, formulating (1.31) recursively yields the shadow banker's Bellman equation:

$$V_{w,t-1} = E_{t-1} \Lambda_{t-1,t} \left[(1-\sigma) n_{w,t} + \sigma V_{w,t} \right]. \tag{1.33}$$

The shadow banker maximizes (1.33) by choosing $s_{w,t}$ subject to (1.30) and (1.32). We start by guessing that (1.33) is linear in assets $Q_t s_{w,t}$ and net worth $n_{w,t}$ which yields

$$V_{w,t} = \mu_{ws,t} Q_t s_{w,t} + \nu_{w,t} n_{w,t}, \tag{1.34}$$

where $\mu_{w,st}$ is the excess return of loans over interbank loans, and $\nu_{w,t}$ is the marginal value of net worth.

Defining the ratio of assets $Q_t s_{w,t}$ to net worth $n_{w,t}$ as the leverage ratio of the shadow banker $\phi_{w,t}$, we can combine (1.34) and (1.32) to obtain:

$$\phi_{w,t} = \frac{Q_t s_{w,t}}{n_{w,t}} = \frac{\nu_{w,t} - \theta_t(1-\omega)}{\theta_t \omega - \mu_{w,st}}. \tag{1.35}$$

By combining the guess (1.34), the Bellman equation (1.33), the incentive constraint (1.32), the leverage ratio $\phi_{w,t}$ and the evolution of net worth (1.30) of the shadow banker, we get

$$V_{w,t} = E_t \varOmega_{w,t+1} \left[(R_{wk,t+1} - R_{b,t+1}) Q_t s_{w,t} + R_{b,t+1} n_{w,t} \right], \tag{1.36}$$

where stochastic discount factor $\varOmega_{wt+1}$ is given by

$$\varOmega_{w,t+1} = \varLambda_{t,t+1} \left[1 - \sigma + \sigma \theta_{t+1} [\omega \phi_{w,t+1} + (1-\omega)] \right].$$

To verify the initial guess, the coefficients of (1.34) have to satisfy

$$\mu_{ws,t} = E_t \varOmega_{w,t+1} (R_{wk,t+1} - R_{b,t+1}) \tag{1.37a}$$

$$\nu_{w,t} = E_t \varOmega_{w,t+1} R_{b,t+1}. \tag{1.37b}$$

1.2.6 Resource constraint and central bank policies

The aggregate resource constraint is given by

$$Y_t = C_t + \left[1 + f_i \left(\frac{I_\tau}{I_{\tau-1}} \right) \right] I_t + \frac{\iota}{2} (S_{r,t})^2 + \varGamma_t, \tag{1.38}$$

where $\varGamma_t$ shows the resource costs of central bank intermediation. Since the central bank can perfectly commit to repay its debt to its creditors, it is able to intermediate funds without being balance-sheet constrained like banks. However, unconventional policies come at costs $\varGamma_t$. Without these costs, it would be beneficial for the central bank to always engage in credit markets. Instead, resource costs impose a burden on central bank intermediation and restrict it solely to intervention during crises. We assume that these costs arise due to the high administrative effort when intervening in the markets caused by, among others, the central bank's limited information about favorable investment projects and its less efficient monitoring technology (see e.g. Gertler and Karadi 2011). Thus, during normal times, unconventional policy leads to an inefficient public engagement in private financial markets since the costs of engagement are higher compared to retail banks. We follow Gertler et al. (2012) and Dedola et al. (2013) by assuming an increasing resource cost function:[3]

$$\varGamma_t = \tau_1 \left(\varPsi_{S,t} Q_t S_t + M_t + \varPsi_{B,t} B_t \right) + \tau_2 \left(\varPsi_{S,t} Q_t S_t \right)^2 + \tau_2 \left(M_t \right)^2 + \tau_2 \left(\varPsi_{B,t} B_t \right)^2. \tag{1.39}$$

[3] A convex function seems plausible for us. We try to incorporate different aspects of a higher central bank intermediation such as e.g. higher management and exit costs and potential risks of default of these intermediated assets.

Conventional monetary policy is characterized by a standard Taylor rule

$$i_t = \rho i_{t-1} + (1-\rho)\left[i + \kappa_\pi \pi_t + \kappa_y(\log Y_t - \log Y)\right], \tag{1.40}$$

where i_t denotes the nominal interest rate, i the steady-state nominal interest rate and Y the steady-state level of output. The Fisher equation interrelates the nominal interest rate i_t to the real rate according to

$$i_t = R_{t+1} E_t \pi_{t+1}. \tag{1.41}$$

However, when letting the shocks hit the economy it will become obvious that during times of stress conventional monetary policy alone appears to be an inappropriate tool for stabilization. Both output and inflation experience severe drops and show high volatility. Accordingly, we assume that the central bank is allowed to conduct unconventional monetary policies to stabilize the economy. Our understanding of unconventional measures closely follows Gertler and Karadi (2011), Gertler and Kiyotaki (2011), Gertler et al. (2012), Dedola et al. (2013), Gertler and Karadi (2013) and Nuguer (2016). There, the central bank conducts unconventional measures whenever the economy is hit by a shock that puts downward pressure on the price of capital Q_t, inducing an increase in the return of capital and a rise in credit spreads. As such, a crisis situation is an event when credit spreads rise sharply above their steady-state values. To alleviate such downturns the central bank intervenes in credit markets and begins to take over a fraction of financial assets (loans) based on simple feedback rules. Since central banks like the ECB or the Fed have a range of different unconventional measures and intervene in different markets we implement a set of different feedback rules available to the monetary authority. Especially, we assume that the central bank can *(a),* directly intervene in the market for non-financial loans *(b),* intervene in the funding market between retail and shadow banks, or *(c),* provide loans directly to retail banks.

Direct intervention in the market for non-financial loans requires the central bank to directly purchase loans from non-financial firms which is comparable to recent attempts of the ECB to intervene in the sector for corporate bonds. The feedback rule takes the form

$$\Psi_{S,t} = \kappa_S[E_t(R_{rk,t+1} - R_{t+1}) - (R_{rk} - R)] \tag{1.42}$$

The central bank intermediates the fraction ψ_t^S of overall non-financial loans in response to movements in the difference between the spread on the return on non-financial loans and the risk-free rate, $R_{rk,t+1} - R_{t+1}$, and its steady-state value $R_{rk} - R$. The feedback parameter κ_S governs the strength of intervention. Through conducting this policy, the central banks aims at stabilizing the asset price Q and lowering credit spreads. As a result, output and inflation should return to their steady-state values at a faster pace.

If the central bank engages in the funding market between retail and shadow banks, i.e. the market for interbank debt, it purchases interbank loans from retail banks. The feedback rule now responds to changes in the spread between the return on interbank loans and the risk-free rate, $R_{b,t+1} - R_{t+1}$, and its steady-state value $R_b - R$ and gets

$$\Psi_{B,t} = \kappa_B[E_t(R_{b,t+1} - R_{t+1}) - (R_b - R)], \tag{1.43}$$

where ψ_t^B is now the fraction of overall interbank debt B_t that is funded by the central bank. κ_B is the feedback parameter for this kind of intervention. The aim of this policy is to stabilize the drop in credit between intermediaries through acquiring a share of these credits.

As a third policy option and in line with Dedola et al. (2013), we implement a form of liquidity facility where the central bank provides loans directly to retail banks, following the feedback rule

$$\Psi_{M,t} = \kappa_M[E_t(R_{rk,t+1} - R_{t+1}) - (R_{rk} - R)], \tag{1.44}$$

where

$$\Psi_{M,t} = \frac{M_t}{Q_t S_t}$$

is the ratio of aggregate liquidity facilities to non-financial loans. Conducting this kind of policy implies that the central bank places loans directly on the balance sheet of retail banks and thereby mitigates potential losses that result from devaluations of the asset side. The main difference between the last two mentioned policies is their transmission mechanism. Whereas liquidity facilities are an additional source of funding and strengthen the balance sheet of retail banks and, accordingly, their overall lending activities, interventions in the funding market between intermediaries rather incentivize the retail bank to off-load interbank loans in order to protect the balance sheet from devaluations.

Resource costs and expenditures due to intervention policies are financed by lump sum taxes T_t and one-period riskless government bonds ($B_{g,t} = \Psi_{S,t} Q_t S_t + M_t + \Psi_{B,t} B_t$) that are issued to households. The government pays the risk-free rate R_t for these bonds. We get the following budget constraint

$$\Gamma_t = T_t + (R_{g,t} - R_t) M_{t-1} + (R_{b,t} - R_t)\, \Psi_{B,t-1} B_{t-1} + (R_{rk,t} - R_t)\, \Psi_{S,t-1} Q_{t-1} S_{t-1}. \tag{1.45}$$

We implement three sources of disturbances into the model, among them a shock to the quality of capital ψ_t, and shocks to the diversion parameters θ_t and γ_t. The latter two shocks are specific to the financial sector and are supposed to replicate a change of financial constraints. GKP use variations in these parameters to model changes in the size of the shadow banking sector. Thereby, they highlight the emergence of financial innovation that led to an increased availability of credit. In addition, MNA model such shocks to illustrate a breakdown of securitization activity, i.e. a collapse of the shadow banking sector.

1.2.7 Aggregation and equilibrium

Aggregate net worth is given by the sum of the net worth of existing (surviving) bankers who retain net worth according to (1.20) and net worth of the fraction of new, entering bankers. The latter receive startup funds $\xi_r [R_{rk,t} (Q_{t-1} + \iota S_{r,t-1}) S_{r,t-1} + R_{b,t} B_{r,t-1}]/(1-\sigma)$ from their respective household. Accordingly, we express aggregate net worth as

$$\begin{aligned} N_{r,t} &= \left[\sigma \left(R_{rk,t} - R_t - (R_{rk,t} - R_{b,t}) b^*_{r,t-1}\right) + \xi_r \left(R_{rk,t} - (R_{rk,t} - R_{b,t}) b^*_{r,t-1}\right)\right] A_{t-1} \\ &\quad + \sigma R_t N_{r,t-1} - \sigma (R_{g,t} - R_t) M_{t-1}, \end{aligned} \tag{1.46}$$

where the ratio of interbank loans to total assets $A_t = (Q_t + \iota S_{r,t}) S_{r,t} + B_{r,t}$ is given by $b^*_{r,t} = B_{r,t}/A_t$. Aggregate net worth of the shadow banking sector evolves according to

$$N_{w,t} = [\sigma (R_{wk,t} - R_{b,t}) + \xi_w R_{wk,t}] Q_{t-1} S_{w,t-1} + \sigma R_{b,t} N_{w,t-1}, \tag{1.47}$$

where new bankers receive startup funds $\xi_w R_{wk,t} Q_{t-1} S_{w,t-1}/(1-\sigma)$.

The model is closed with the market clearing conditions for non-financial loans and for interbank debt. The non-financial loan markets clear when total loan demand from non-financial firms equals total supply of loans from retail banks and shadow banks, following the equation

$$(1 - \Psi_{S,t}) S_t = S_{r,t} + S_{w,t}, \tag{1.48}$$

where $\Psi_{S,t} S_t$ is the fraction of non-financial loans intermediated by the central bank in case of intervention by the same. The market for interbank debt clears when total demand from shadow banks equals total supply from retail banks

$$(1 - \Psi_{B,t}) B_{w,t} = B_{r,t}, \tag{1.49}$$

where $\Psi_{B,t} B_{w,t}$ describes the intervention by the central bank in the interbank market.

1.3 Model Analysis

1.3.1 Calibration and welfare measure

Table 1.1 lists the values for our parameters that we use when simulating the model. The time interval of the model is a quarter. The conventional parameter choices for households (e.g. discount factor of $\beta = 0.99$ which implies a steady-state risk-free rate of roughly 4.1% per annum, habit parameter of $h = 0.815$, utility weight of labor of $\chi = 2.585$ to ensure $L = 1/3$, inverse Frisch elasticity of labor supply $\varphi = 0.276$), intermediate goods firms, capital producers and retailers are standard values and in accordance with, e.g., Gertler and Karadi (2011).

Households		
β	0.99	Discount factor
h	0.815	Habit parameter
χ	2.585	Relative utility weight of labor
φ	0.276	Inverse Frisch elasticity of labor supply
Intermediate goods producers		
α	0.33	Capital share in production
δ	0.025	Depreciation rate
Capital producers		
η_i	1.728	Elasticity of investment
Retailers		
ε	4.167	Elasticity of substitution between goods
ζ	0.779	Calvo parameter
ζ_P	0.241	Measure of price indexation
Financial intermediaries		
σ	0.90	Survival probability
ι	0.0003	Management cost
θ	0.2443	Divertable fraction of assets
γ	0.50	Relative divertibility of retail banks' interbank loans
ω	0.5935	Relative divertibility of shadow banks' interbank loans
ξ_r	0.0153	Proportional startup transfer to new retail bankers
ξ_w	0.0089	Proportional startup transfer to new shadow bankers
Conventional monetary policy		
ρ	0	Smoothing parameter
κ_π	1.5	Weight of inflation in Taylor rule
κ_y	0.5/4	Weight of output gap in Taylor rule

Table 1.1: Parametrization

The remaining parameters describe the setup of the financial sector and the central bank. Here, we chose parameter values similar to MNA in order to reproduce the following values for the steady-state. The surviving rates of retail and shadow bankers σ generate a dividend payout rate of 10%. The annual spread between non-financial loans and deposits, $R_{rk} - R$, as well as the relevant spread for shadow bankers, $R_{wk} - R_b$, are set to 100 basis points. Regarding the annual spread between the interbank loan rate and the deposit rate, MNA point out that comparable ABS spreads lie within a relevant range of 0-70 basis point. Thus, $R_b - R$ is chosen to equal 50 basis points. Following MNA, the leverage ratios are set to $(S_r + B)/N_r = 5.2$ and $\phi_w = 8$ in order to replicate the extraordinary high degree of leverage within the shadow banking sector. However, a ratio of 8 is a rather conservative value for entities in the shadow banking system (see MNA and GKP). Furthermore, in our benchmark scenario, we target a size of the shadow banking sector to 25%, i.e.

Scenario	Y	C	L	K	S_r	N_r	B	S_w	N_w
no S-banks	0.820	0.688	0.332	5.125	5.125	1.050	0	0	0
25% S-banks	0.835	0.698	0.333	5.392	4.044	1.006	1.180	1.348	0.169
45% S-banks	0.854	0.709	0.335	5.708	3.145	0.982	2.266	2.563	0.298

Table 1.2: Steady states of selected variables in the three scenarios

$S_w/K = 0.25$. This entails a ratio of interbank loans to non-financial loans (B/S_r) of 0.3 and the ratio of retail bank non-financial loans to net worth (S_r/N_r) of 4, which is roughly identical to the median ratio of commercial banks' loans to the sum of Tier 1 and 2 capital as fixed in the Basel regulation (MNA). In our benchmark calibration, we follow Dedola et al. (2013) and set the resource costs of government intermediation to $\tau_1 = 0.00001$ and $\tau_2 = 0.0001$. In accordance with, for instance, Gertler and Karadi (2011), Gertler et al. (2012) and Nuguer (2016), the credit policy rule parameter κ_S is set to 100, describing an "aggressive" credit policy. To guarantee comparability among policies, the parameters for interbank policies and liquidity facilities, κ_B, and κ_M respectively, are set such that the amount of government purchases relative to output, $B_{g,t}/Y_t$ is the same on impact. For the liquidity provision, we choose $\lambda = \gamma$ which leads to $R_g - R = R_b - R$ and allows for comparability between interbank loans and liquidity facilities. The three shocks $(\psi_t, \theta_t, \gamma_t)$ follow AR(1) processes with autoregressive factors of $(0.66, 0.8, 0.8)$ and the disturbances are a 1% decline in ψ_t, a 10% increase in θ_t and a 20% increase in γ_t.[4] These magnitudes guarantee roughly comparable welfare losses. To account for the effect of variations in the size of the shadow banking sector, we run all three shocks in different versions of our model. We capture alterations in the size of shadow banking through the interbank agency friction parameter ω (see (1.32). A lower (higher) ω increases (decreases) the attractiveness of interbank borrowing which leads to more (less) credit intermediation by shadow banks. The no S-banks scenario ($\omega = 0.6932$) is a reduced setup similar to Gertler and Karadi (2011), where only one single financial intermediary, the retail bank, is active. The 25% S-banks scenario (benchmark case) matches the size of euro area shadow intermediation while the 45% S-banks scenario ($\omega = 0.5$) leads to an allocation that is rather comparable to findings for the US financial sector.

Table 1.2 summarizes the results for selected variables. Relaxing the shadow banks' incentive constraint let them operate with higher leverage ratios while retail banks also relax their incentive constraint by increasing interbank lending (see (1.22)). Since shadow banks have a cost advantage over retail banks (see (1.10)), a higher shadow banking sector leads to a more efficient financial intermediation and thus a more efficient steady state.

Welfare evaluations are conducted by using the second-order approximation ap-

[4]The first two autoregressive factors are in line with Dedola et al. (2013) while the third is chosen for the sake of comparability.

proach of Schmitt-Grohé and Uribe (2004, 2007). To be more precise, we calculate the unconditional expected value of lifetime utility $E(\Phi_t)$ of the representative household, where the welfare criterion (see Faia and Monacelli, 2007) is measured by

$$\Phi_t = U(C_t - hC_{t-1}, L_t) + \beta E_t \Phi_{t+1}, \tag{1.50}$$

by taking a second-order approximation of the model and (1.50) about the steady state for each shock.[5] Welfare gains from unconventional policy interventions are determined as consumption equivalents υ that make the representative household indifferent between the conventional policy (simple Taylor rule) case and the unconventional policy cases. Let $E(\Phi_t^*)$ be the welfare level that follows from an intervention policy. Then, υ satisfy

$$E \sum_{\tau=t}^{\infty} \beta^{\tau-t} U((1+\upsilon)(C_\tau - hC_{\tau-1}), L_\tau) = E(\Phi_t^*), \tag{1.51}$$

meaning that the no policy intervention ($E(\Phi_t)$), i.e. only conventional policy is in place, with consumption equivalents must be equal to $E(\Phi_t^*)$. Given the utility function (1.1), υ can be obtained from

$$\upsilon = \exp\{(1-\beta)(E(\Phi_t^*) - E(\Phi_t))\} - 1. \tag{1.52}$$

1.3.2 Crises experiments

We now run crises experiments and analyze our model in the face of the three disturbances, a shock to the quality of capital ψ_t and two shocks specific to the financial sector that affect the financial constraints of intermediaries, namely θ_t and γ_t. To obtain the pure dynamics of the model, we turn off any unconventional policy measures. In section 1.3.3, we work out the transmission mechanisms and effects of different unconventional monetary policy measures.

Let us begin by analyzing the dynamics of a shock to the quality of capital. Figure 1.1 shows the impulse responses.[6]

The order of events in the no S-banks scenario is analogous to the crisis experiment of Gertler and Karadi (2011): the sudden and unexpected decline in the quality of already installed capital drives down asset values which deteriorates retail banks'

[5] Leaving the steady-state distortions uncorrected seems more plausible to us, although this could lead to situations where shocks improve welfare (see also Galí and Monacelli, 2016). However, this is not the case in our analysis. Furthermore, we calculate welfare gains from policy interventions compared to a simple Taylor rule instead of using steady-state welfare as a benchmark. Using conditional welfare as the criterion leads to virtually unchanged results (available upon request).

[6] The impulse responses are computed as absolute deviations from the different steady states (see also Table 1.2). This approach guarantees better traceability of the results for the different scenarios.

net worth. Since banks are leverage-constrained, they start a fire sale of assets which depresses the price of capital Q_t. This induces an increase in credit spreads and a sharp cut in investment and output. As inflation drops, the central bank reacts with a reduction of the policy rate in order to stabilize inflation and output.

Increasing the size of shadow intermediation to 25% yields a more severe and persistent recession. While both intermediaries face a deterioration in net worth, the reduction in shadow banks' net worth is more severe since shadow banks' leverage multiple is higher than that of retail banks. The negative impact on the balance sheet of shadow banks is amplified by the fact that retail banks are now able to transfer losses into the shadow banking sector. The fire sale in the shadow banking sector induces retail banks to cut down interbank lending, $b^*_{r,t}$ decreases. Simultaneously, retail bankers are able to increase lending to non-financial firms since a higher $S_{r,t}$ increases their franchise value and relaxes their incentive constraint. As a result, their net worth recovers faster. However, they are less efficient in providing loans to non-financial firms and the increase in $S_{r,t}$ cannot compensate the reduction of $S_{w,t}$. The drop in overall intermediated credit is stronger and Q_t contracts more which leads to higher credit spreads as well as stronger and more protracted declines in investment and output. The effect on inflation is ambiguous: the initial drop is larger while π_t is more stable in the aftermath. An even higher credit intermediation via shadow banks (45% S-banks) puts more pronounced downward pressure on financial activity and amplifies the described effects.

Let our focus now turn to the shocks θ_t and γ_t within the financial sector that affect the agency problems of the intermediaries. While the former is a general loss of confidence in the banking system, the latter is an interbank shock and can be interpreted as a securitization crisis. Although our model does not directly account for the process of securitization, it replicates the core mechanisms of shadow banking. Accordingly, a γ_t-shock changes the collateral value of shadow bank loans held by retail banks. The impulse responses of the shocks are shown in the Figures 1.2 and 1.3.

Starting with the no S-banks scenario, the loss of confidence (θ_t-shock) affects the incentive constraint of retail bankers, the collateral value of assets shrinks. They start a deleveraging process by reducing loans and deposits to meet the leverage constraint. This drives down the asset price Q_t, credit spreads rise, investment and thus output decline. As output and inflation drop, the central bank lowers the policy rate in order to stabilize both targets.

In the economy with 25% shadow intermediation, both intermediaries face a reduction of the collateral value of their assets. Both start a deleveraging process which drives down the price of capital. However, since retail banks are aware of the incentive of shadow banks to divert assets, they reduce interbank lending which depresses the reduction in $S_{w,t}$ still further. Simultaneously, they expand their amount of non-financial loans which rises their franchise value and relaxes their incentive constraint. Again, the existence of shadow banks allows retail banks to transfer a share of the losses off their balance sheet into the shadow banking sector. However, the drop in overall credit is stronger, credit spreads are higher and output losses are larger and more persistent. Similar to the capital quality shock, we obtain an ambiguous effect on inflation. As in the experiment before, increasing the size of shadow banking to 45% of intermediated credit yields comparable dynamics of the core variables though showing larger and more prolonged swings.

Suppose now a decline in the collateral value of shadow bank loans held by retail banks in the 25% S-banks scenario. The effects of this rise in γ_t are similar to the θ_t-shock. Retail banks are forced to restructure their balance sheet by reducing lending to shadow banks while increasing the amount of non-financial loans. Since shadow banks are dependent on funds from retail banks, they have to deleverage and scale down their lending activity to the non-financial sector, $S_{w,t}$ shrinks and so does $N_{w,t}$. In the aggregate, overall intermediated credit and Q_t drop, credit spreads rise whereas investment, output and inflation fall. In the 45% S-banks scenario, retail banks hold a greater amount of interbank loans. As the agency friction worsens, retail banks reduce lending to shadow banks more strongly, $b^*_{r,t}$ drops more. This amplifies the described effects which leads to larger and more protracted swings in the core variables.

The main results are summarized in

Proposition 1.1 *Turn off any unconventional policy. a) Suppose a negative shock to the quality of capital. The higher the credit intermediation via shadow banks, the stronger the decline in the price of capital, the higher the rise in credit spreads and the more severe and prolonged the drop in overall credit and output. The effect on inflation is ambiguous. b) The same holds true in the case of a loss of confidence in the banking system. c) Suppose a negative interbank shock. The higher the credit intermediation via shadow banks, the stronger the decline in the price of capital, the higher the rise in credit spreads and the more severe and prolonged the drop in overall credit, output and inflation.*

1.3.3 Implications of unconventional monetary policy

As the former section showed, following the described shocks, a simple Taylor rule is not able to stabilize the business cycle. This raises the question of whether an optimal conventional policy would be more effective in stabilizing the economy or is there a need for unconventional policy interventions. To answer this, we run the model with an optimized Taylor rule and compare the welfare gains measured by (1.52) with the gains by following the simple unconventional feedback rules (1.42), (1.43) and (1.44) outlined in section 1.2.6. We allow for interest rate smoothing and solve for the welfare-maximizing parameters by applying grid search as in Bergin et al. (2007).[7] Table 1.3 shows the welfare gains of the policies compared to the

[7] We arranged the following grid: the interest rate smoothing parameter ranged from 0 to 1 with a step size of 0.05 while the parameters for inflation and output vary between 0 and 5 with a step

simple Taylor rule case. A simple and shock-invariant policy of direct intervention in the market for non-financial loans (S-Policy) outweighs a Taylor rule that is optimized for every single shock. In the case of an interbank shock, the optimal conventional policy fails compared to the simple unconventional policies. For shocks in ψ_t and θ_t, the optimal Taylor rule outperforms simple liquidity facilities (M-Policy) and partially simple interbank credit policy (B-Policy). However, these benefits diminish or are completely offset as the shadow banking sector grows. To sum up, unconventional policies can lead to significant welfare improvements.

Again, we begin by analyzing the dynamics of a shock to the quality of capital. Figure 1.4 shows the impulse responses. The most striking result is that direct asset purchases (S-Policy) are the superior policy option given the chosen parameter values for the resource costs (τ_1, τ_2) and feedback parameters ($\kappa_S, \kappa_B, \kappa_M$) of central bank intervention. The superiority of direct asset purchases stems from the point of intervention of that policy. By starting to purchase non-financial loans (financial assets), i.e. acquire a share of overall intermediated credit, the central bank is able to directly impact on the asset price Q_t. Since the considered capital quality shock induces a drop in Q_t, direct purchases intervene at the very source of economic disturbances. In contrast, interbank interventions (B-Policy) and liquidity facilities (M-Policy) mainly operate through the impact on the balance sheet of retail banks and change their financing conditions. We will elaborate on their stabilization effects and transmission mechanism later on. The S-Policy lowers the drop in Q_t what in turn stabilizes credit spreads and moderates the downturn in the shadow banking sector, intermediation by shadow banks decreases but less compared to the other scenarios. The resulting effect on investment and output is cushioned, both drop less. Note that direct purchases of assets lead to a side effect. Since non-financial credit intermediated by the central bank amounts to roughly 5% on impact and tapers off very slowly over time, retail banks experience a crowding out of their lending activity to non-financial firms, $S_{r,t}$ drops. The lower intermediation by retail banks is amplified by the effect of lower credit spreads on their evolution of net worth $N_{r,t}$. Since the rebuilding of net worth takes longer, the incentive constraint of retail banker tightens for several periods and forces them to intermediate lower amounts of $S_{r,t}$.

Liquidity facilities (M-Policy) and interbank interventions (B-Policy) show less efficiency in stabilizing the economy compared to the S-Policy scenario. The initial drop in Q_t is only halved while credit spreads widen more. Accordingly, the decline in output is less moderated. Regarding the balance sheet items (except for $b^*_{r,t}$), both policies deliver comparable initial effects. This results from the assumption of $\lambda = \gamma$. By combining (1.25a) and (1.25b), we find that $R_g - R = R_b - R$, making both options equally effective for relaxations of retail bankers' incentive constraint. Initially, the banker is indifferent between holding another unit of liquidity facility m_t and paying the excess cost $R_{g,t} - R_t$ or, alternatively, reducing interbank funding

size of 0.125.

Policy	25% S-banks ψ_t	θ_t	γ_t	45% S-banks ψ_t	θ_t	γ_t
Optimal Taylor rule	0.905	0.437	0.121	1.144	0.592	0.255
Simple S-Policy	1.150	1.737	1.536	1.783	2.495	2.712
Simple B-Policy	0.644	0.559	0.845	1.077	1.116	1.466
Simple M-Policy	0.448	0.248	0.770	0.856	0.788	1.335

Table 1.3: Welfare gains of different policies compared to a simple Taylor rule in percentage terms

$b_{r,t}$ by one unit and giving up the excess return $R_{b,t} - R_t$. The first-round effect is the same: retail bankers increase $S_{r,t}$ in order to raise the franchise value. However, the slightly different transmission channels lead to diverging output effects.

Due to their binding incentive constraint, shadow banks cannot use the interbank lending policy to expand their balance sheet. They primarily benefit from a more stable Q_t. Since retail banks can only use these additional funds to drive down $b^*_{r,t}$ which is now intermediated by the central bank, $\Psi_{B,t}$ massively increases. Although $S_{r,t}$ initially increases, it drops in the aftermath. The decline in overall credit is longer lasting which explains the output response. The drop is initially moderated, and the maximum decline hits the economy at a later date. Thus, the recession is postponed. Concerning the welfare gains of this policy (see Table 1.3), they are mainly driven by lower labor supply (not shown). In contrast, liquidity facilities are an additional source of funding for retail banks, they stabilize the balance sheet and mitigate the cut-off from interbank loans. Retail banks increase $S_{r,t,}$ and due to the higher credit spreads their net worth recovers faster. Shadow banks benefit from the more stable Q_t and $b^*_{r,t}$. Compared to the conventional policy case, the drop in overall intermediated credit as well as output are lower.

In the first instance, it seems that the M-Policy delivers the lowest stabilization effects. However, since the findings for liquidity facilities are sensitive to the parametrization of λ, we now run two alternative scenarios which are shown in Figure 1.5. By increasing λ to $\lambda = 0.8$, every additional unit of liquidity provision induces a stronger relaxation of the incentive constraint. Initially, the retail banker increases $S_{r,t}$ and reduces his position of $b^*_{r,t}$ in order to increase $V_{r,t}$. However, the effect of λ on the incentive constraint makes this restructuring now less urgent and the retail banker simultaneously starts to drive down the holdings of $S_{r,t}$ and begins to rebuild $b^*_{r,t}$ faster. This effect moderates the fire sale of assets in the shadow banking sector, benefiting shadow banks by rebuilding $S_{w,t}$ at a faster pace. Overall credit is higher, Q_t is more protected and the recovery of output is faster while showing less volatility. If we lower λ, e.g. $\lambda = 0.2$, the formerly explained relaxation of the incentive constraint diminishes and so does the stabilizing impact of liquidity provision on the balance sheet of retail bankers. The effect on output is straightforward: the drop is stronger and more protracted.

Let us now turn our focus on the shocks θ_t and γ_t. Since both shocks affect the incentive constraint of retail banks in a very similar vein, the ensuing reactions of intermediaries as well as the effects of unconventional policy measures are equivalent. The impulse responses are shown in Figure 1.6 and Figure 1.7.

Similar to the capital quality shock, direct asset purchases (S-Policy) are the superior policy option as they deliver the highest degree of stabilization. However, retail bankers, normally substituting $b_{r,t}$ with $S_{r,t}$ to relax the incentive constraint, are again faced with the aforementioned crowding out effect which implies a long-lasting credit intermediation by the central bank. Again, the interbank lending policy drives down $b^*_{r,t}$ while $\Psi_{B,t}$ massively increases. The initial drop in overall credit is moderated, whereas the decline is prolonged which results in a postponed output response. While inflation is benign, the welfare gain comes from lower labor supply.

In contrast, the different transmission channel of liquidity facilities is obvious. As an additional source of funding, they stabilize the balance sheet of retail banks, the reduction in $b^*_{r,t}$ is less severe. Shadow banks benefit from the more stable Q_t and $b^*_{r,t}$. The drop in output is lower, but still stronger than in the S-Policy case. As before, we find that variations in λ induce changes to the efficiency of liquidity facilities. The higher the value for λ, the higher the stabilizing effect for the balance sheet of retail banks. They rebuild $b^*_{r,t}$ faster, helping shadow banks to rebuild $S_{w,t}$ faster. Both output and inflation decrease less and show more stable recoveries.

We can summarize

Proposition 1.2 *Suppose negative shocks to the quality of capital, the confidence in the banking system or the collateral value of interbank assets. a) All three unconventional policy measures outperform the standard Taylor rule. b) In terms of output and inflation stabilization, direct asset purchases outperform liquidity facilities, while liquidity facilities outperform interbank interventions. The effectiveness of direct asset purchases stems from the fact that the decline in the price of capital can be almost offset, credit spreads are the lowest, the drop in output is less severe and inflation is substantially stabilized. c) Purchases of interbank loans have an on-impact stabilizing effect. However, they lead to postponed declines in overall credit and output. d) The effectiveness of liquidity facilities is sensitive to λ. The higher λ, the stronger the stabilization effect on the price of capital, credit spreads, output and inflation.*

Next, we consider variations in the size of the shadow banking sector. Table 1.4 shows standard deviations of core variables under all three unconventional policies relative to the standard deviations in the conventional policy case. For instance, a value of 0.886 means that the S-Policy leads to a standard deviation of output that is 11% lower than under the conventional monetary policy.

The most striking result is that the output-stabilization effect of all unconventional policies is increasing in the share of credit intermediation by shadow banks.

	5% S-banks			25% S-banks			45% S-banks		
	S-Pol	B-Pol	M-Pol	S-Pol	B-Pol	M-Pol	S-Pol	B-Pol	M-Pol
				ψ_t-shock					
Y	0.886	1.093	0.981	0.831	1.008	0.934	0.785	0.953	0.901
π	0.728	0.976	0.954	0.740	1.022	0.975	0.688	1.041	0.966
K	0.944	1.049	0.992	0.894	0.995	0.957	0.857	0.958	0.931
Q	0.299	0.637	0.667	0.317	0.649	0.673	0.322	0.657	0.673
				θ_t-shock					
Y	0.558	1.012	0.801	0.483	0.861	0.730	0.412	0.770	0.686
π	0.467	1.223	0.925	0.521	1.308	0.974	0.471	1.186	0.911
K	0.756	1.001	0.756	0.484	0.721	0.658	0.405	0.656	0.630
Q	0.061	0.534	0.559	0.067	0.541	0.559	0.072	0.548	0.559
				γ_t-shock					
Y	0.724	0.940	0.845	0.455	0.832	0.715	0.308	0.734	0.641
π	0.526	1.131	0.933	0.504	1.255	0.958	0.415	1.187	0.905
K	0.799	0.930	0.858	0.454	0.702	0.643	0.278	0.577	0.550
Q	0.063	0.524	0.558	0.062	0.536	0.556	0.058	0.541	0.553

Table 1.4: Standard deviation of selected variables relative to the standard deviation in the conventional policy case

As shown in the previous sections, a higher shadow banking sector leads to more efficient but also more vulnerable financial intermediation due to the stronger financial accelerator effect of the binding leverage constraints. Hence, policies aimed at and able to stabilize this intermediation process are more effective the higher the credit intermediation via shadow banks. In terms of output and inflation stabilization, direct asset purchases are the most effective measure while liquidity facilities outperform interbank interventions. Again, it can be seen that the S-Policy primarily works through stabilizing Q_t. However, for shocks in ψ_t and θ_t, it seems that the B-Policy is only useful when we pass a certain threshold of shadow banking sector size. Below that threshold, interbank interventions lead to more output volatility. Furthermore, it seems that the B-Policy leads to generally higher inflation volatility independent of the size of the shadow banking sector.

Proposition 1.3 *Suppose negative shocks to the quality of capital, the confidence in the banking system or the collateral value of interbank assets. a) The higher the credit intermediation via shadow banks, the more effective are the three unconventional policy measures in terms of output stabilization. The effect on inflation is ambiguous. b) The usefulness of interbank interventions is sensitive to the kind of shock and the size of the shadow banking sector.*

1.3.4 Optimal policy and welfare implications

In this subsection, we compute the optimal policy responses and calculate the maximum welfare gains from unconventional policies depending on different resource costs parametrizations. Since we cannot rely on actual data for the efficiency costs parametrization (τ_1, τ_2), we follow Dedola et al. (2013) and Gertler et al. (2012) and choose reasonable values of purchasing high grade securities (e.g. mortgage backed securities). Thus, we conduct our analysis of the welfare effects for a range of values for τ_2 from 0 to 0.0012 while $\tau_1 = 0.1\tau_2$.

In order to calculate welfare, we take a second-order approximation of the model and (1.50) about the steady state for each shock given the feedback parameter of each unconventional policy rule. Then, we search for the optimal values of $\kappa_S, \kappa_B, \kappa_M$ that maximize $E(\Phi_t)$. Finally, we determine the welfare benefits of unconventional policy in the form of consumption equivalents υ (see (1.52)). Figure 1.8 shows the welfare gains under each policy for different scenarios and different values of τ_2.

Let us start with some general results.[8] Independently of the kind of shock, the relative efficiency of direct asset purchases compared to the other policies is increasing in the resource costs of implementing unconventional policies. Comparing the panels of the top three rows, we can conclude that the higher λ, the higher are the welfare gains of liquidity facilities. The panels in the top and bottom rows show that the advantage of the S-Policy and M-Policy compared to the interbank intervention increases as the size of the shadow banking sector grows.

Focusing on the ψ_t-shock, we see that, except for small values of τ_2 and a high value of λ, direct purchases of non-financial loans are the superior unconventional policy. For low resource costs, it seems that interbank-loan purchases have an advantage over the other policies. However, this advantage vanishes as λ or credit intermediation via shadow banks increases. Here, liquidity facilities almost completely outperform interbank interventions.

As regards a shock in θ_t, irrespective of shadow banking sector size and resource costs parametrization, the S-Policy outperforms the M-Policy while liquidity facilities outperform the B-Policy. In the case of a higher λ, liquidity facilities could be more welfare-improving than direct purchases of non-financial loans.

In the case of a γ_t-shock, interbank interventions outperform liquidity facilities except for higher τ_2, while the M-Policy outperforms the S-Policy. However, the advantage of the B-Policy over liquidity facilities diminishes as λ increases while it is completely offset when the size of the shadow banking sector is larger. Here, the M-Policy is superior, whereas direct non-financial asset purchases are the second-best option.

To sum up, there is no one-size-fits-all solution. Furthermore, all unconventional policies are implemented under equal resource costs. As this is a completely unsolved

[8] Note that the advantage of a policy in the case of zero resource cost is pointless and can be ignored.

	Determ.	Conv. Policy Mean	Conv. Policy SD	S-Policy Mean	S-Policy SD	B-Policy Mean	B-Policy SD	M-Policy Mean	M-Policy SD
					ψ_t-shock				
C	0.698	0.684	0.048	0.693	0.042	0.694	0.051	0.695	0.038
L	0.333	0.331	0.019	0.332	0.013	0.333	0.005	0.334	0.021
					θ_t-shock				
C	0.698	0.683	0.014	0.700	0.004	0.697	0.018	0.699	0.002
L	0.333	0.332	0.020	0.334	0.004	0.334	0.016	0.334	0.001
					γ_t-shock				
C	0.698	0.684	0.003	0.697	0.001	0.698	0.007	0.697	< 0.001
L	0.333	0.332	0.004	0.333	0.001	0.333	0.004	0.333	< 0.001

Table 1.5: Deterministic and stochastic steady states under different policies in the benchmark calibration

empirical issue, we could relax this assumption and suggest that the S-Policy might lead to the highest resource costs due to the difficulty of managing non-financial loans by the central bank. As described above, mutual interbank lending largely destroys idiosyncratic risks of non-financial loans, thereby being a safer asset and more pledgeable. Thus, the resource costs of managing these assets should be at least lower than in the S-Policy case. However, the financial crisis has shown that this may not always be the case. Regarding the M-Policy, Gertler and Kiyotaki (2011) stress that there might be capacity constraints on the ability of the central bank to monitor the retail banks' activities. However, we can suggest that the resource cost would be relatively low due to the possibility to use the penalty rate $R_{g,t}$ (via λ) as "control tool". Under these suggestions, it seems that liquidity provisions might be the superior solution as a higher penalty rate combined with low resource costs make it the most effective policy option.[9]

If we consider the circumstances for the Fed and ECB, we could assume that the resource costs of unconventional policies are higher for the ECB since the currency union is more heterogenous than the US. Thus, for the Fed which means 45% S-banks and low τ_2, liquidity facilities are superior at least for shocks in ψ_t and γ_t, but also in the case of a loss of confidence in the banking system by increasing $R_{g,t}$ (via λ).[10] Direct asset purchases seem to be also highly appropriate. For the ECB which means 25% S-banks and higher values of τ_2, we get the same result: liquidity facilities with a high penalty rate are the first-best solution.

Nevertheless at first glance, it seems that, at least in the benchmark case, the

[9] See the second and bottom rows in Figure 1.8.

[10] For the Fed case, see the bottom row in Figure 1.8. By increasing λ, the M-Policy line would shift upward making it the superior policy. For the ECB case, see the panels in the second row. In the case of a γ_t-shock, a further increase in λ would make the M-Policy outperforming the B-Policy even for midsize values of τ_2.

B-Policy leads to the highest welfare gains in the case of a γ_t-shock and also for low resource costs in the ψ_t-shock scenario. How can this outcome, which is contradictory to our previous findings, be explained? Table 1.5 gives a first clue. It shows the means and standard deviations of consumption and labor for all policy scenarios in the benchmark calibration. The welfare gain of the interbank lending policy mainly stems from the first-order effect of a shift in the means due to uncertainty. Concerning the second-order welfare component, the B-Policy leads to an even higher consumption variance. However, given our utility function (1.1) which is logarithmic in consumption, the higher variance does not affect welfare in a second-order approximation. Adapting the utility function, i.e. the intertemporal elasticity of substitution differs from unity, would lead to an overwhelming advantage of the S-Policy as well as M-Policy. In addition, the alleged large welfare improvements of the B-Policy are also driven by the calculation of welfare gains as an indefinite flow. For this policy, the main part is received decades after the crisis. This computation is also criticized by Gertler and Karadi (2011). As every shock leads to a crisis that should be treated as a single event, they propose to only cumulate the benefits of the moderation of the crisis and not the benefits for years after the crisis. On the contrary, calculating welfare in this manner is not consistent with the model as there is no microfoundation for using only a short-time period to calculate welfare gains. However, this measure would also favor direct asset purchases and liquidity facilities. Figure 1.9 illustrates this argument and points to another issue: the exit from unconventional monetary policy. The figure shows the ratio of central bank's expenditures due to unconventional policy relative to output for $\tau_2 = 0.0001$ and $\tau_2 = 0.001$ in the 25% and 45% S-banks scenarios. It can be seen that the B-Policy, which might be preferable for low values of τ_2 in the case of shocks in ψ_t and γ_t, leads to extreme prolonged positions. After ten years, the central bank is still engaged in the interbank loan market with expenditures in the amount of 40% and 10% of output. This is not a plausible crisis management. For a ψ_t-shock, the S-Policy leads to the lowest share of expenditures per GDP which tapers off more quickly compared to the other policies. However, for the financial sector shocks, this policy also results in permanent central bank intermediation. Here, liquidity facilities seem to be more appropriate. Although the central bank massively increases the amount of liquidity facilities in the crisis period, this intervention tapers off very quickly. Thus, for these shocks, not only being the most appropriate unconventional policy tool, liquidity provisions also imply an early exit, leading to the capability to fight the next crisis.

1.4 Conclusions

In this paper, we build a comprehensive DSGE-model featuring financial intermediation with shadow banking that enables use to evaluate different unconventional policy measures, their relative effectiveness and the optimal policy intervention. We endow the central bank with three different unconventional measures: direct purchases of assets, an intervention policy in the funding process between retail and shadow banks and liquidity facilities. We use these measures to analyze their effectiveness in stabilizing financial markets and the real economy. In a second step, we compute the optimal monetary policy responses to business cycle and financial sector shocks and calculate the maximum welfare gains from unconventional policies depending on different resource costs.

We can draw three major results from our analyses: first, regardless of the shock, unconventional policy measures stabilize the standard targets output and inflation and improve welfare. Hereby, direct asset purchases outperform liquidity provision, which outperform interbank interventions. Given the different points of intervention, this result is straightforward. If the central bank purchases assets and intervenes in the markets for these assets, it directly affects its price. As a consequence, credit spreads only deviate slightly, investment and output as well as inflation recover much faster. A higher shadow banking sector and the accompanied higher leverage induce a sharper recession but also makes unconventional monetary policy more effective. Second, the usefulness of interbank interventions is highly sensitive to the kind of shock and the size of the shadow banking sector. However, the central bank should be aware of the fact that this measure is only useful given certain circumstances and when the identification of the source of the shock is unproblematic. Third, our welfare analysis shows that liquidity provisions seem to be the most appropriate unconventional policy tool closely followed by direct asset purchases. However, that finding is conditional on several aspects, e.g. the financial structure of the economy, reasonable assumptions for the resource costs of interventions and a foreseeable exit. Resource costs may reflect the massive expansion of the balance sheet of the central bank and the accompanying problem of exiting from these positions, or the administrative efforts of intervention. However, comparing the structure of the markets the Fed and the ECB have to manage, it is obvious that these costs may differ between central banks and that there is no one-size-fits-all solution for optimal unconventional measures.

Although our analysis points to a tapering process that can be interpreted as an exit, we do not explicitly model an active exit from unconventional policies. Nevertheless, some questions are worth considering: what are the macroeconomic impacts of driving down large scale asset purchases, is there a mixture of conventional and unconventional policies to best deal with an exit, how could the Fed or the ECB downscale their balance sheet positions? To answer these questions, our analysis could be extended by explicitly modelling exit strategies in the sense of Foerster (2015).

The recent financial crisis has not only spawned changes in the framework of monetary policy, it has also changed thinking about regulation and macroprudential oversight with several new measures being put into place. Macroprudential tools could be easily implemented into our framework along the lines of GKP. These are interesting issues for future research.

Appendix: Figures

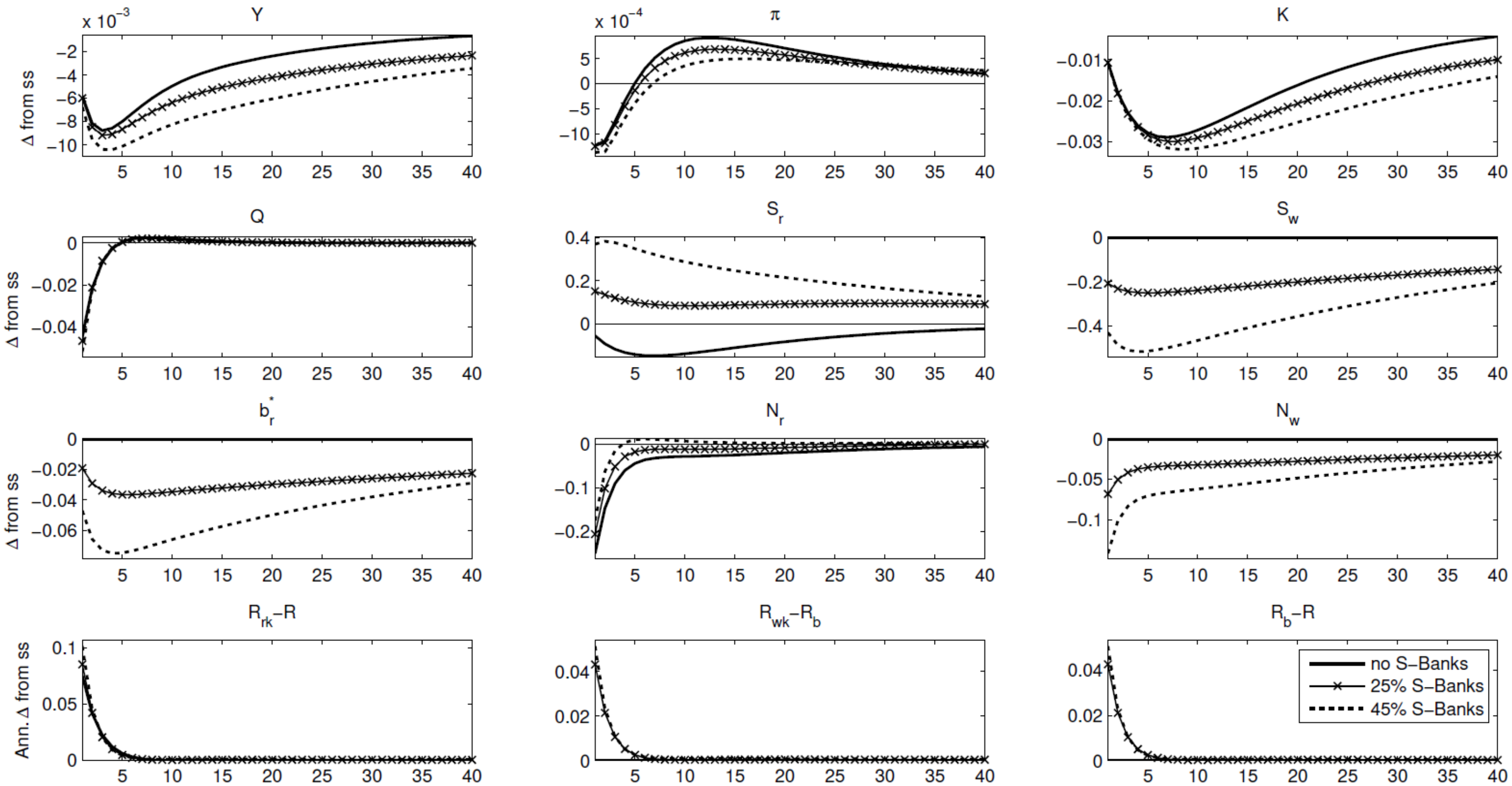


Figure 1.1: Impulse responses to a capital quality shock

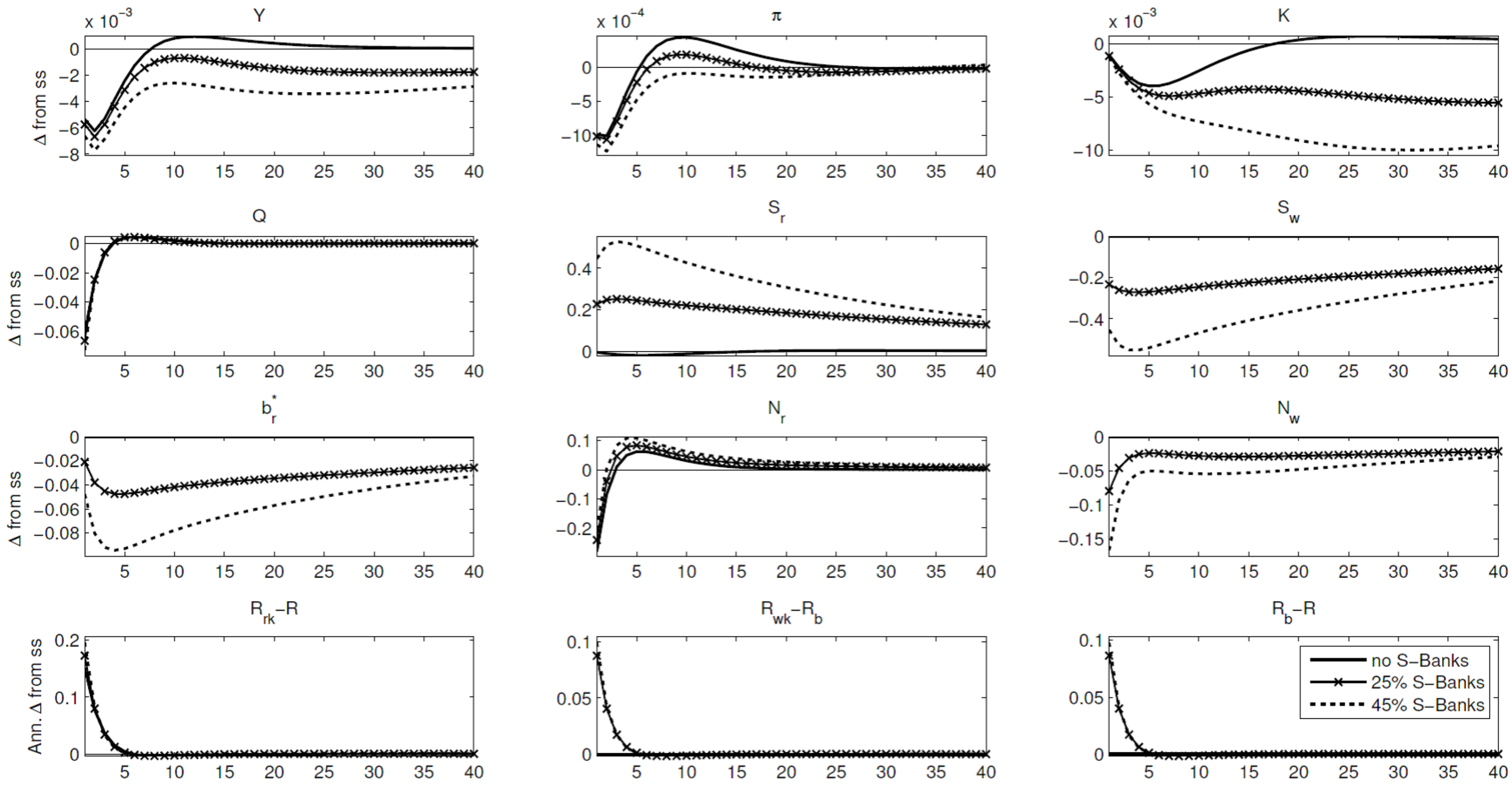


Figure 1.2: Impulse responses to an overall financial shock

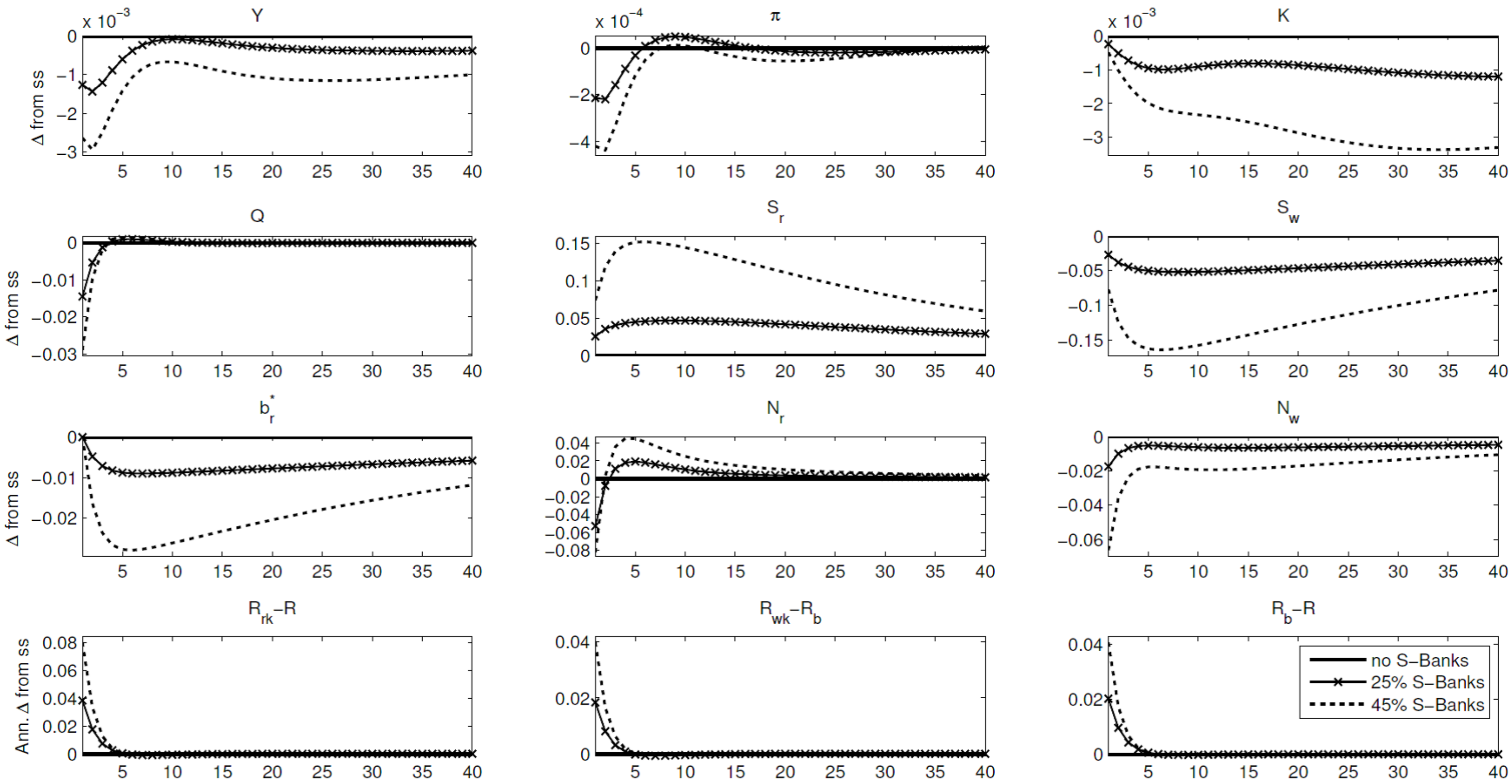


Figure 1.3: Impulse responses to an interbank shock

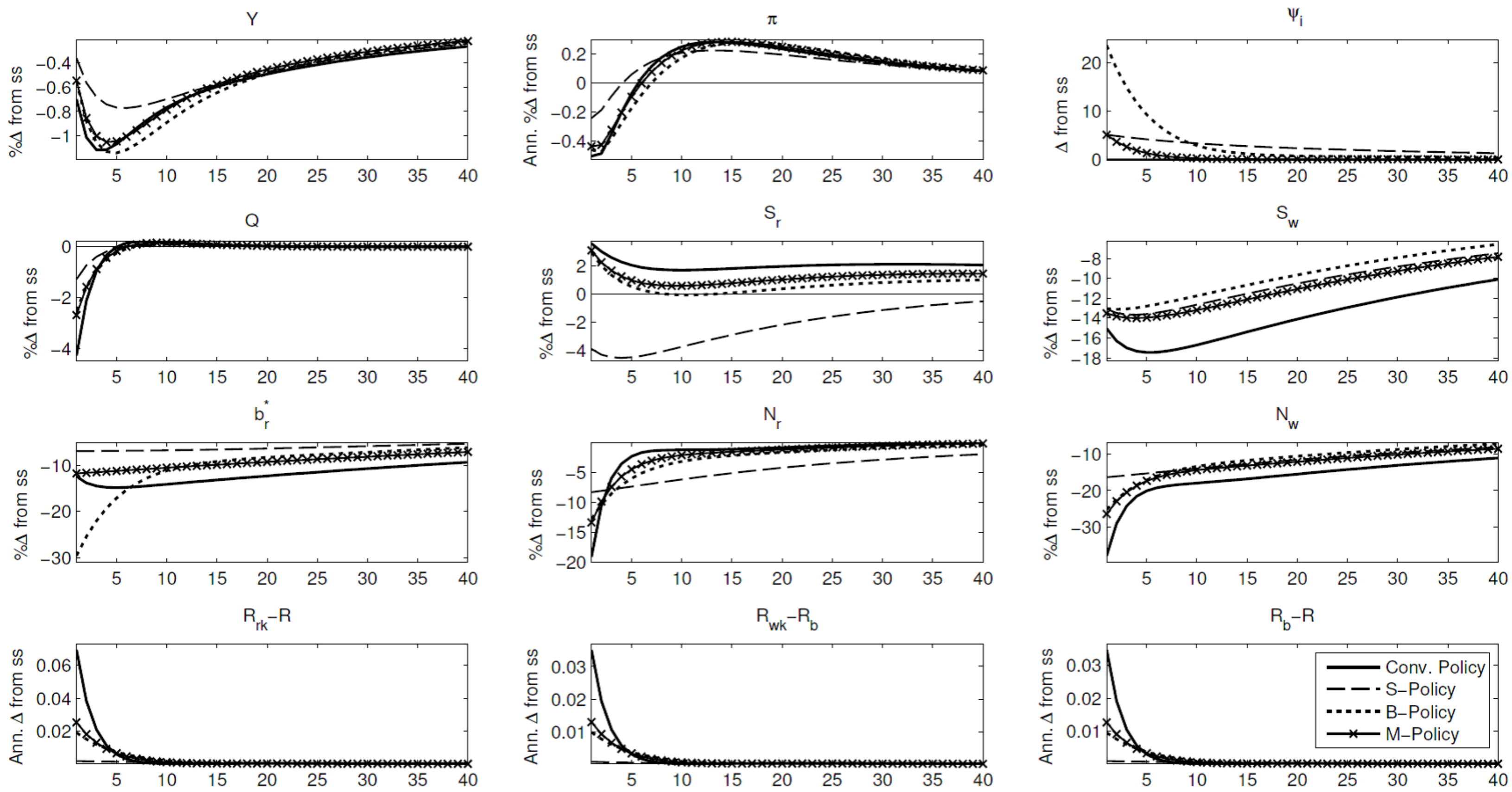


Figure 1.4: Impulse responses to a capital quality shock with policy responses

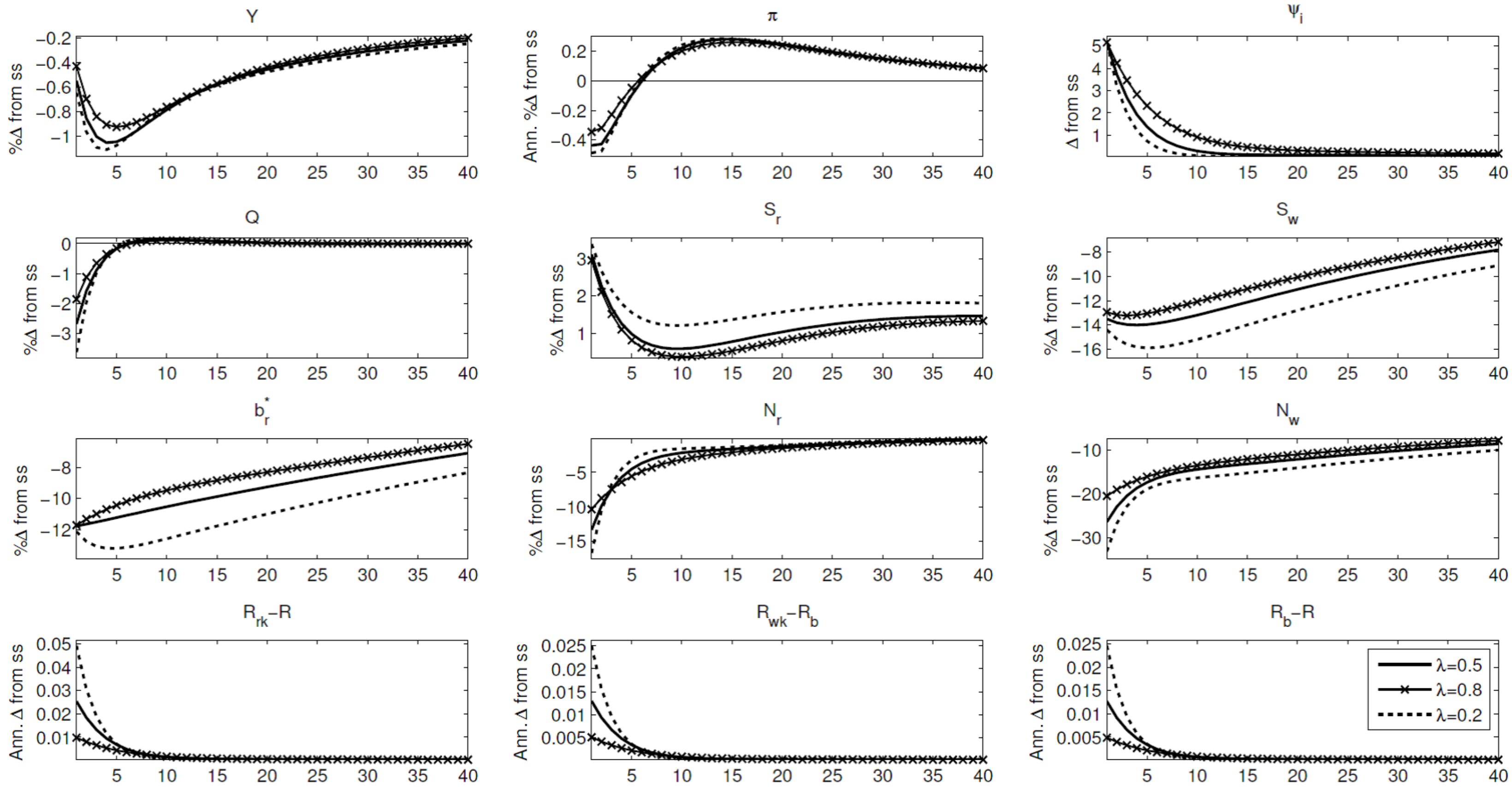


Figure 1.5: Impulse responses to variations in lambda

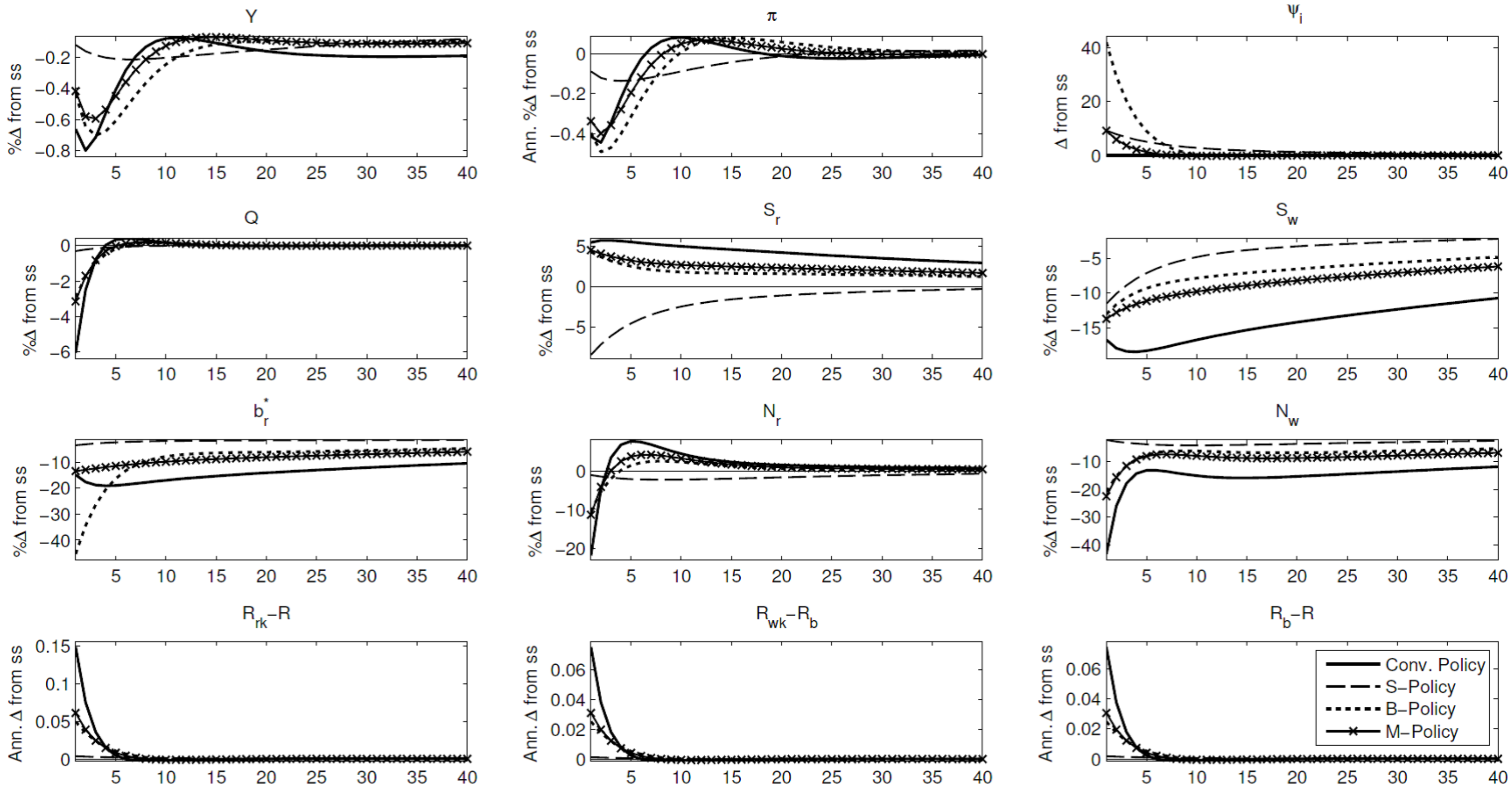


Figure 1.6: Impulse responses to an overall financial shock with policy responses

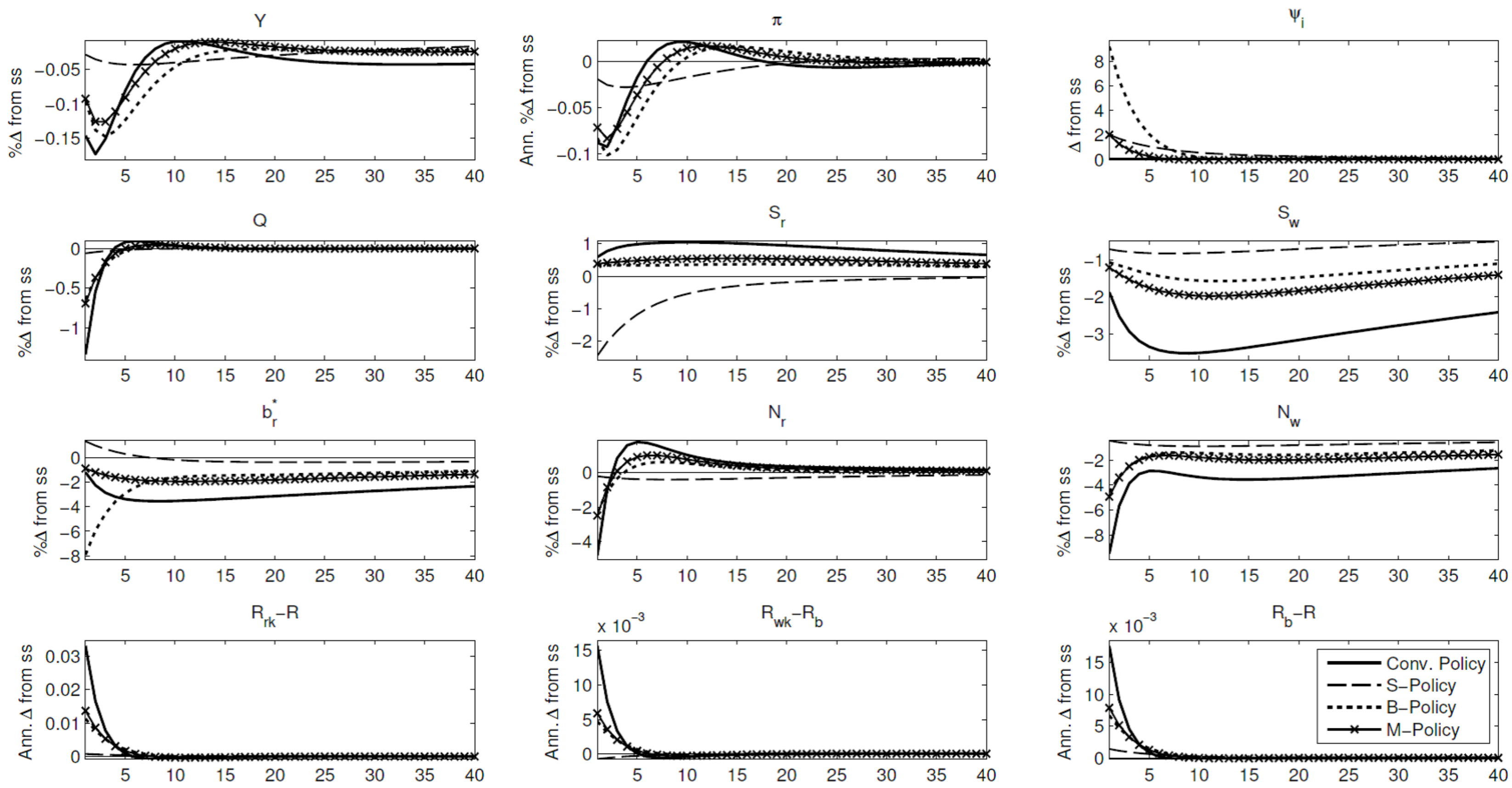


Figure 1.7: Impulse responses to an interbank shock with policy responses

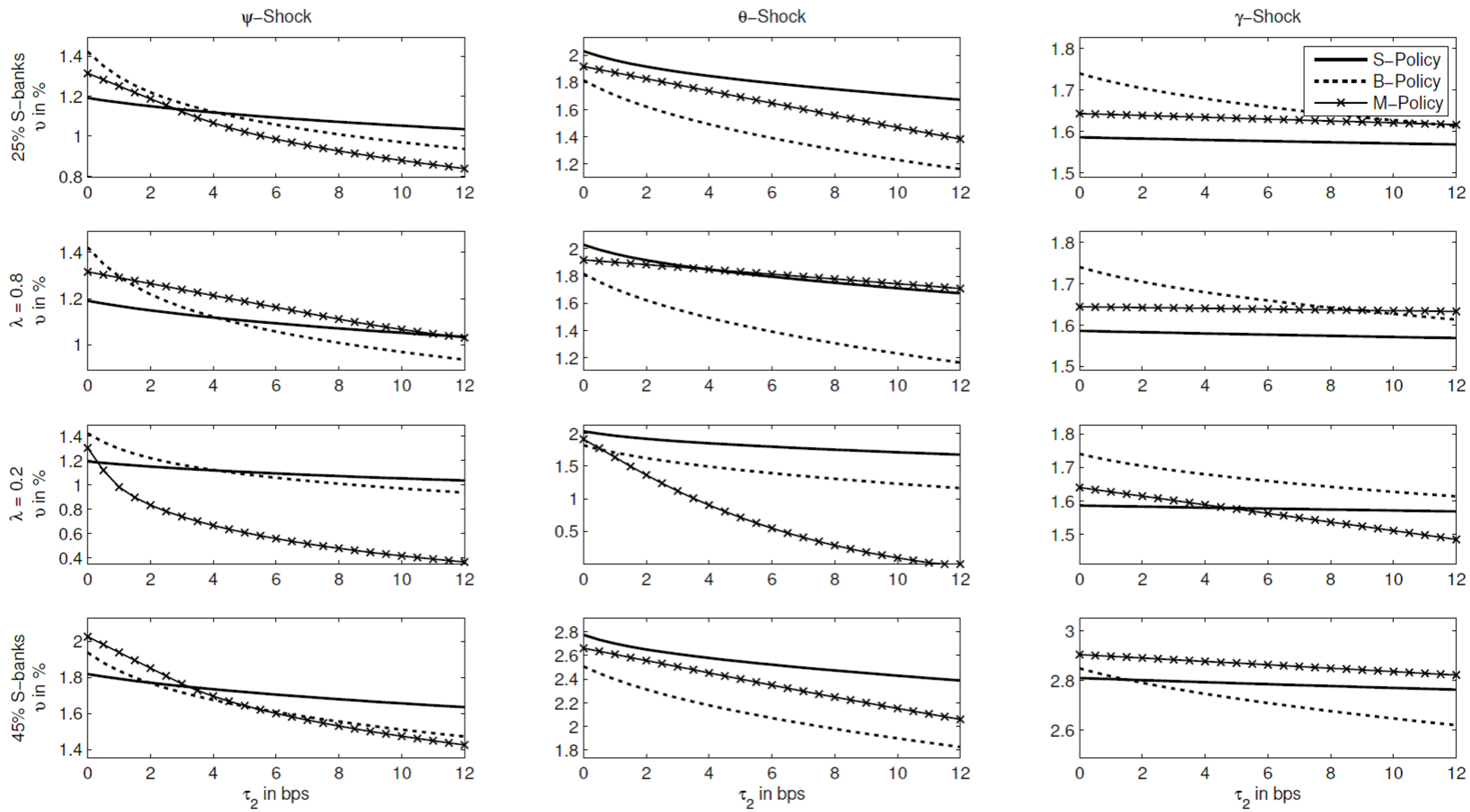


Figure 1.8: Welfare gains from optimal unconventional policies

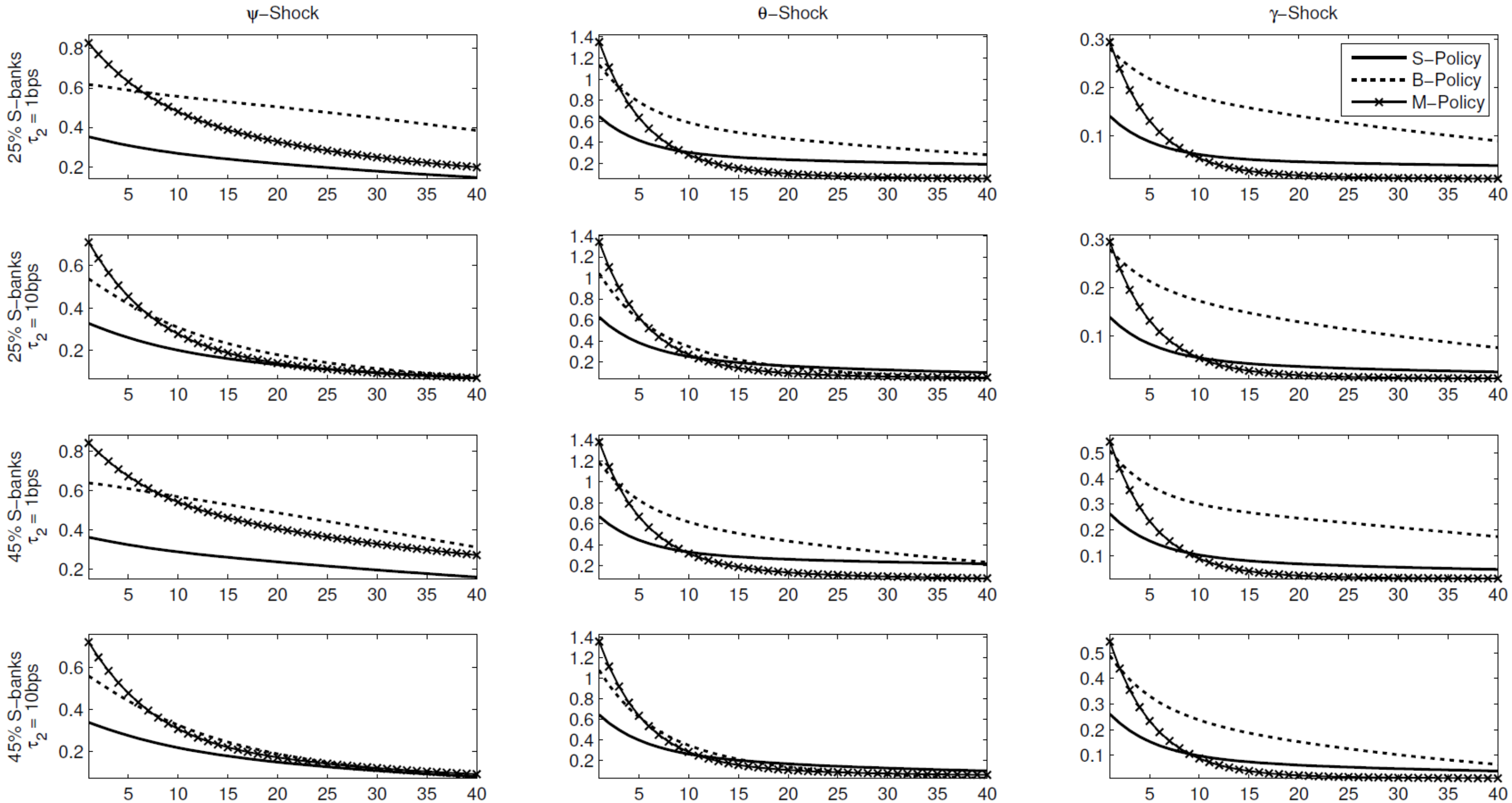


Figure 1.9: Expenditures for optimal unconventional policies in relation to output

Chapter 2

Shadow Banking and the Design of Macroprudential Policy in a Monetary Union

2.1 Introduction

An unprecedented feature of the Global Financial Crisis (GFC) was the international synchronization of core macroeconomic real and financial variables. As lately pointed out by Perri and Quadrini (2018) or Imbs (2010), the decade before the GFC and the periods thereafter showed exceptionally high comovements in financial and business cycles along major industrialized countries. Among others, two distinctive features fostered these developments. On the one hand, the last decades showed a trend of financial globalization through cross-border banking activities, leading to an integration of financial systems (Claessens 2017). While this accounts for the bulk of advanced economies, it has especially been the case for Europe and the euro area. Prior to the GFC, EU and euro area located banks accounted for 57% of global cross-border banking flows (Emter et al. 2019). Intra-euro area cross-border banking flows likewise increased in importance. Amounting to €700 billion in 1999, they tripled until 2008 to reach roughly €2100 billion (Poutineau and Vermandel 2015). On the other hand, shadow banking gained in importance as a provider of credit. As it combined high leverage and excessive credit growth with missing regulatory requirements, shadow banking appeared as a significant vulnerability and risk to financial stability. In Europe, its amount increased from EUR 9 trillion in 2003 to EUR 31 trillion in 2017, reflecting roughly 40% of total euro area financial assets (Kirchner 2020). As regards the banking exposure towards EU and euro area shadow banking entities, Abad et al. (2017) show that one third of EU-banking exposure is towards shadow banking entities within EU member countries (largely within the euro area). In the wake of the GFC, these developments have been responded to with international regulatory reforms that resulted in macroprudential regulations aimed at the resilience and stability of financial systems (the BASEL III-accords).

However, given tightly regulated banking sectors on the one hand, and largely unregulated shadow banking sectors on the other, a gap in financial stability policy emerges that may induce cross-sector substitution effects (Abad et al. 2017). This is especially important in the context of a monetary union within which financial linkages in combination with a single market and a common currency promote economic and financial integration and thereby a synchronization of real and financial variables. What arises as a natural question in this context then is to what extent country-specific (i.e. at the level of national authorities) or superordinate macroprudential measures (i.e. at the level of the ESRB and ECB) are able to mitigate the transmission and impact of shocks and how they interact with monetary policy.

In this paper, we address these considerations and develop a monetary DSGE-model to document the optimal design of macroprudential measures in the context of a monetary union within which shadow banking exists alongside retail banking. Our core model builds on the stylized two-country model with financial frictions of Dedola et al. (2013) that we adjust to a two-country monetary union setup with nominal frictions and shadow banking. In this setup, retail banks collect deposits and bank equity from households and use these funds to make loans to domestic goods producers and domestic shadow banks (we loosely think of this as interbank credit). Shadow banks, however, are not able to collect deposits or equity from households and are dependent on funds from their sponsoring retail banks. They use interbank credit and retained earnings to make loans to both domestic and foreign intermediate goods producers. Accordingly, our benchmark scenario features financial integration realized through cross-border activities of shadow banks. As a result of this cross-border financial integration, the main financial variables are perfectly aligned internationally. A supranational central bank targets inflation through the union-wide nominal interest rate and macroprudential supervision follows the common BASEL III-Accords. We roughly capture these objectives through a capital buffer based on the outside equity ratio of retail banks. The policy rule reacts countercyclically to changes in credit spreads from its steady-state level as a sign for financial distress. More precisely, when a shock forces a deep recession with accompanied downturns in macroeconomic and financial variables, credit spreads tend to widen and hence put additional pressure on economic activity. In such a case, macroprudential policy reacts by allowing retail banks to operate at a higher leverage ratio through holding less equity capital against their outstanding assets. As this allows retail banks to operate their business with lower levels of capital, it moderates the process of deleveraging and motivates credit origination.

In this setup, we analyze the design of monetary and macroprudential policy when real (technology) and financial (net worth) shocks hit the monetary union. A financial shock unfolds equivalent destructive impacts in both countries while a real shock hits with varyingly strong impacts. The impact on the productive sectors depends on the nature of the shock (real vs. financial and union-wide vs. idiosyncratic shocks) while financial variables co-move as a result of integration in the financial sphere. Using regulatory policies in the setup of a monetary union then implies considerations on the country-specific vs. union-wide arrangement of such policies as internationally integrated financial markets might require common prudential standards (Cecchetti and Tucker 2016). We address these aspects and consider country-specific and union-wide macroprudential regulation and their optimal design to stabilize household welfare.

Our analysis allows the following results. In the case of shocks to the real sphere, we find that the existence of shadow banking intensifies the financial accelerator effects. Shadow banks, highly leveraged and dependent on retail banking funds, appear to be an additional source of instability and thus operate as a shock amplifier. However, during financial shocks, shadow banking under financial autarky rather operates as shock absorber as it can partly compensate the losses incurred by retail banks.

In terms of the optimal design of macroprudential policy, we find that regulation situated at the country-level is only beneficial under financial autarky or absent shadow banking. A sufficiently large stabilization of the relevant household welfare measure is only achieved once macroprudential regulation acts union-wide hence coordinated. Such a supranational macroprudential regulation that symmetrically intervenes in both countries of the union is able to effectively counteract the negative consequences of the observed shocks. While the gains are larger for financial shocks than for real shocks, they are even facilitated through the forces of financial integration. This result seems plausible as macroprudential regulation as based on BASEL III is primarily designed to address system-wide risk in the banking sector and hence financial stability (see e.g. BIS 2010). A policy designed to counteract the build-up of bank exposure is thus highly effective given shocks emanating from this very sector. Furthermore, the follow-up effect of union-wide macroprudential regulation is a more stringent setting of the policy rate through monetary policy. Since financial stability is cared for by the macroprudential regulator, monetary policy is now able to react more aggressively to its primary objective inflation. Moreover, our welfare analysis shows that under real shocks, the mere existence of (national) shadow banking causes increasing welfare losses. In such a case, neither financial integration nor macroprudential policy can compensate the additional losses. As the shadow banking sector in our model (and in general) is unregulated and highly leveraged, it constitutes a vulnerability to the stability of the financial system. A macroprudential regulator equipped with an entity-based regulation approach as in our case thus only indirectly affects the vulnerabilities originating from this sector.

To the best of our knowledge, this is the first paper that analyses the cross-border transmission of shocks and the effectiveness of macroprudential policy in a two-country monetary union model with shadow banking.

The paper is structured as follows: we review related literature in section 2.2. In Section 2.3, we introduce the basic model and our monetary and macroprudential policies. Section 2.4 provides the dynamics of the model. We start with the calibration and then turn towards the international transmission of shocks and the corresponding analyses. We then discuss the implications of macroprudential policy at the country and union level, and analyze the welfare implications given the optimal design. Section 2.5 concludes.

2.2 Related Literature

Our analysis is related to several strands of literature. As we use a monetary DSGE setup with financial intermediaries, our analysis is related to the early wave of models that accounts for banks as intermediaries of financial capital between savers (households) and investors (firms). A seminal paper in this direction is Gertler and Karadi (2011). The authors implement retail banks into an otherwise standard monetary DSGE setup along the lines of Smets and Wouters (2003, 2007) and Christiano et al. (2005). Financial frictions arise as a moral hazard problem between banks and households and restrain banks in their ability to receive unlimited funding from households. In this setup, the authors study the impact of a capital quality shock and the ability of unconventional monetary policy measures (credit market interventions by the central bank) to stabilize the business cycle. The model by Gertler and Kiyotaki (2011) resembles the former except for they implement liquidity risk (in the sense of Kiyotaki and Moore 2012) and abstract from nominal rigidities. Given this setup, the authors analyze unconventional credit policies conducted by the central bank. In Gerali et al. (2010), the banking sector is modeled in monopolistic competition as opposed to perfect competition in Gertler and Karadi or Gertler and Kiyotaki. The authors use the setup to study the impact of real and financial shocks (e.g. bank capital loss) on the business cycle.

Whereas the former papers consider closed-economy models, our model is a two-country setup with international financial flows within a currency union. Accordingly, we join the ranks of the strand of literature that deploys open economy models to study cross-country banking activities and financial flows and the international transmission of shocks. For example, Dedola et al. (2013) use a two-country model with symmetric countries and financial intermediation in the sense of Gertler and Karadi (2011). The financial market is integrated internationally in that households can make deposits in home and foreign banks, and banks can lend internationally to firms. Given this setup, they study the international transmission of financial and real shocks and implement different unconventional credit policies in cooperative and noncooperative settings. Opposed to this, Nuguer (2016) develops a two-country model with an international interbank market where banks can lend to each other on an international scale. As this transmits shocks from one country to another, the setup is used to study the international transmission of shocks through bank balance sheets and the model response to different credit policy measures. While these papers consider two independent countries, we use the setup of a currency union. We are thus close to the approach of Poutineau and Vermandel (2015) who build a two-country DSGE setup for the euro area and study the transmission of shocks through cross-border banking flows. Quint and Rabanal (2014) use an estimated two-country model fitted to the euro area and study the interaction of monetary and macroprudential policies.

In all of the previous models, financial intermediation is conducted trough traditional banking only. We depart from this literature in that we model heterogeneous financial intermediaries as observed before and during the crisis. We thus contribute to a recent strand of literature considering shadow banking alongside traditional (retail) banking. However, while this strand uses closed-economy setups, we implement shadow banking into a two-country monetary union model. In Gertler et al. (2016), the financial intermediation setup of Gertler and Karadi (2011) and the model of banking instability of Gertler and Kiyotaki (2015) are extended to feature a wholesale banking sector, i.e. shadow banking. The authors consider wholesale banks to be borrowers on the interbank market, i.e. "sponsored" by other banks, and to have comparative advantages in managing financial capital. Retail banks use household deposits and are lenders in the interbank market. The authors forgo the productive side and use a financial setup to study bank runs and intervention policies (both macroprudential and monetary). In Meeks et al. (2017), the interaction of retail banks and shadow banks is based on the ability of shadow banks to transform illiquid loans into tradable assets (ABS) of higher collateral value that are purchased by retail banks. Given this setup, the authors analyze the impact of a liquidity crisis and the possibilities of intervention policies to stabilize business cycles. The model by Verona et al. (2013) considers shadow banking as monopolistic competitive investment banks that provide safe credit to a subset of entrepreneurs. Verona et al. (2013) show that once enriching their setup with shadow banks, the model produces impulse response functions to monetary policy shocks that are more in line with empirical observations. Fève et al. (2019a) deploy a calibrated model with retail and shadow banking to evaluate the impact of different macroprudential policies. Kirchner and Schwanebeck (2017) use a setup with retail and shadow banks in the sense of Gertler et al. (2016) to study the optimal design of unconventional monetary policy measures.

Motivated by the GFC, there is a large strand of literature that examines the role of macroprudential policies in DSGE setups with financial intermediaries. We contribute to this strand by analyzing these policies in the context of shadow banking. Noteworthy examples are Angelini et al. (2014) who use the setup of Gerali et al. (2010) and study optimal macroprudential and monetary policies. To this end, the authors deploy a time-varying capital requirement that follows a policy rule reacting to deviations of a loan-to-output ratio to its steady-state level. The optimal degree of intervention is dependent on the ability to minimize the regulators loss function, either in cooperative or noncooperative behavior with the central bank. Poutineau and Vermandel (2017) use a two-country monetary union model with interbank cross-border loan flows between the core and periphery of the union.

The authors implement macroprudential regulation that sets a time-varying capital requirements either reacting to loan supply, loan demand or capital flows. As they study the monetary union case, regulators can act national or union-wide. In contrast, Palek and Schwanebeck (2019) use a two-country monetary union model to study welfare-based optimal monetary and macroprudential policy. In their setup, macroprudential policy is a country-specific countercyclical capital requirement set by the welfare maximizing central bank.

2.3 The Basic Model

The core framework builds on the stylized two-country model with financial frictions of Dedola et al. (2013). We extend this model by allowing for nominal frictions and by implementing shadow banking. In particular, in contrast to Dedola et al. (2013), the two perfectly symmetric countries belong to a currency union. Each country consists of the following agents: households, capital producers, intermediate goods producers, retailers and financial intermediaries split into retail and shadow banks. The financial sector is modelled in the following way: in both countries, traditional retail banks and shadow banks supply the respective productive sector with financial capital. Additionally, shadow banks are internationally active and provide credit to domestic and foreign intermediate goods producers. Financial frictions follow the approach of Gertler and Karadi (2011) and are modelled as an agency problem in the intermediation of funds. For retail banks, it limits the access to deposits from households and for shadow banks the access to funds from retail banks. In this way, financial frictions affect the availability of funds that banks can allocate to intermediate goods producers.

We normalize the total population to one, where the population on the segment $[0, m)$ belongs to the home country, while the population on $[m, 1]$ belongs to the foreign counterpart. The presentation of the model focuses on country Home. Due to assumed symmetry, foreign equations are equivalent. We denote foreign variables by an asterisk.

2.3.1 Households

A continuum of representative infinitely-lived households consumes final goods, saves at retail banks and supplies labor to goods producers. Each household consists of three members: workers, retail bankers and shadow bankers. As empirical patters show that international deposit flows are negligible (see Poutineau and Vermandel 2015), households can only save at domestic retail banks. Workers return the wage they earn back to their respective household and so do bankers with their retained earnings once they have to shut down the bank and leave the industry. Bankers who leave become new workers and to keep the family members constant over time, a corresponding fraction of workers becomes new bankers. To start the banking business, each new banker receives startup funds from her respective household.

The representative infinitely-lived household maximizes the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\rho}}{1-\rho} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \right] \tag{2.1}$$

with consumption index C_t and labor L_t. The parameters β, ρ, χ, and φ are the discount factor, the inverse of the elasticity of intertemporal substitution, the utility weight on labor, and the inverse Frisch elasticity, respectively. The flow of funds reads

$$C_t + D_t + q_t e_t = W_t L_t + R_{t-1} D_{t-1} + R_{e,t} q_{t-1} e_{t-1} - G\left(q_t e_t\right) + \Pi_t - T_t. \tag{2.2}$$

We follow Gertler et al. (2012) and Nelson and Pinter (2018) and allow households to save in two forms: deposits D_t and bank outside equity e_t priced at q_t. Whereas the former is a liquid demand deposit and risk-free as it is a non-state contingent claim, the latter depicts a claim that is contingent on the cash-flows of the bank and a rather illiquid claim as changes to the portfolio are costly. As mentioned above, the income of the household is composed of the real wage W_t earned on hours worked L_t and gross real returns R_{t-1} and $R_{e,t}$ on savings in the form of domestic deposits D_{t-1} and holding bank outside equity e_{t-1} at price q_{t-1} between $t-1$ to t minus adjustment costs $G\left(q_t e_t\right)$ for the equity portfolio. Π_t are net earnings from the ownership of firms, retained earnings from banks and paid startup funds for new bankers while T_t denotes lump-sum taxes.

Maximizing the households utility function subject to the flow of funds constraint yields the first-order conditions for labor supply, consumption and bank equity:

$$U_{C_t} W_t = \chi L_t^{\varphi} \tag{2.3}$$

$$E_t \Lambda_{t,t+1} R_t = 1 \tag{2.4}$$

$$E_t \Lambda_{t,t+1} R_{e,t+1} = 1 + G'\left(q_t e_t\right). \tag{2.5}$$

The marginal utility of consumption is defined as

$$U_{C_t} \equiv C_t^{-\rho} \tag{2.6}$$

and the households stochastic discount factor is

$$\Lambda_{t,t+1} \equiv \beta_t \frac{U_{C_{t+1}}}{U_{C_t}}. \tag{2.7}$$

The consumption index is defined as

$$C_t \equiv \left[\frac{\left(C_{H,t}\right)^m \left(C_{F,t}\right)^{1-m}}{m^m (1-m)^{1-m}} \right], \tag{2.8}$$

where $C_{H,t}$ and $C_{F,t}$ are consumption bundles of domestic and foreign goods.[1] Let $P_{H,t}$ $(P_{F,t})$ be the producer price index in country H (F) so that the corresponding consumer price index is given by $P_t = (P_{H,t})^m (P_{F,t})^{1-m}$. Prices are set in the origin country, but due to the absence of trade barriers, the law of one price holds for each good. Assuming identical preferences in both countries of the monetary union results in the purchasing power parity condition $P_t = P_t^*$. By taking prices as given and by making use of the definition of the terms of trade as the relative price of foreign goods in terms of home goods, i.e. $ToT_t \equiv P_{F,t}/P_{H,t}$, cost minimization leads to the standard demand functions

$$C_{H,t} = mToT_t^{1-m}C_t \tag{2.9}$$
$$C_{F,t} = (1-m)ToT_t^{-m}C_t. \tag{2.10}$$

We assume that the adjustment costs for bank equity holdings of households are quadratic and are scaled by the total amount of retail banks' assets $(S_{r,t} + B_{r,t})$. The functional form reads:

$$G(q_t e_t) = \frac{\eta_e}{2}\left(\frac{q_t e_t/(S_{r,t}+B_{r,t})}{qe/(S_r+B_r)} - 1\right)^2 \frac{qe}{(S_r+B_r)}(S_{r,t}+B_{r,t}), \tag{2.11}$$

where variables without a time subscript denote steady-state values. By defining retail banks' outside equity ratio as

$$\tau_t \equiv \frac{q_t e_t}{S_{r,t}+B_{r,t}}, \tag{2.12}$$

the marginal portfolio costs are

$$G'(q_t e_t) = \eta_e\left(\frac{\tau_t}{\tau} - 1\right). \tag{2.13}$$

Using (2.4) in combination with (2.5) gives the equity supply curve:

$$E_t \Lambda_{t,t+1}(R_{e,t+1} - R_t) = \eta_e\left(\frac{\tau_t}{\tau} - 1\right). \tag{2.14}$$

This equation depicts the costs to the household of supplying equity to the banking system. If the marginal adjustment costs increase due to a rise in retail bank's equity ratio, households demand a higher return on their equity holdings compared to deposits. Accordingly, the spread $(R_{e,t+1} - R_t)$ rises.

[1] The definition implies an elasticity of substitution between the two bundles of goods that is restricted to unity. This so-called "macro" Armington elasticity of one can be justified by recent research as for example Feenstra et al. (2018).

2.3.2 Intermediate goods producers

Perfectly competitive goods firms use a Cobb-Douglas production function given by

$$Y_{m,t} = A_t {K_t}^{\alpha} L_t^{1-\alpha} \tag{2.15}$$

to produce intermediate output $Y_{m,t}$, that is sold to retailers at the real price $P_{m,t}$. Total factor productivity A_t follows an exogenous autoregressive process in order to capture technology shocks. Capital for production in the subsequent period $t+1$ needs to be purchased from capital producers at the end of period t. Denote S_t as this capital stock "in process" at the end of t for $t+1$. Then, S_t is given by the sum of current investment I_t and existing undepreciated capital $(1-\delta)K_t$:

$$S_t = I_t + (1-\delta)K_t. \tag{2.16}$$

At the beginning of the next period, capital in process is transformed into capital for production purposes according to

$$K_{t+1} = S_t. \tag{2.17}$$

Since goods producers have no own financial resources at their disposal to rent capital from capital goods producers, they obtain funds (loans) from financial intermediaries in exchange for perfectly state-contingent securities. For simplicity, we assume that the intermediation process between goods producers and banks is frictionless. Banks can perfectly monitor goods producers and enforce all contractual obligations while firms can perfectly commit to pay all future returns to the bank. Each unit of security is a perfect claim on the future payouts of a unit of capital and priced at Q_t, the price for new capital. Accordingly, financial intermediaries are exposed to fluctuations in the price of capital.

Profit maximization of the goods producers leads to the first-order conditions for labor input

$$W_t = (1-\alpha)\frac{P_{m,t}Y_{m,t}}{L_t}, \tag{2.18}$$

and capital input, formulated as the real return on capital

$$R_{k,t} = \frac{\alpha\frac{P_{m,t}Y_{m,t}}{K_t} + (1-\delta)Q_t}{Q_{t-1}}. \tag{2.19}$$

As bank loans are claims on the capital, they yield the same return $R_{k,t}$. On the other hand, outside equity can be understood as claims on the banking sector and therefore also claims on capital. Hence, they yield the following real return:

$$R_{e,t} = \frac{\alpha\frac{P_{m,t}Y_{m,t}}{K_t} + (1-\delta)q_t}{q_{t-1}}. \tag{2.20}$$

2.3.3 Capital goods firms

Competitive capital goods firms produce new capital goods and sell capital to goods producers at the price Q_t. Production of capital goods is subject to investment adjustment costs following the functional form

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{2.21}$$

satisfying $f(1) = f'(1) = 0$ and $f''(1) > 0$. By choosing investment I_t, capital producers maximize their profits according to the objective function

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{t,t+1} \left\{ Q_t I_t - \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \right\}. \tag{2.22}$$

Profit maximization leads to the standard price of capital

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right). \tag{2.23}$$

2.3.4 Retailers

Monopolistically competitive retailers produce final goods by using the intermediate output as input and label it at no cost. Thus, final domestic output Y_t as a CES aggregate of a continuum of retail output is given by

$$Y_t = \left[\int_0^1 (Y_t(h))^{\frac{\varepsilon-1}{\varepsilon}} dh\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2.24}$$

where $Y_t(h)$ denotes the output of retailer h and ε is the elasticity of substitution between goods. Cost minimization leads to

$$Y_t(h) = \left(\frac{P_{H,t}(h)}{P_{H,t}}\right)^{-\varepsilon} Y_t, \;\; P_{H,t} = \left[\int_0^1 (P_{H,t}(h))^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}. \tag{2.25}$$

To introduce nominal rigidities, we introduce price setting à la Calvo (1983) and assume that only the fraction $1 - \zeta$ of retailers is able to adjust their prices each period, whereas the fraction ζ of retailers cannot reset their prices. The retailers optimization problem boils down to choose the optimal price $P^*_{H,t}$ in order to maximize profits following

$$\max E_0 \sum_{t=0}^{\infty} \zeta^i \Lambda_{t,t+1} \left[\frac{\overline{P}_{H,t}}{P_{H,t+1}} - T_m P_{m,t+1}\right] Y_{t+1}(h), \tag{2.26}$$

where $T_m = (\varepsilon - 1)/\varepsilon$ is a steady-state subsidy financed by lump-sum taxes in order to eliminate steady-state inefficiencies due to monopolistic competition. The first-order condition is given by

$$E_0 \sum_{t=0}^{\infty} \zeta^i \Lambda_{t,t+1} \left[\frac{\overline{P}_{H,t}}{P_{H,t+1}} - \frac{\varepsilon}{\varepsilon - 1} T_m P_{m,t+1} \right] Y_{t+1}(h) = 0 \tag{2.27}$$

and the domestic aggregate price index evolves according to

$$P_{H,t} = \left[(1-\zeta)(\overline{P}_{H,t})^{1-\varepsilon} + \zeta (P_{H,t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \tag{2.28}$$

2.3.5 Financial intermediaries

Within each country, financial intermediaries are responsible for channeling funds from savers (households) to investors (intermediate goods firms). An important feature of integrated currency unions are cross-border interactions of large banks with shadow banking entities that are active in multiple countries. We capture this phenomenon by allowing retail banks to shift parts of their balance sheet, namely interbank credits, to domestic shadow banking entities that are able to invest in both countries. Hence, cross-border financial integration is realized via the shadow banking system which is therefore crucial in transmitting shocks and fluctuations between the countries. In this setup, retail banks collect deposits and bank equity from households and use these funds to make loans to domestic goods producers and domestic shadow banks. Shadow banks are not able to collect deposits or equity from households and are dependent on funds from their sponsoring retail banks. They use interbank credit and retained earnings to make loans to both domestic and foreign intermediate goods producers.

Retail banking

Perfectly competitive retail banks are managed by bankers and owned by households. At the beginning of period t, retail bank j uses deposits $D_{j,t}$ from households other the ones they own, net worth $N_{j,r,t}$ from retained earnings and outside equity $e_{j,t}$ at price q_t to fund loan origination consisting of loans to goods producers $S_{j,r,t}$, priced at Q_t, and interbank loans to the shadow banking system $B_{j,r,t}$. We can write the balance sheet identity during period t as

$$Q_t S_{j,r,t} + B_{j,r,t} = D_{j,t} + q_t e_{j,t} + N_{j,r,t}. \tag{2.29}$$

Net worth $N_{j,r,t+1}$ evolves as the difference between interest earnings $R_{k,t+1}$ on non-financial loans $S_{j,r,t}$ and earnings $R_{b,t+1}$ from interbank loans $B_{j,r,t}$ to shadow banks net of obligations for deposits $D_{j,t}$ at R_t and outside equity $q_t e_{j,t}$ at $R_{e,t+1}$. It reads

$$\begin{aligned} N_{j,r,t+1} &= (1+T_k) R_{k,t+1} Q_t S_{j,r,t} + R_{b,t+1} B_{j,r,t} - R_t D_{j,t} - R_{e,t+1} q_t e_{j,t} \\ N_{j,r,t+1} &= ((1+T_k) R_{k,t+1} - R_t - (R_{e,t+1} - R_t)\, \tau_{j,t})\, Q_t S_{j,r,t} + \\ &\quad (R_{b,t+1} - R_t - (R_{e,t+1} - R_t)\, \tau_{j,t})\, B_{j,r,t} + R_t N_{j,r,t}, \end{aligned} \tag{2.30}$$

where T_k is a steady-state subsidy to banks financed by lump-sum taxes in order to eliminate steady-state inefficiencies due to frictional financial intermediation. Hereby, we follow Nelson and Pinter (2018) and implement this subsidy to pin the steady-state credit spread down to zero, i.e. $R_k = R$. Therefore, the steady state of the real side of the model will be equivalent to the one of a real business cycle model. Besides, note that net worth of the retail banker is decreasing in the outside equity ratio $\tau_t(j)$ when $R_{e,t+1} - R_t > 0$.

Whereas net worth is an ensured endowment for the retail banker, the acquisition of deposits and equity from households is dependent on a moral hazard problem between the two parties. It follows Gertler and Karadi (2011) and limits the ability of retail banks to obtain funds by assuming that banks have an incentive to run away with (i.e. divert) a fraction of their balance sheet. In doing so, retail banks extract the fraction θ_r, return it back to their household and announce bankruptcy in the next period since the remaining fraction $1-\theta_r$ is reclaimed from the other households. Accordingly, households are only willing to supply deposits and equity to banks if they observe that banks will remain active and proceed with doing business in the ongoing periods. Let the discounted future payouts from accumulating net worth and hence the incentive from staying in business be $V_{r,t}$, then the incentive constraint for the retail banker reads

$$V_{j,r,t} \geq \theta_r \left[Q_t S_{j,r,t} + \gamma B_{j,r,t} \right]. \tag{2.31}$$

The timing is that still in period t but after raising new deposits and equity, banks decide about diverting instead of maximizing the value of net worth. This is noticed by households at the beginning of the next period $t+1$ and immediately turns into bankruptcy for the banker. We are assuming that the ability to divert assets is dependent on the use of funds. Funds used for firm credit supply are governed by θ_r $(0 < \theta_r < 1)$ and funds for the shadow banking sector (interbank loans) are governed by $\theta_r \gamma$ with $(0 < \gamma < 1)$. This means that domestic non-financial loans are easier to divert compared to interbank loans. We think of this as reflecting different collateral values of assets (based on Meeks et al. 2017).

The value function of the retail banker is given by the following Bellman equation:

$$V_{j,r,t} = E_t \Lambda_{t,t+1} \left[(1-\sigma) N_{j,r,t+1} + \sigma V_{j,r,t+1} \right], \tag{2.32}$$

where σ is the surviving probability and $\Lambda_{t,t+1}$ the discount factor (same as for households since bankers are members of the very same). When bankers have to exit the industry with probability $(1-\sigma)$, they return the acquired net worth back to their household. Otherwise, they continue to maximize the value of the bank.

Retail banks are supervised by a macroprudential regulator that sets the outside equity ratio $\tau_{j,t}$, which we will call the capital buffer, to avoid excessive leverage. As the supply of outside equity from households is increasing in $R_{e,t+1}$ over R_t, the capital buffer in (2.30) restricts the accumulation of net worth when $R_{e,t+1} - R_t > 0$. Lower levels of net worth reduce the value of the bank in (2.32), thereby tighten the incentive constraint (2.31) and reduce credit supply. As the macroprudential authority sets a capital buffer requirement that is identical for all retail banks, we will drop the index j.

The retail banker chooses $S_{j,r,t}$, $B_{j,r,t}$ to maximize (2.32) subject to (2.30), (2.31), and the capital buffer requirement τ_t. We formalize this maximization problem by guessing (and later verifying) that the franchise value of the bank can be written as

$$\begin{aligned} V_{j,r,t} &= \upsilon_{rs,t} Q_t S_{j,r,t} + \upsilon_{rb,t} B_{j,r,t} - \upsilon_{rd,t} D_{j,t} - \upsilon_{re,t} q_t e_{j,t} \\ V_{j,r,t} &= \left(\upsilon_{rs,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t}\right)\tau_t\right) Q_t S_{j,r,t} \\ &\quad + \left(\upsilon_{rb,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t}\right)\tau_t\right) B_{j,r,t} + \upsilon_{rd,t} N_{j,r,t}, \end{aligned} \tag{2.33}$$

where the coefficients $\upsilon_{rs,t}$, $\upsilon_{rb,t}$, $\upsilon_{rd,t}$, and $\upsilon_{re,t}$ are the marginal values of each balance sheet item except for $N_{j,r,t}$ as the marginal value of net worth is equal to the marginal value of $D_{j,t}$.

The first-order conditions can be combined to yield

$$\left(\upsilon_{rs,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t}\right)\tau_t\right) = \frac{1}{\gamma}\left(\upsilon_{rb,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t}\right)\tau_t\right). \tag{2.34}$$

The left-hand side expresses the excess return (adjusted for outside equity) for the retail bank of assigning another unit of credit to firms. The right-hand side shows that providing interbank loans has two effects. On the one hand, the retail banker receives an excess return (adjusted for outside equity) of assigning another unit of interbank loan. On the other hand, these loans lead to a relaxation of the incentive constraint governed by γ and the resulting increased willingness of households to supply further deposits. As both effects have to equal the excess return of assigning another unit of credit to firms, the retail banker accepts a lower excess return on interbank loans if the corresponding relaxation effect via γ is strong enough

Combining (2.34), the guess (2.33) and the incentive constraint (2.31) yields a formula for the ratio of total assets to net worth that the households are willing to accept:

$$\frac{Q_t S_{j,r,t} + \gamma B_{j,r,t}}{N_{j,r,t}} = \frac{\upsilon_{rd,t}}{\theta_r - \left(\upsilon_{rs,t} - \upsilon_{rd,t} - \left(\upsilon_{re,t} - \upsilon_{rd,t}\right)\tau_t\right)} \equiv \phi_{r,t} \tag{2.35}$$

which we define as leverage ratio $\phi_{r,t}$. By using this equation together with the Bellman equation (2.32) and the guess (2.33), we can rewrite the value function of the retail banker as

$$V_{j,r,t} = E_t \Lambda_{t,t+1} \Omega_{r,t+1} N_{j,r,t+1}, \tag{2.36}$$

where $\Omega_{r,t+1} = 1 - \sigma + \sigma\left(\upsilon_{rd,t+1} + \left(\upsilon_{rs,t+1} - \upsilon_{rd,t+1} - \left(\upsilon_{re,t+1} - \upsilon_{rd,t+1}\right)\tau_{t+1}\right)\phi_{r,t+1}\right)$ and $N_{j,r,t+1}$ is given by (2.30). Due to the financial friction, the stochastic discount factor of retail banks differs from that of households by the factor Ω_{rt+1}.

To verify the initial guess, the coefficients of (2.33) have to satisfy

$$\begin{aligned} \upsilon_{rs,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} (1+T_k) R_{k,t+1} \\ \upsilon_{rb,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} R_{b,t+1} \\ \upsilon_{rd,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} R_t \\ \upsilon_{re,t} &= E_t \Lambda_{t,t+1} \Omega_{r,t+1} R_{e,t+1}. \end{aligned} \tag{2.37}$$

These equations together with the "allowed" leverage ratio (2.35) show how the retail bank is limited in the provision of loans and restricted to its net worth. Note, that the leverage ratio is the same for all retail banks as it does not depend on specific factors of bank j. Hence, we can drop the index j. The leverage ratio is increasing in the excess return on firm credits, $\upsilon_{rs,t} - \upsilon_{rd,t}$, as well as in the marginal value of net worth $\upsilon_{rd,t}$ since both increase the incentive to stay in business and therefore households show a higher willingness to deposit funds. The opposite is true for θ_r: the higher the ability to divert funds, the lower the willingness of households to deposits funds. The lower is γ, the larger the incentive-constraint relaxing effect of interbank loans as retail banks can provide more interbank loans while operating with the same (allowed) leverage ratio. The capital buffer requirement also enters the leverage ratio (2.35). As mentioned above, an increase in τ_t restricts the accumulation of net worth, given $R_{e,t+1} - R_t > 0$. This lowers the franchise value of the retail bank, and hence tightens the incentive constraint. Households have a lower willingness to deposit funds which is equivalent to a lower accepted leverage ratio.

Aggregate retail banks' net worth in the home country is given by the sum of surviving bankers' net worth which evolves according to (2.30) and entering bankers' startup funds, which is given by $\xi_r [R_{k,t} Q_{t-1} S_{r,t-1} + R_{b,t} B_{r,t-1}]/(1-\sigma)$ and provided by their respective household. Thus, aggregate net worth evolves according to

$$\begin{aligned} N_{r,t} &= \left((1+T_k)\sigma + \xi_r\right) R_{k,t} Q_{t-1} S_{r,t-1} + \left(\sigma + \xi_r\right) R_{b,t} B_{r,t-1} \\ &\quad - \sigma R_{t-1} D_{t-1} - \sigma R_{e,t} \left(Q_{t-1} S_{r,t-1} + B_{r,t-1}\right) \tau_{t-1}. \end{aligned} \tag{2.38}$$

Shadow banking

We model shadow banking as a subset of financial intermediation that has access to funds from domestic retail banks. By combining these interbank funds with their own net worth, shadow banks (or wholesale banks) make loans to both domestic and foreign intermediate goods firms. A core difference to retail banks lies in the assumption that shadow banks do not have access to deposits from households. As experienced during the GFC, shadow banking is mainly dependent on sponsoring retail banks and invested in multiple countries.

Accordingly, at the beginning of period t, shadow banker j uses net worth $N_{j,w,t}$ from retained earnings and interbank funds from domestic retail banks $B_{j,w,t}$ to make loans to domestic and foreign intermediate goods producers $Q_t S_{H,j,w,t} + Q_t^* S_{F,j,w,t}$.

The balance sheet during period t writes

$$S_{j,w,t} \equiv Q_t S_{H,j,w,t} + Q_t^* S_{F,j,w,t} = N_{j,w,t} + B_{j,w,t}. \tag{2.39}$$

Net worth in period $t+1$ evolves as the difference between earnings from loans $Q_t S_{H,j,w,t}$ and $Q_t^* S_{F,j,w,t}$ at $R_{k,t+1}$ and $R_{k,t+1}^*$ net off obligations to pay for the acquired funds $B_{j,w,t}$ at rate $R_{b,t+1}$. It evolves as

$$\begin{aligned} N_{j,w,t+1} &= (1+T_k)R_{k,t+1}Q_t S_{H,j,w,t} + R_{k,t+1}^* Q_t^* S_{F,j,w,t} - R_{b,t+1}B_{j,w,t} \\ N_{j,w,t+1} &= \big((1+T_k)R_{k,t+1} - R_{b,t+1} - \big((1+T_k)R_{k,t+1} - (1+T_k^*)R_{k,t+1}^*\big) x_{j,w,t}\big) S_{j,w,t} \\ &\quad + R_{b,t+1}N_{j,w,t}, \end{aligned} \tag{2.40}$$

where $x_{j,w,t} \equiv Q_t^* S_{F,j,w,t}/S_{j,w,t}$ denotes the share of foreign loans in the total amount of assets. Note that in order to have an efficient steady state both retail and shadow banks must receive the steady-state subsidy.

Similar to retail banks, shadow banks are constrained in their ability to raise funds from domestic retail banks due to a moral hazard problem. Retail banks are only willing to supply funds to shadow banks, if the latter can stick to the following incentive constraint:

$$V_{j,w,t} \geq \theta_w S_{j,w,t}. \tag{2.41}$$

It compares the gain from remaining in business (the franchise value $V_{j,w,t}$) with the gain from diverting a fraction of the balance sheet θ_w, returning it back to the own household and declaring bankruptcy in the following period. Accordingly, retail banks are only willing to supply interbank funds to shadow banks if they observe that shadow banks will remain active and proceed with doing business in the ongoing periods. We assume that there is no differentiation between domestic and foreign assets. This is similar to the one in Dedola et al. (2013), where retail banks are the only financial intermediaries which face an identical problem. However, we think that this assumption holds even more so for shadow banks since they bundle those assets together to issue $B_{j,w,t}$ which can be thought of as asset-backed securities.

The franchise value function of the shadow banker can also be written as Bellman equation

$$V_{j,w,t} = E_t \Lambda_{t,t+1}\left[(1-\sigma) N_{j,w,t+1} + \sigma V_{j,w,t+1}\right], \tag{2.42}$$

where σ is the surviving probability of the shadow bank and $\Lambda_{t,t+1}$ the stochastic discount factor, which again is the same as for households. The shadow banker chooses $S_{j,w,t}$, $x_{j,w,t}$ to maximize this franchise value subject to (2.40), (2.41). We formalize this maximization problem by using the following linear solution as guess

$$\begin{aligned} V_{j,w,t} &= \upsilon_{ws,t} Q_t S_{H,j,w,t} + \upsilon_{ws*,t} Q_t^* S_{F,j,w,t} - \upsilon_{wb,t} B_{j,w,t} \\ V_{j,w,t} &= \left(\upsilon_{ws,t} - \upsilon_{wb,t} - \left(\upsilon_{ws,t} - \upsilon_{ws*,t}\right) x_{j,w,t}\right) S_{j,w,t} + \upsilon_{wb,t} N_{j,w,t} \end{aligned} \tag{2.43}$$

where the coefficients $\upsilon_{ws,t}$ and $\upsilon_{ws*,t}$ are the marginal values of loans to domestic and foreign intermediate goods producers while $\upsilon_{wb,t}$ is the marginal value of net worth. The first-order conditions lead to a standard portfolio choice condition

$$\upsilon_{ws,t} = \upsilon_{ws*,t}, \tag{2.44}$$

stating that both marginal values have to be equalized.

Combining this equation, the conjecture (2.43) and the incentive constraint (2.41) yields a formula for the ratio of total assets to net worth that the retail banks are willing to accept:

$$\frac{S_{j,w,t}}{N_{j,w,t}} = \frac{\upsilon_{wb,t}}{\theta_w - (\upsilon_{ws,t} - \upsilon_{wb,t})} \equiv \phi_{w,t}, \tag{2.45}$$

which we define as leverage ratio $\phi_{w,t}$. By using this equation together with the Bellman equation (2.42) and the guess (2.43), we can rewrite the value function of the shadow banker as

$$V_{j,w,t} = E_t \Lambda_{t,t+1} \Omega_{w,t+1} N_{j,w,t+1}, \tag{2.46}$$

where $\Omega_{w,t+1} = 1 - \sigma + \sigma \left(\upsilon_{wb,t+1} + (\upsilon_{ws,t+1} - \upsilon_{wb,t+1})\, \phi_{w,t+1}\right)$ and $N_{j,w,t+1}$ is given by (2.40). Due to the financial friction, the stochastic discount factor of shadow banks also differs from that of households by the factor Ω_{wt+1}.

Verifying the initial conjecture (2.43) leads to the following coefficients

$$\begin{aligned}
\upsilon_{ws,t} &= E_t \Lambda_{t,t+1} \Omega_{w,t+1} (1 + T_k) R_{k,t+1} \\
\upsilon_{ws*,t} &= E_t \Lambda_{t,t+1} \Omega_{w,t+1} (1 + T_k^*) R_{k,t+1}^* \\
\upsilon_{wb,t} &= E_t \Lambda_{t,t+1} \Omega_{w,t+1} R_{b,t+1}.
\end{aligned} \tag{2.47}$$

These equations together with the accepted leverage ratio (2.45) show how the shadow bank is limited in the provision of loans and restricted to its net worth. As with retail banks, we can drop index j since the leverage ratio is independent from bank-specific factors of bank j. The leverage ratio is increasing in the excess return on firm credits, $\upsilon_{ws,t} - \upsilon_{wb,t}$, as well as in the marginal value of net worth $\upsilon_{wb,t}$ since both increase the incentive to stay in business and therefore retail banks are more willing to provide funds. The opposite is true for θ_w: the higher the ability to divert funds, the lower the willingness of retail banks to grant interbank loans.

Using these coefficients, we can rewrite the portfolio choice condition (2.44) which is equivalent to the one in the model of Dedola et al. (2013):

$$E_t \left\{ \Lambda_{t,t+1} \Omega_{w,t+1} \left((1 + T_k) R_{k,t+1} - (1 + T_k^*) R_{k,t+1}^* \right) \right\} = 0.$$

Note that foreign shadow banks face an analogous condition. In a first-order approximation, optimal international asset portfolios $(x_{w,t}, x_{w,t}^*)$ are not defined as $E_t R_{k,t+1} \simeq E_t R_{k,t+1}^*$.[2] Only the steady states x_w, x_w^* enter the model up to first

[2] Due to symmetry, the steady-state subsidies will be identical in both countries.

order. These could be derived by various approaches.[3] However, our subsequent analysis of optimal policy shows that it is only relevant whether shadow banks are engaged in both countries or not.[4] This stems from the assumption of symmetric countries. Hence, we also choose a symmetric portfolio allocation.

Aggregate net worth of the shadow banking sector is given by the sum of surviving bankers' net worth which evolves according to (2.40) and entering bankers' startup funds, which is given by $\xi_w R_{k,t} Q_{t-1} S_{w,t-1}/(1-\sigma)$ and provided by their respective household. Thus, aggregate net worth evolves according to

$$\begin{aligned} N_{w,t} &= \sigma\left((1+T_k)R_{k,t} - \left((1+T_k)R_{k,t} - (1+T_k^*)R_{k,t}^*\right)x_{w,t-1}\right)S_{w,t-1} \\ &\quad -\sigma R_{wb,t}B_{w,t-1} + \xi_w\left(R_{k,t} - \left(R_{k,t} - R_{k,t}^*\right)x_{w,t-1}\right)S_{w,t-1} \qquad (2.48) \end{aligned}$$

2.3.6 Equilibrium

The model is closed with the market clearing conditions for goods, non-financial loans as well as interbank funds, and with the policy response functions.

Home final goods market clearing reads

$$Y_t = C_{H,t} + \frac{(1-m)}{m}C_{H,t}^* + \frac{P_t}{P_{H,t}}\left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right]I_t. \qquad (2.49)$$

The market for interbank funds clears when demand by shadow banks equals supply by retail banks:

$$B_{w,t} = B_{r,t} \equiv B_t. \qquad (2.50)$$

The markets for non-financial loans clear when firms' total loan demand meets total loan supply from the banking sector. Thus we get

$$Q_t K_t = Q_t S_{r,t} + Q_t S_{H,w,t} + \frac{(1-m)}{m} Q_t S_{H,w,t}^* \qquad (2.51)$$

$$Q_t^* K_t^* = Q_t^* S_{r,t}^* + Q_t^* S_{F,w,t}^* + \frac{m}{(1-m)} Q_t^* S_{F,w,t}. \qquad (2.52)$$

2.3.7 Policies and welfare objective

Before we turn the focus on policies, we want to emphasize the implications of purchasing power parity together with a common nominal interest rate. The Fisher equation interrelates the nominal interest rate i_t to the real rate according to

$$R_t = \frac{i_t}{E_t \pi_{t+1}^U}, \qquad (2.53)$$

[3] For instance, by using the method developed by Devereux and Sutherland (2011) or by using CES aggregators to simplify the modeling of the international portfolio allocation (e.g. Auray et al., 2018).

[4] Results for this issue are available upon request.

where $\pi_t^U \equiv P_t/P_{t-1}$ and the superscript U denotes union-wide (aggregate) variables. Due to purchasing power parity, home and foreign consumer price inflation rates are identical: $\pi_t = \pi_t^* = \pi_t^U$. As a result, real interest rates in both countries are equalized: $R_t = R_t^*$. Recall that $E_t R_{k,t+1} \simeq E_t R^*_{k,t+1}$ holds up to first order. When there are no differences in macroprudential policy, i.e. $\tau_t = \tau_t^*$, cross-border financial integration via the shadow banking system leads to an equalization of the marginal values $\upsilon_{rs,t} \simeq \upsilon^*_{rs,t}$, $\upsilon_{rb,t} \simeq \upsilon^*_{rb,t}$, $\upsilon_{rd,t} \simeq \upsilon^*_{rd,t}$, $\upsilon_{re,t} \simeq \upsilon^*_{re,t}$, $\upsilon_{ws,t} \simeq \upsilon^*_{ws,t}$, $\upsilon_{wb,t} \simeq \upsilon^*_{wb,t}$ and therefore to an equalization of leverage ratios $\phi_{r,t} \simeq \phi^*_{r,t}$ and $\phi_{w,t} \simeq \phi^*_{w,t}$ up to first order due to symmetry. This result is similar to the one obtained by Dedola et al. (2013), but different in its derivation. Here, an internationally active shadow banking sector leads to the described equalization and hence to a cross-border transmission channel.

For the sake of simplicity and tractability, monetary policy is characterized by strict inflation targeting

$$\widehat{i}_t = \kappa_\pi \widehat{\pi}_t^U, \tag{2.54}$$

where a "^" symbol is used to denote the percentage deviation of a variable from its steady-state value. A union-wide (aggregate) variable $\widehat{z}_t^U$ is defined as the weighted average of national variables, $\widehat{z}_t^U \equiv m\widehat{z}_t + (1-m)\widehat{z}_t^*$. In the analysis of the model, we will also make use of relative variables $\widehat{z}_t^R$ which are defined as $\widehat{z}_t^R \equiv \widehat{z}_t - \widehat{z}_t^*$.

Macroprudential regulation follows the BASEL III-Accords. Based on the experiences of the GFC, these regulations are geared towards improving the quality, composition and consistency of bank equity capital by implementing leverage restrictions and more adequate and resilient capital buffers (Bank for International Settlements 2010). We capture these objectives by implementing a macroprudential regulator that sets a capital buffer based on the outside equity ratio of retail banks. The macroprudential tool used to steer the capital buffer is a policy rule that reacts to changes in credit spreads from its steady-state level as a sign for financial distress. The usage of credit spreads as indicators of financial distress is motivated by empirical evidence. Akinci and Queralto (2017) report that real economic activity and credit spreads tend to move asymmetrically. During crises times when macro variables like GDP or investment drop immensely, credit spreads increase sharply and financial variables like bank equity decrease. Gilchrist and Zakrajsek (2012) report similar evidence and show that credit spreads are appropriate signs of financial turmoil.

In our experiments, the considered disturbances bring about a recession that is characterized by a significant drop in macroeconomic variables, downturns in financial aggregates and accompanied widening in credit spreads. To counteract these developments, macroprudential regulation sets capital buffers. However, using regulatory policies in the setup of a currency union implies considerations of country- vs. union-wide arrangement of such policies. Depending on these arrangements, macroprudential policy either follows a union-wide or two country-specific simple feedback rules in the form of

$$
\begin{aligned}
\widehat{\tau}_t^U &= -\kappa_\tau^U(\widehat{R}_{k,t+1}^U - \widehat{R}_t^U) \\
\widehat{\tau}_t &= -\kappa_\tau(\widehat{R}_{k,t+1} - \widehat{R}_t) \\
\widehat{\tau}_t^* &= -\kappa_\tau^*(\widehat{R}_{k,t+1}^* - \widehat{R}_t^*), \qquad (2.55)
\end{aligned}
$$

which state that the respective tool countercyclically reacts to changes in the credit spread depending on the weights $\kappa_\tau^U, \kappa_\tau, \kappa_\tau^*$. Once the economy runs through a recession and credit spreads widen, the response is to reduce capital buffers which leads to an increase in retail banks' "accepted" leverage ratio. This, in turn, allows retail banks to operate their business with lower levels of net worth. The process of deleveraging is moderated.

The parameters for monetary policy (κ_π) and macroprudential policy ($\kappa_\tau^U, \kappa_\tau, \kappa_\tau^*$) are set optimally according to the following objective function that can be derived from a second-order Taylor expansion of households utility functions around the efficient steady state (see Appendix for details):

$$
-E_0\left\{\sum_{t=0}^{\infty}\beta^t\frac{1}{2}\mathcal{L}_t\right\} + t.i.p.,
$$

where $t.i.p.$ stands for terms independent of policy. Under the assumption of symmetry with regards to real-side variables, the per-period quadratic deadweight loss function is given by

$$
\begin{aligned}
\mathcal{L}_t = &\frac{Y}{C}\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right)\frac{\varepsilon\zeta}{(1-\zeta)(1-\beta\zeta)}\left[(\widehat{\pi}_t^U)^2 + m\,(1-m)\,(\widehat{\pi}_t^R)^2\right] \\
&-\frac{Y}{C}\left[(\widehat{Y}_t^U)^2 + m\,(1-m)\,(\widehat{Y}_t^R)^2\right] + \frac{\rho}{2}\left[(\widehat{C}_t^U)^2 + m\,(1-m)\,(\widehat{C}_t^R)^2\right] \\
&+\frac{Y}{C}(1-\alpha)\,(1+\varphi)\left[(\widehat{L}_t^U)^2 + m\,(1-m)\,(\widehat{L}_t^R)^2\right] \\
&+\frac{I}{C}\left[(\widehat{I}_t^U)^2 + m\,(1-m)\,(\widehat{I}_t^R)^2\right] + \frac{I}{C}\eta_I\left[(\Delta\widehat{I}_t^U)^2 + m\,(1-m)\,(\Delta\widehat{I}_t^R)^2\right] \\
&+\frac{\tau}{C}\,(S_r+B)\,\eta_e\left[(\widehat{\tau}_t^U)^2 + m\,(1-m)\,(\widehat{\tau}_t^R)^2\right], \qquad (2.56)
\end{aligned}
$$

where $\Delta\widehat{I}_t^U \equiv \widehat{I}_t^U - \widehat{I}_{t-1}^U$ and $\Delta\widehat{I}_t^R \equiv \widehat{I}_t^R - \widehat{I}_{t-1}^R$.

In this representation, the weights of the respective variables are functions of deep model parameters that we specify in the following section. The variables in the first three lines are the standard target variables and weights for a two-country currency union. Aggregate and relative inflation leads to undesirable union-wide and relative price dispersions as these imply inefficient production of goods. As individuals are averse to fluctuations in consumption and hours worked, these variables also lead to welfare losses. The fourth line enters the loss function due to existence and depreciation of capital and due to the per se costs of adjusting investment.

Note that the loss function is increasing in output conditional on variances in inflation, consumption, labor, and investment as a higher variance could lead to more income making the households better off. As output is linked to the other variables via the resource constraints, one could show that this positive effect is realized by higher volatilities of the other, loss-inducing variables. Thus, by eliminating this variable using e.g. the goods market clearing condition, the allegedly positive effect will turn out to be partly negative. However we will not eliminate further variables from the welfare function as this will make the analysis more complicated by introducing various covariances.[5] By abstracting from capital, i.e. $\alpha = 0, Y = C, I = 0$ and $\tau = 0$, and by using the production functions as well as the resource constraints to eliminate labor and consumption, we would obtain the standard loss function as, for example, in Benigno (2004) with inflation output and the terms of trade as objectives.

The fifth line enters the loss function due to the existence of portfolio adjustments costs of bank outside equity that households have to bear. As adjusting the equity portfolio in response to fluctuations of retail banks asset side leads to costs for the respective household (see 2.13), any changes directly transfer into a loss. Given that the outside equity ratio of retail banks is set by the macroprudential regulator, the macroprudential tool directly enters the loss function. Then, using the capital buffers during crises (and moving it from its steady-state level) automatically leads to welfare losses per se. However, the policymaker takes these losses into account when setting the instrument. These losses depend on the steady-state amount of retail banks' asset side and therefore on the size of the shadow banking sector.

In the case of merely a union-wide macroprudential tool, i.e. the policymaker has only the two aggregate tools $\widehat{i}_t$ and $\widehat{\tau}_t^U$, relative variables cannot be addressed. Fluctuations in relative variables still create welfare losses but the policymaker ignores them by dropping differentials from the objective function.

2.4 Dynamics

2.4.1 Calibration

This section represents the parametrization of our model. For most of the parameters for households, goods producers and capital producers we follow, among others, Gertler and Karadi (2011) and use common standard values. Table 2.1 shows the respective values. In our benchmark scenario, the countries are of equal size, i.e. $m = 0.5$, and the parameters from Table 2.1 apply to both countries.

To be more precise: the time interval is a quarter. The household discount factor β is 0.99 and implies a steady-state risk-free rate of roughly 4.1% per year. A relative utility weight of labor of 3.713 ensures $L = L^* = 1/3$. The Frisch elasticity of labor

[5] See Edge (2003) for further details.

Households		
Discount factor	β	0.99
Relative utility weight of labor	χ	3.713
Inverse Frisch elasticity of labor supply	φ	0.276
Elasticity of equity spread to capital buffer	η_e	1
Goods producers		
Capital share in production	α	0.33
Depreciation rate	δ	0.025
Capital producers		
Elasticity of investment	η_I	1.728
Retailers		
Elasticity of substitution between goods	ε	4.167
Calvo parameter	ζ	0.779
Financial intermediaries in the benchmark scenario		
Survival probability	σ	0.90
Divertable fraction of assets in retail banking	θ_r	0.2012
Divertable fraction of assets in shadow banking	θ_w	0.1475
Relative divertibility of retail banks' interbank loans	γ	0.25
Proportional startup transfer to new retail bankers	ξ_r	0.0111
Proportional startup transfer to new shadow bankers	ξ_w	0.0095
Steady-state capital buffer	τ	0.05

Table 2.1: Parametrization

supply φ is 0.276. For the elasticity of the equity spread to the capital buffer, we follow Nelson and Pinter (2018) by setting η_e to 1 which rather provides an upper bound for this effect. The remaining values of the parametrization of the real side of the model (intermediate goods firms, capital producers and retailers) are standard.

The parameters that determine the financial setup are chosen in line with the shadow banking model of Meeks et al. (2017). In particular, the surviving rate of retail banks and shadow banks, σ, is chosen to generate a dividend payout rate of 10%. Banks' relevant annual spread between non-financial loans and the risk-free rate, $(1 + T_k)R_k - R$, is set to 100 basis points which is also in line with the euro area model of Lama and Rabanal (2014). As $R_k = R$, the steady state of the real side of the model is equivalent to the one of an efficient real business cycle model. The relevant spread for shadow banks, $(1 + T_k)R_k - R_b$, is set to 75 basis points. To replicate the extraordinary high degree of leverage in the shadow banking sector, we calibrate the leverage ratio for retail banks to 5.2 and for shadow banks to 8. However, as seen during the recent crisis, this is a rather conservative value. Furthermore, in our benchmark scenario, we target a size of the shadow banking sector of 25% of total loan origination/capital, i.e. $S_w/K = 0.25$. This entails a ratio of interbank loans to non-financial loans B/S_r of 0.3 and a ratio of retail bank non-financial loans to inside and outside equity, $QS_r/(N_r + qe)$, of 4. Following Nelson and Pinter (2018), the steady-state capital buffer τ equals 5%. The parameters θ_r, θ_w, γ, ξ_r, and ξ_w are set to match the mentioned targets.

As mentioned above, the steady state of our model is efficient due to subsidies. Hence, frictions due to retail or shadow banks or demanding a certain capital buffer have no welfare effect in the steady state. However, this modeling approach allows us to analyze the dynamics of different scenarios regarding the financial side for identical real-side steady states. In the following, we compare our described benchmark scenario with the scenarios of national shadow banking (no financial integration) and no shadow banking at all. In the former two cases, we obtain a steady-state value for the overall leverage ratio of the banking system, $QK/(N_r + N_w)$, of 5.9. In the case of no shadow banks, only national retail banks are active in the banking sector providing credit to domestic firms. In this scenario, we set θ_r and ξ_r to 0.2095 and 0.0141 respectively, in order to have the identical overall leverage ratio of the banking system, i.e. $QK/N_r = 5.9$.

The shocks could occur either as union-wide or as country-specific disturbances. The technology shocks follow AR (1) processes with autoregressive factors of 0.8 and standard deviations of 0.01. The net worth shocks are transitory 10% shocks.

2.4.2 International transmission of shocks

Before we present the analysis of the impulse responses to the disturbances, we want to make the reader aware of the nature of the two kinds of shocks and the role of international integration in the transmission processes. The first is a negative shock to the total factor productivity and the second a shock to net worth of retail banks. We have chosen these shocks to reflect a real-side shock and a financial-side shock.

The shock to the total factor productivity, i.e. productivity shock, is a standard disturbance in the DSGE-literature and recently used in Gertler and Karadi (2011) or Nelson and Pinter (2018). It reflects an exogenous supply-side disturbance and directly hits the production function of intermediate goods producers. The immediate impact on output is clearly destructive as investment falls, among others, due to a rise in credit spreads. This is a consequence of the negative impact on capital and hence transmitted to financial intermediaries who hold capital as collateral (assets) on their balance sheet. They are instantly exposed to the shock and the resulting fluctuation in asset values. In turn, financial intermediaries respond with adjustments to their net worth to compensate for the losses on their asset side. In the consequence, the economy passes through a deep recession. [6]

[6] Sims (2011) points out that the meaningfulness of technology shocks as drivers of business cycles crucially hinges on the concept of technology being an observable variable. As it is, however, not readily observable since measurements require data and theoretical approaches, its role is questioned. To overcome these shortcomings and to find an adequate disturbance for the GFC, a frequent approach to model large-scale downturns is the usage of capital quality shocks (see e.g. Gertler and Karadi 2011, Dedola et al. 2013 or Kirchner and Schwanebeck 2017). The

The second disturbance emerges within the financial system and is a negative shock to the net worth of retail banks as for example introduced by Nelson and Pinter (2018). This disturbance is purely financial in nature. It hits retail banks' aggregate net worth and thereby destroys regulatory bank capital. This forces retail banks to reduce their asset holdings to levels that correspond to their post-shock net worth level. The ensuing consequence for retail banks is to adjust loan origination to the productive sector what in turn depresses real economic activity.

The international implications of these shocks vary with the degree of real and financial integration. Country-specific shocks can induce a synchronization of macroeconomic variables if the integration of the real and financial sphere is sufficiently large. As the next section shows, there are, however, differences between purely financial (net worth) and real (technology) shocks. What arises as a natural question then is to what extent macroprudential measures are able to mitigate the country-specific and union-wide effects of the shocks and how they interact with monetary policy. It is thus of interest to study the impact of country-specific and union-wide policy coordination given different levels of real and financial integration. We report the findings in the following.

2.4.3 Impulse response analysis

Our benchmark scenario is a world with full integration of the financial sphere due to internationally active shadow banks, i.e. they supply credit to domestic and foreign firms. For each shock, we compare our benchmark with the scenarios of national shadow banking (no financial integration) and no shadow banking at all. As union-wide shocks under the assumption of symmetry would resemble closed-economy scenarios that have already been analyzed in the literature (see, for instance, Gertler et al., 2016 and Meeks et al., 2017), we focus our analysis on idiosyncratic shocks to the home country.

Home technology shock: Figure 2.1 and 2.2 show the home technology shock. The immediate reactions are drops in output, consumption, and investment exacerbated by increases in credit spreads and the policy rate. As inflation increases due to higher marginal costs of intermediate goods firms and since home country inflation drives aggregate inflation, optimal monetary policy sets a higher nominal interest rate. The initial downturns are followed by a destruction of the capital stock. As already pointed out by Gertler and Karadi (2011) or Krenz (2018), the impact

impulse responses generated by this shock reveal a destructive impact on the model and enable to study crises of comparable magnitude to the GFC. However, this comes with drawbacks (see e.g. Krenz 2018). The destructive impact of the shock is chiefly caused by its implementation into the model. As it simultaneously hits the production function (like a technology shock), the process of capital accumulation and the balance sheet of banks via the impact on capital, the shock operates through multiple channels and induces large downturns with persistent impact. We want to avoid such transmission mechanisms resulting from capital quality shocks and rather focus on technology as a source of disturbance.

of financial intermediation on the downturn caused by a technology shock is rather small. Accordingly, the model response is largely driven by changes in real variables. However, the financial accelerator can be described in the following way *(no shadow banking)*. As capital and investment fall in the aftermath of the shock, so does the price of capital. This now brings about a transmission to the financial sector since financial intermediaries (only retail banks) hold capital as collateral on their balance sheet and supply the productive sector with credit. The lower capital stock and the accompanied devaluation of the capital price destroys banks' net worth. This induces a fire sale of assets in order to meet the leverage ratio constraint which eventually results in a lower credit supply.

Although not hit by the shock, the repercussions are transmitted to foreign via international trade, i.e. the drop in demand for goods. The on impact decreases in capital and investment are comparable to in home and force foreign to run through a similar recession, but less severe compared to home.

Once the flow of credit to the real sector is divided between retail and shadow banks *(national shadow banking)*, the shock is more destructive as the financial accelerator becomes stronger. Shadow banking obviously acts as a shock amplifier. The drop in output is larger and the recession is more persistent. Both financial intermediaries reduce net worth. Retail banks can moderate the effect on their balance sheet by reducing interbank lending (shifting losses to shadow banks) and increase lending to firms what in turn improves their franchise value. For shadow banks, the negative effect of the shock is strengthened by their higher degree of leverage and retail banks cutting back interbank funds. As a major financing source disappears, shadow banks fire sale assets and reduce lending. As shadow credit intermediation drops and retail banks cannot fully compensate the reduction, the output loss increases. As mentioned, foreign feels the repercussions through the trade channel. Although smaller in magnitude, the effect of shadow banking is destructive. Without financial integration, foreign is thus partly protected from too stark fluctuations at the real side. To sum up, in the presence of real shocks, national shadow banking acts as an additional friction in the financial sector, it amplifies the repercussions.

Once shadow banking supplies domestic and foreign firms with credit, the model features full integration *(benchmark scenario)*. What we observe is that the change in the amplification of real shocks through financial integration is small. The main mechanism of transmission remains the international consumption channel. However, home is now hit harder once opening the financial side. The immediate drop in output is stronger as investment and capital both decrease more. The latter is a direct consequence of an increase in the credit spread. As it widens, it makes investment less attractive. However, retail banks are able to benefit by increasing loan supply to the productive sector as this helps them to improve their franchise value. While retail banks partly benefit, shadow banks do not. A reduction in interbank funding by retail banks worsens their financing structure and forces them to reduce credit supply. Their net worth drops.

Foreign now benefits from the introduction of financial integration. The impact on output is clearly positive as a result of a reduction in the drop in investment and capital. The latter drops less as the widening in relevant credit spreads decreases. Although retail banks reduce credit supply to firms, they increase interbank funds to shadow banks. This, combined with a decrease in the leverage ratio, helps shadow banks to increase credit supply and reduce the negative impact on their net worth. While the forces of financial integration tend to cushion the transmission of a real shock, the mechanisms at work help to stabilize the variables in the welfare objective (2.56) as the benefits of foreign outweigh the losses of home.

Home net worth shock: Figure 2.3 and 2.4 show the results for a retail bank net worth shock in the home country. This shock is purely financial in nature and, accordingly, takes full effect at the financial side of the model. Retail banks hold the entire capital stock and the sudden reduction of their net worth is followed by massive fire sales of assets, a downward spiral in asset prices and a destruction of the capital stock *(no shadow banking)*. The effects are fully transmitted throughout the economy and the impact of this financial shock is clearly destructive. Although not hit by the shock, the repercussions are transmitted to foreign via the international trade in goods. However, the effect is outweighed by expansionary monetary policy. Since the decrease in home inflation drives aggregate inflation, the central bank lowers the interest rate. Hence, foreign undergoes a mild boom.

Now, once the capital stock is divided between retail and shadow banks *(national shadow banking)*, the impact of the sudden reduction in retail banks' net worth is moderated by their lower fraction of managed capital. Although retail banks extend interbank lending to shadow banks to moderate the negative impact on their franchise value, the drop in the price of capital spills over to the shadow banking sector, forcing them to start a deleveraging process. Hence, net worth and credit supply by shadow banks drop in the aftermath of the shock, but roughly three periods after the initial disturbance they are able to expand credit supply to firms to positive levels. Thus, overall credit supply and therefore capital decrease by a lower amount and the negative effect on output can be moderated. As the decrease in home inflation is smaller, the decrease in the policy rate can be smaller to stabilize union inflation. As monetary policy is the main transmission channel, the boom in foreign is smaller even under a stronger financial accelerator. Hence, in the face of a net worth shock, shadow banking moderates the downturn and acts as a shock absorber.

When shadow credit intermediation is extended to an international level *(benchmark scenario)*, foreign is now fully exposed to the shock through the forces of financial integration that bring about a perfect equalization of spreads and leverage ratios in the shadow banking sector. Given the synchronized financial side of the model, this purely financial shock has now identical real-side effects in both countries. The consequence of the idiosyncratic shock in home is a truly global recession with synchronized downturns in investment, employment, and output in both countries which cannot be corrected by monetary policy as the nominal interest rate is too blunt to offset financial disturbances.

Proposition 2.1 *In the case of shocks to the real sphere, the existence of shadow banking intensifies the financial accelerator effects and operates as a shock amplifier. Financial integration cushions the transmission to foreign. During financial shocks, shadow banking under financial autarky rather operates as shock absorber as it can partly compensate the losses incurred by retail banks. Financial integration induces a union-wide recession.*

Proof. See text. ■

Accordingly, what we observe is that in all of the considered scenarios, monetary policy at the union-level is not able to adequately address the financial effects of the disturbances. There seems to be a clear role for macroprudential policy.

2.4.4 Implications for the conduct of macroprudential policy

Continuing the analysis of the idiosyncratic shocks above, we focus on the case of full financial integration and allow for either a country-specific or union-wide macroprudential tool. The policymaker optimizes both the monetary as well as the macroprudential policy rules according to the welfare objective (2.56). This implies full coordination of both policies which is an appropriate assumption for a monetary union as the euro area (see e.g. Palek and Schwanebeck 2019).

As a result of cross-border financial integration via shadow banks, the main financial variables are perfectly aligned internationally (see figures 2.1-2.4). Hence, any shock leads to identical movements in leverage ratios and credit spreads in both countries. Introducing macroprudential policy as a financial instrument at the national level could change this result. However, by following a welfare objective that takes both countries into account, it is optimal to reduce relative gaps between the members of the monetary union instead of creating new relative differences in financial variables. Thus, the prudential policy reactions have to be identical in both countries. This is equivalent to having a union-wide tool only.

Proposition 2.2 *In the case of full financial integration, there are no additional welfare gains from having country-specific macroprudential tools.*

Proof. See text. ■

To illustrate the stabilization effects of a union-wide macroprudential tool (or national tools that are set identically), we plot graphs symbolizing the actual gap of comparing the scenario with macroprudential policy (P) to the one without this policy (nP), in which there is solely optimized monetary policy. For instance, if a variable shows a drop due to a shock, an increase in this gap would display a lower decrease under macroprudential policy. On the other hand, if a variable increases following a shock, an increase in the gap would show that the variable rises even more under prudential policy.

While the solid line in figures 2.1-2.4 illustrate the repercussions of both shocks under cross-border financial integration via shadow banks, figures 2.5 and 2.6 show the corresponding gaps or changes due to macroprudential policy for the home technology and home net worth shock. As the union-wide tool affects both economies via the already perfectly harmonized financial sphere, it has identical stabilization effects in both countries. Hence, the figures only display home variables as the gaps are identical for foreign.

Home technology shock and macroprudential regulation: As a direct consequence of the macroprudential intervention, the drop in retail banks' net worth can be reduced since the policy positively affects the (allowed) leverage ratio. While this would normally benefit credit supply by retail banks, they rather use the policy to slightly reduce credit origination and shift assets through the interbank market to shadow banks. Shadow banks, in turn, benefit and can increase their loan supply to the productive sector. Credit spreads decrease and the overall influence on credit supply is positive. Hence, the reduction in capital can be moderated (positive gap). In turn, the effect on output is positive which would eventually lead to more inflation. However, as macroprudential policy moderates the targets of the welfare objective besides inflation, monetary policy can react more aggressively. Under macroprudential policy, the increase in the monetary policy rate is slightly higher in order to stabilize the increase in union inflation to a larger extent. The higher interest rate leads to a further drop in Y on impact. In the subsequent periods, the positive effect of macroprudential policy on capital dominates this negative effect of monetary policy. Hence, we obtain a stabilization effect (positive gap).

Home net worth shock and macroprudential regulation: In contrast to the technology shock, the origin of this shock is the financial sector. As a consequence, the macroprudential tool is more effective in stabilizing the welfare targets. The transmission channel of macroprudential policy is the same as above, eventually stabilizing the capital stock and thereby stabilizing output. As this shock leads to lower union inflation, the inflationary output-stabilizing effect of macroprudential policy also stabilizes inflation. Hence, monetary policy reduce the interest rate by a lesser amount. However, this effect is outweighed by macroprudential policy which results in an overall positive output response.

So far we have discussed the implication of full financial integration via shadow banks for macroprudential policy under these two idiosyncratic shocks. Next, we turn to the implications of other scenarios regarding the modelling of shadow banks. We also allow for union-wide shocks to identify the gains from having a union-wide macroprudential tool. Obviously, there are no gains from country-specific tools in these cases and due to symmetry, financial integration does not affect the outcomes. Table (2.2) shows the welfare losses and optimized policy parameters under different scenarios and for different instrument sets. Losses are expressed in percentage points and have to be interpreted as fraction of steady-state consumption that must be given up to equate welfare in the stochastic economy to that in a deterministic steady state.

To begin with, we want to focus our attention on the impact of shadow banking on welfare results. The question of interest is how the household welfare is dependent on the structure of the financial system given different shocks and policy responses. Proposition 3 highlights the main outcomes.

Proposition 2.3 *Under real shocks, the mere existence of (national) shadow banking causes increasing welfare losses. Then, neither financial integration nor macroprudential policy can compensate the additional losses. Under a financial shock, shadow banking (domestic and international) reduces welfare losses. Macroprudential policy leads to further welfare gains.*

Proof. See text below. ■

Table (2.2) shows the respective welfare losses. To be precise, we compare the losses for an idiosyncratic technology shock in line 1 for noS vs. S vs. FI with the corresponding losses in line 3, when a union-wide macroprudential tool (τ^U) complements monetary policy. What we observe is that once shadow banking takes over a fraction of domestic credit origination, the loss incurred by households increases from 2.89 to 3.09. Acting under full financial integration then leads to a reduction in the welfare loss to 3.05, but this number clearly remains above levels observed without shadow banking (noS). These effects are a direct consequence of the fact that the introduction of shadow banking magnifies the financial accelerator effect. In a world without shadow banking, only retail banks are subject to the financial friction that drives an inefficient wedge between borrowing and lending rates. Once shadow banking takes over a fraction of credit supply, this effect is strengthened, the financial accelerator becomes more powerful. Accordingly, welfare losses must necessarily increase given a shock to the real sphere. In a financially integrated union, these losses slightly decrease as the forces of financial integration cushion the negative effects of the shock. However, this can only partly offset the incurred losses. Considering now the scenario with monetary policy and a union-wide macroprudential tool (τ^U), hence the losses in line 3 (3.00 and 2.96), it gets obvious that the welfare stabilizing effect of the macroprudential tool is never sufficiently large to reduce the household losses to levels observed without shadow banking (compare any, 2.89 or 2.83). This obviously stems from the fact that shadow banking is per definition unregulated and thus an additional vulnerability of the system and a risk to financial stability. Hence, a macroprudential regulator equipped with entity-based tools (i.e. geared towards the regular banking sector) can only indirectly affect inefficiencies and vulnerabilities originating from the shadow banking sector. As such, shadow banking can be interpreted as a additional disturbance per se.

However, considering the case of a shock to retail banks' net worth puts another complexion on things. What we observe now is that once shadow banking takes over a fraction of domestic credit origination (line 1, idiosyncratic net worth shock), the loss incurred by households decreases from 7.03 to 4.44. Acting under full financial integration again reduces the incurred loss to 1.26. Obviously, shadow banking now acts as a shock absorber and moderates the downturn what in turn leads to welfare improvements. As already discussed in the former sections, this is a direct consequence of shadow banking taking over a fraction of the capital stock through credit intermediation. The absolute impact on retail banks' net worth remains unchanged but the relative strength of the impact on the economy is reduced as they now hold less capital. Considering now the scenario with monetary policy and a union-wide macroprudential tool (τ^U), hence the losses in line 3 (4.34 and 1.16), we observe that the union-wide macroprudential tool now unfolds welfare stabilizing effects that are sufficiently large to reduce the household losses for every observed scenario (without and with shadow banking). However, this result certainly hinges on the fact that we abstract from modeling any costs (i.e. efficiency losses) or disturbances arising from the existence of shadow banking or additional uncertainty due to the lack of regulation in this sector. Considering costs or disturbances arising in the shadow banking sector could eventually lead to welfare losses due to the existence of shadow banking.

We now want to turn the focus of attention on the design of macroprudential policy. The question of interest is how the household welfare is dependent on the design of macroprudential policy given varying structures of the financial system. Our findings are summarized in the following.

Proposition 2.4 *A union-wide macroprudential regulation is welfare improving for both real and financial shocks, the forces of financial integration even facilitate its effectiveness. The gains are the largest for a financial shock. Country-specific macroprudential tools are only beneficial under financial autarky or absent shadow banks.*

Proof. See text below. ■

Again, Table (2.2) shows the respective welfare losses. To be precise, we compare the losses in line 1 for S vs. FI (3.09 vs. 3.05 and 4.44 vs. 1.26) with the corresponding losses in line 3 (3.00 vs. 2.96 and 4.43 vs. 1.16), when a union-wide macroprudential tool (τ^U) complements monetary policy. Although the improvements are larger under the net worth shock and, in general, should be larger for idiosyncratic financial shocks, a union-wide macroprudential regulation (in combination with monetary policy) is effective in reducing the incurred welfare losses of households in all of the considered cases. The fact that we observe the gains to be larger for financial shocks then for real shocks can be ascribed to the objective and especially the point of intervention of macroprudential regulation. As it is designed to increase the resilience and hence the stability of the financial system and works through the leverage ratio and hence the balance sheet of retail banks (see 2.35), it is necessarily most effective against disturbances emanating from the financial sphere. Due to the harmonization of the financial spheres of both countries, the effectiveness even increases. Disturbances arising from the real sphere can be addressed, but less effectively. While not exclusively, this calls for a purposeful usage of fiscal policies.

Furthermore, taking a closer look at the interaction of monetary and macroprudential policy, we observe that if macroprudential policy is coordinated at the union-level, the response of monetary policy to inflation is more aggressive. This can be seen by comparing the optimal parameter value for monetary policy κ_π in line 2 for idiosyncratic technology and net worth shocks (4.42 and 7.08, respectively) with the κ_π-values in line 4 (4.97 and 7.28). Obviously, due to macroprudential policy, monetary policy can put a larger weight on its primary objective inflation which reduces the welfare loss of households. This supports the positive effects of macroprudential policy and results in welfare improvements.

Finally, our welfare analysis reveals that switching from union-wide to country-specific macroprudential tools entails advantages only if considering countries in financial autarky or absent shadow banking. However, we then observe these gains to be larger for financial shocks than for real shocks.

As we only consider the extreme cases of no financial integration and full financial integration under full coordination, these results rather show the lower and the upper bounds of the "first-best" welfare gains. While national macroprudential policy is beneficial in cases of no shadow banking or at least no integration via the financial side, these benefits seem to vanish with the degree of financial integration. As the former two cases are rather unrealistic scenarios for monetary unions such as the euro area or the U.S., the additional welfare gains from having country-specific macroprudential policy seems to be rather scarce or even questionable. It is plausible to assume that once integrated at the financial side to a certain degree, macroprudential policy needs to be coordinated at the supranational level. In a world with country-specific rules and missing common regulatory arrangements, differences in regulations would induce regulatory arbitrage causing cross-country substitution and relocation effects and possibly a worsening of the effects of shocks. In addition, there is a clear role for governance considerations and political issues. The possibility of political fall-outs at the national level favors macroprudential regulation at a supranational level. For reasons of unpopularity of tighter regulations, e.g. disadvantages of banking competition, macroprudential policy could be inactive at the national level. These political-economy considerations are beyond the scope of our analysis. Gros and Schoenmaker (2014) as well as Schoenmaker (2013) address some of these institutional arrangement issues for the euro area. A starting point for theoretical consideration can be found in De Paoli and Paustian (2017). They analyze strategic

		technology shock					net worth shock				
		union		idiosyncratic			union		idiosyncratic		
scenario		no S	S/FI	no S	S	FI	no S	S/FI	no S	S	FI
i	Loss	3.72	4.52	2.89	3.09	3.05	8.14	5.05	7.03	4.44	1.26
	κ_π	5.24	4.42	5.24	4.42	4.42	6.91	7.08	6.91	7.08	7.08
i, τ^U	Loss	3.51	4.16	2.83	3.00	2.96	7.44	4.62	6.86	4.34	1.16
	κ_π	5.74	4.97	5.74	4.97	4.97	6.99	7.28	6.99	7.28	7.28
	κ_τ^U	0.74	0.99	0.74	0.99	0.99	0.47	0.43	0.47	0.43	0.43
i, τ, τ^*	Loss			2.78	2.93	2.96			5.94	3.71	1.16
	κ_π			5.74	4.97	4.97			6.85	7.11	7.28
	κ_τ			0.05	0.17	0.99			0.71	0.68	0.43
	κ_τ^*			1.53	1.99	0.99			4.46	5.55	0.43

Table 2.2: Welfare losses under the scenarios: no shadow banks (no S), with shadow banks but no financial integration (S), and full financial integration (FI)

interdependencies in a single-country setting with retail banking.

2.5 Conclusion

In this paper we study the interaction of international shadow banking with optimized monetary and macroprudential policy in a two-country currency union DSGE model. In our benchmark setup, we allow for financial integration through international shadow banks that are, besides domestic credit intermediation, able to extend cross-border credits to foreign firms. As a result the financial sectors are aligned internationally and any shock leads to identical movements in leverage ratios and credit spreads in both countries.

We can draw the following conclusions: Our analysis shows that in the presence of shocks to the real sphere, the existence of shadow banking intensifies the financial accelerator effects. Shadow banks, highly leveraged and dependent on retail banking funds, appear to be an additional source of instability and thus operate as a shock amplifier. However, our analysis also reveals that during financial shocks, shadow banking under financial autarky rather operates as shock absorber. In this scenario, it can partly compensate the losses incurred by retail banks and thereby unfold its stabilizing effect.

In terms of the optimal design of macroprudential policy, our analysis demonstrates that regulation situated at the country-level is only beneficial under financial autarky or absent shadow banking. A sufficiently large stabilization of the relevant household welfare measure is only achieved once macroprudential regulation acts union-wide hence coordinated. Such a supranational macroprudential regulation that symmetrically intervenes in both countries of the union is able to effectively counteract the negative consequences of the observed shocks. While the gains are larger for financial shocks than for real shocks, they are even facilitated through the forces of financial integration. This result seems plausible since a macroprudential regulation that is based on BASEL III is primarily designed to address systemic risk in the banking sector and hence financial stability (see e.g. BIS 2010). A policy designed to counteract the build-up of bank exposure is thus highly effective given shocks emanating from this very sector. Furthermore, the follow-up effect of union-wide macroprudential regulation is a more stringent setting of the policy rate through monetary policy. Since financial stability is cared for by the macroprudential regulator, monetary policy is now able to react more aggressively to its primary objective inflation. Moreover, our welfare analysis shows that under real shocks, the mere existence of (national) shadow banking causes increasing welfare losses. In such a case, neither financial integration nor macroprudential policy can compensate the additional losses. As the shadow banking sector in our model (and in general) is unregulated and highly leveraged, it constitutes a vulnerability to the stability of the financial system. A macroprudential regulator equipped with an entity-based regulation approach as in our case thus only indirectly affects the vulnerabilities originating from this sector.

However, our analysis leaves room for several interesting extensions but that are beyond the scope of this paper. While we consider financial integration via shadow banks that are engaged in both countries, an asymmetric approach with unilateral financial flows in the sense of Nuguer (2016) could change the conduct of macroprudential policy in a monetary union. Another interesting extension would be the aforementioned political-economy considerations and strategic interactions between the central bank and macroprudential authorities as in De Paoli and Paustian (2017). In a heterogeneous union like the euro area, these considerations are especially important as member countries might be in favor of different (monetary and) macroprudential objectives. It would thus be interesting to take into account game theoretical issues for the optimal arrangement of such policies. It seems very likely that these issues would even more favor macroprudential policy-making at the union level. We leave these questions for future research.

Appendix: Union's Welfare Loss

Let X_t be a generic variable and X its steady state. Then, we define $\widehat{X}_t$ as the log deviation of X_t around X, $\widehat{X}_t = \log(X_t/X)$. Hence, using a second-order Taylor approximation yields

$$\frac{X_t - X}{X} = \exp(\widehat{X}_t) - 1 \simeq \widehat{X}_t + \frac{1}{2}\widehat{X}_t^2.$$

In the following, we will drop terms independent of policy (e.g. stand-alone shock terms) and terms of third and higher order.

The policy maker's welfare objective is defined as the unconditional expectation of home and foreign households' average lifetime utility. Starting from the period utility function

$$\begin{aligned} mU(C_t, L_t) + (1-m)U(C_t^*, L_t^*) \;\equiv\; U_t^U &= m\left[\frac{C_t^{1-\rho}}{1-\rho} - \chi\frac{L_t^{1+\varphi}}{1+\varphi}\right] \\ &+(1-m)\left[\frac{(C_t^*)^{1-\rho}}{1-\rho} - \chi\frac{(L_t^*)^{1+\varphi}}{1+\varphi}\right], \end{aligned}$$

we obtain the following second-order approximation:

$$\begin{aligned} U_t^U \;\simeq\; & U^U + U_C C\left[m\frac{C_t - C}{C} + (1-m)\frac{C_t^* - C}{C}\right] \\ & + \frac{1}{2}U_{CC}C^2\left[m\left(\frac{C_t - C}{C}\right)^2 + (1-m)\left(\frac{C_t^* - C}{C}\right)^2\right] \\ & . - U_L L\left[m\frac{L_t - L}{L} + (1-m)\frac{L_t^* - L}{L}\right] \\ & . - \frac{1}{2}U_{LL}L^2\left[m\left(\frac{L_t - L}{L}\right)^2 + (1-m)\left(\frac{L_t^* - L}{L}\right)^2\right], \end{aligned}$$

where $C = C^*, L = L^*$ due to symmetry and therefore $U = U^* = U^U$ as well as $U_C = U_{C^*}$, $U_{CC} = U_{C^*C^*}$, $U_L = U_{L^*}$, $U_{LL} = U_{L^*L^*}$.

Rearranging the terms and using log deviations yields

$$\begin{aligned} \frac{U_t^U - U^U}{U_C C} \;\simeq\; & m\widehat{C}_t + (1-m)\widehat{C}_t^* + \frac{1-\rho}{2}\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] \\ & - \frac{U_L L}{U_C C}\left(m\widehat{L}_t + (1-m)\widehat{L}_t^* + \frac{1+\varphi}{2}\left[m\widehat{L}_t^2 + (1-m)\left(\widehat{L}_t^*\right)^2\right]\right). \end{aligned}$$

Labor market clearing in an efficient steady state reads

$$\frac{U_L}{U_C} = (1-\alpha)\frac{Y}{L},$$

which leads to

$$
\begin{aligned}
\frac{U_t^U - U^U}{U_C C} &\simeq m\widehat{C}_t + (1-m)\widehat{C}_t^* + \frac{1-\rho}{2}\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] \\
&\quad -(1-\alpha)\frac{Y}{C}\left(m\widehat{L}_t + (1-m)\widehat{L}_t^*\right) \\
&\quad -\frac{1}{2}(1-\alpha)(1+\varphi)\frac{Y}{C}\left[m\widehat{L}_t^2 + (1-m)\left(\widehat{L}_t^*\right)^2\right]
\end{aligned}
$$

We can eliminate the linear consumption term by using the aggregate resource constraint which can be derived by combining the budget constraints of all agents of the model. We obtain the following approximation

$$
\begin{aligned}
m\widehat{C}_t + (1-m)\widehat{C}_t^* &= -\frac{1}{2}\left[m\widehat{C}_t^2 + (1-m)\left(\widehat{C}_t^*\right)^2\right] + \frac{Y}{C}\left(m\widehat{Y}_t + (1-m)\widehat{Y}_t^*\right) \\
&\quad +\frac{1}{2}\frac{Y}{C}\left[m\widehat{Y}_t^2 + (1-m)\left(\widehat{Y}_t^*\right)^2\right] \\
&\quad -\frac{I}{C}\left(m\widehat{I}_t + (1-m)\widehat{I}_t^* + \frac{1}{2}\left[m\widehat{I}_t^2 + (1-m)\left(\widehat{I}_t^*\right)^2\right]\right) \\
&\quad -\frac{1}{2}\frac{I}{C}\eta_i\left[m\left(\widehat{I}_t - \widehat{I}_{t-1}\right)^2 (1-m)\left(\widehat{I}_t^* - \widehat{I}_{t-1}^*\right)^2\right] \\
&\quad -\frac{1}{2}\frac{\tau}{C}\left(S_r + B\right)\eta_e\left[m\widehat{\tau_t}^2 + (1-m)\left(\widehat{\tau}_t^*\right)^2\right].
\end{aligned}
$$

The linear terms in labor can be eliminated by the use of the production function of both countries combined with price dispersion resulting from retailers. These read

$$
\begin{aligned}
\left[\int_0^1 \left(\frac{P_{H,t}(h)}{P_{H,t}}\right)^{-\varepsilon} di\right] Y_t &= A_t K_{t-1}^{\alpha} L_t^{1-\alpha} \\
\left[\int_0^1 \left(\frac{P_{F,t}(f)}{P_{F,t}}\right)^{-\varepsilon} di\right] Y_t^* &= A_t^*\left(K_{t-1}^*\right)^{\alpha}\left(L_t^*\right)^{1-\alpha}.
\end{aligned}
$$

Approximating and rearranging yields

$$
\begin{aligned}
\widehat{L}_t &= \frac{1}{1-\alpha}\left(\widehat{Y}_t - \widehat{A}_t - \alpha\widehat{K}_{t-1} + \frac{1}{2}\varepsilon\left(1 + \frac{\varepsilon\alpha}{1-\alpha}\right) var_h\widehat{p}_t(h)\right) \\
\widehat{L}_t^* &= \frac{1}{1-\alpha}\left(\widehat{Y}_t^* - \widehat{A}_t^* - \alpha\widehat{K}_{t-1}^* + \frac{1}{2}\varepsilon\left(1 + \frac{\varepsilon\alpha}{1-\alpha}\right) var_f\widehat{p}_t(f)\right).
\end{aligned}
$$

Hence,

$$
\begin{aligned}
\frac{U_t^U - U^U}{U_C C} \simeq\ & \frac{Y}{C} m \left(\alpha \widehat{K}_{t-1} - \frac{I}{Y} \widehat{I}_t \right) + \frac{Y}{C} m \left(\alpha \widehat{K}_{t-1}^* - \frac{I}{Y} \widehat{I}_t^* \right) \\
& - m \frac{1}{2} \frac{Y}{C} \varepsilon \left(1 + \frac{\varepsilon \alpha}{1-\alpha} \right) var_h \widehat{p}_t \left(h \right) \\
& - (1-m) \frac{1}{2} \frac{Y}{C} \varepsilon \left(1 + \frac{\varepsilon \alpha}{1-\alpha} \right) var_f \widehat{p}_t \left(f \right) \\
& + \frac{1}{2} \frac{Y}{C} \left[m \widehat{Y}_t^2 + (1-m) \left(\widehat{Y}_t^* \right)^2 \right] \\
& - \frac{1}{2} \rho \left[m \widehat{C}_t^2 + (1-m) \left(\widehat{C}_t^* \right)^2 \right] \\
& - \frac{1}{2} (1-\alpha) (1+\varphi) \frac{Y}{C} \left[m \widehat{L}_t^2 + (1-m) \left(\widehat{L}_t^* \right)^2 \right] \\
& - \frac{1}{2} \frac{I}{C} \left[m \widehat{I}_t^2 + (1-m) \left(\widehat{I}_t^* \right)^2 \right] \\
& - \frac{1}{2} \frac{I}{C} \eta_i \left[m \left(\widehat{I}_t - \widehat{I}_{t-1} \right)^2 (1-m) \left(\widehat{I}_t^* - \widehat{I}_{t-1}^* \right)^2 \right] \\
& - \frac{1}{2} \frac{\tau}{C} \left(S_r + B \right) \eta_e \left[m \widehat{\tau}_t{}^2 + (1-m) (\widehat{\tau}_t^*)^2 \right].
\end{aligned}
$$

To eliminate the remaining first-order terms we follow the approach of Edge (2003). Recall that in an efficient steady state it holds that

$$
\begin{aligned}
I &= \delta K \\
R &= \frac{1}{\beta} = R_k = \alpha \frac{Y}{K} + (1-\delta),
\end{aligned}
$$

which can be combined to yield

$$
\frac{I}{Y} = \frac{\alpha \beta \delta}{1 - \beta \left(1 - \delta \right)}.
$$

Furthermore, log-linearizing the equation for the evolution of capital results in

$$
\widehat{K}_t = \delta \widehat{I}_t + \left(1 - \delta \right) \widehat{K}_{t-1}.
$$

Now we can rewrite the linear terms as follows

$$
\begin{aligned}
\alpha \widehat{K}_{t-1} - \frac{I}{Y} \widehat{I}_t &= \alpha \widehat{K}_{t-1} - \frac{\alpha \beta \delta}{1 - \beta \left(1 - \delta \right)} \widehat{I}_t \\
&= \alpha \widehat{K}_{t-1} - \frac{\alpha \beta}{1 - \beta \left(1 - \delta \right)} \left[\widehat{K}_t - \left(1 - \delta \right) \widehat{K}_{t-1} \right] \\
&= \frac{\alpha}{1 - \beta \left(1 - \delta \right)} \left[\widehat{K}_{t-1} - \beta \widehat{K}_t \right].
\end{aligned}
$$

Since overall utility is a discounted sum of period utility, we can simplify this further:

$$E_0\sum_{t=0}^{\infty}\beta^t\left(\alpha\widehat{K}_{t-1}-\frac{I}{Y}\widehat{I}_t\right) = \frac{\alpha}{1-\beta(1-\delta)}E_0\left[\begin{array}{c}\widehat{K}_0-\beta\widehat{K}_1+\beta\left(\widehat{K}_1-\beta\widehat{K}_2\right)\\ +\beta^2\left(\widehat{K}_2-\beta\widehat{K}_3\right)+...\\ +\beta^t\left(\widehat{K}_t-\beta\widehat{K}_{t+1}\right)+...\end{array}\right]$$
$$= \frac{\alpha}{1-\beta(1-\delta)}E_0\widehat{K}_0.$$

As $\widehat{K}_0$ is assumed to be independent of policy, these linear terms can be dropped. The same can be applied for $\left(\alpha\widehat{K}^*_{t-1}-\frac{I}{Y}\widehat{I}^*_t\right)$

Finally, it can be shown (see e.g. Woodford, 2003, chap. 6) that

$$E_0\sum_{t=0}^{\infty}\beta^t var_h\widehat{p}_t(h) = \frac{\zeta}{(1-\zeta)(1-\beta\zeta)}E_0\sum_{t=0}^{\infty}\beta^t(\widehat{\pi}_t)^2$$
$$E_0\sum_{t=0}^{\infty}\beta^t var_f\widehat{p}_t(f) = \frac{\zeta}{(1-\zeta)(1-\beta\zeta)}E_0\sum_{t=0}^{\infty}\beta^t(\widehat{\pi}^*_t)^2$$

Using these expressions, the welfare function can be written as

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t\frac{U^U_t-U^U}{U_C C}\right\} = -E_0\left\{\sum_{t=0}^{\infty}\beta^t\frac{1}{2}\mathcal{L}_t\right\}+t.i.p.,$$

where

$$\begin{aligned}\mathcal{L}_t = {} & \frac{Y}{C}\left(1+\frac{\varepsilon\alpha}{1-\alpha}\right)\frac{\varepsilon\zeta}{(1-\zeta)(1-\beta\zeta)}\left[(\widehat{\pi}^U_t)^2+m(1-m)(\widehat{\pi}^R_t)^2\right]\\ & -\frac{Y}{C}\left[(\widehat{Y}^U_t)^2+m(1-m)(\widehat{Y}^R_t)^2\right]+\frac{\rho}{2}\left[(\widehat{C}^U_t)^2+m(1-m)(\widehat{C}^R_t)^2\right]\\ & +\frac{Y}{C}(1-\alpha)(1+\varphi)\left[(\widehat{L}^U_t)^2+m(1-m)(\widehat{L}^R_t)^2\right]\\ & +\frac{I}{C}\left[(\widehat{I}^U_t)^2+m(1-m)(\widehat{I}^R_t)^2\right]+\frac{I}{C}\eta_I\left[(\Delta\widehat{I}^U_t)^2+m(1-m)(\Delta\widehat{I}^R_t)^2\right]\\ & +\frac{\tau}{C}(S_r+B)\eta_e\left[(\widehat{\tau}^U_t)^2+m(1-m)(\widehat{\tau}^R_t)^2\right],\end{aligned}$$

in which we make use of the relation $m\widehat{z}^2_t+(1-m)(\widehat{z}^*_t)^2=(\widehat{z}^U_t)^2+m(1-m)(\widehat{z}^R_t)^2$ for any pair of variables $\widehat{z}_t,\widehat{z}^*_t$.

Appendix: Figures

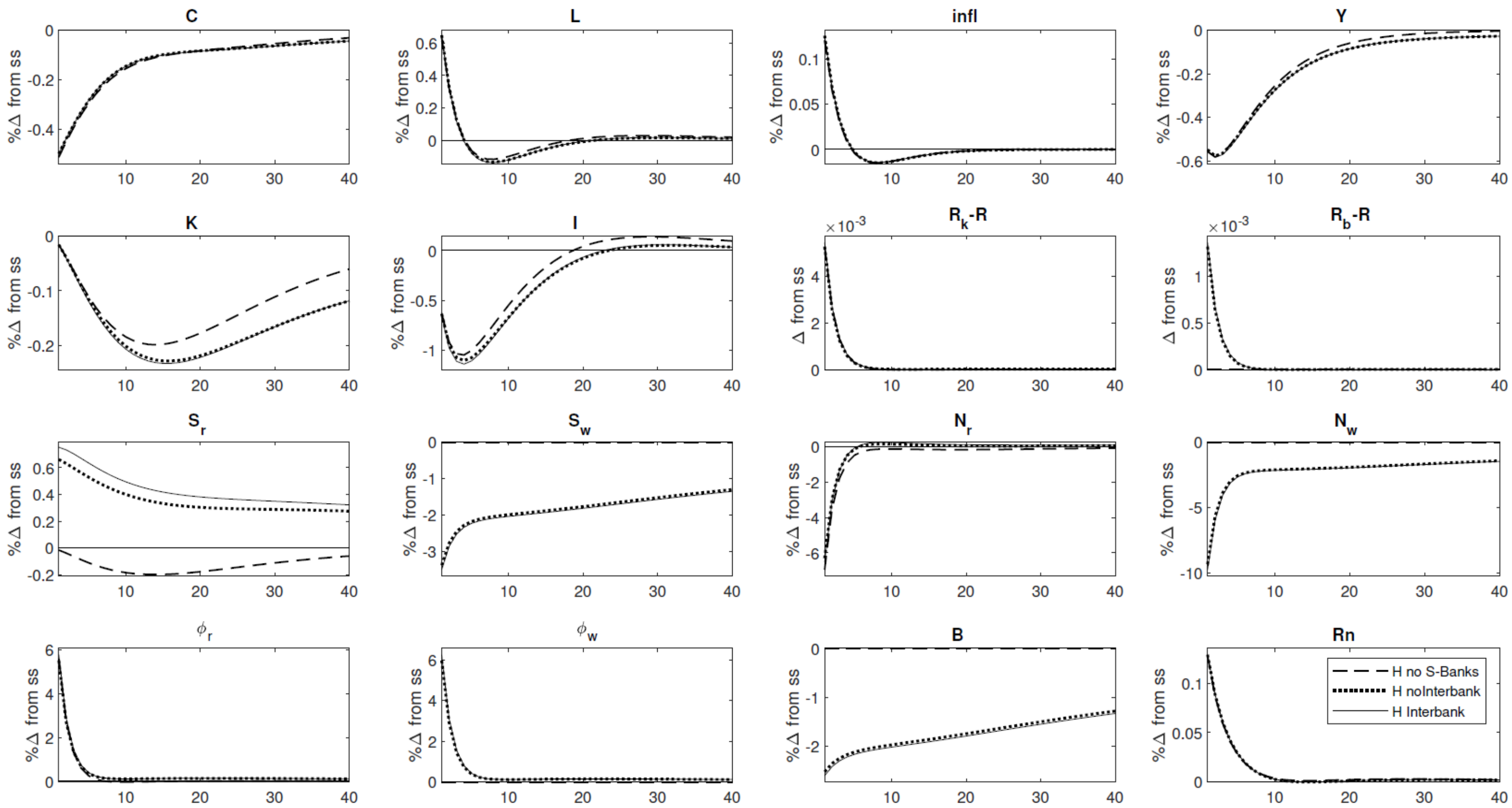


Figure 2.1: Country home: technology shock in home

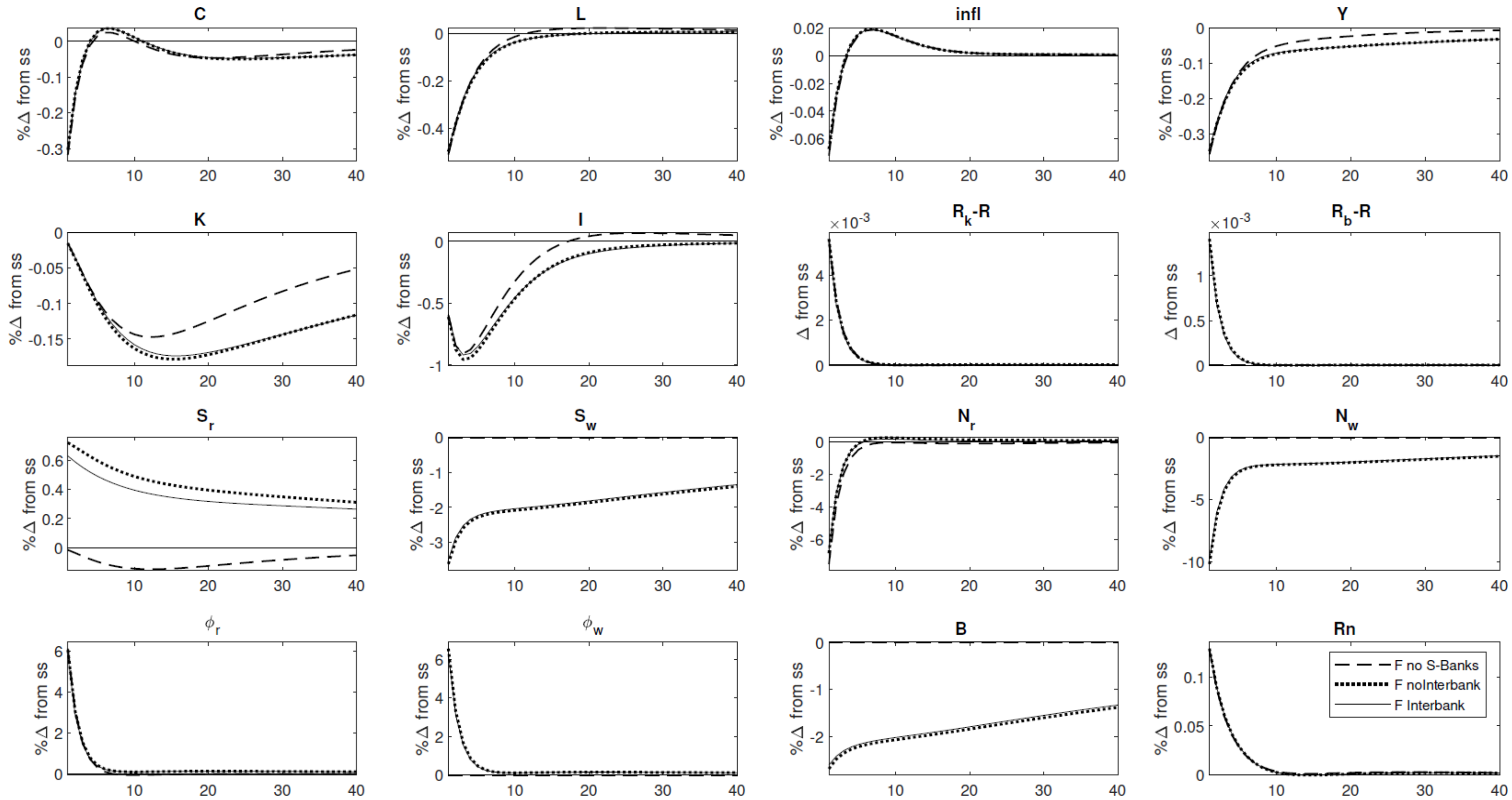


Figure 2.2: Country foreign: technology shock in home

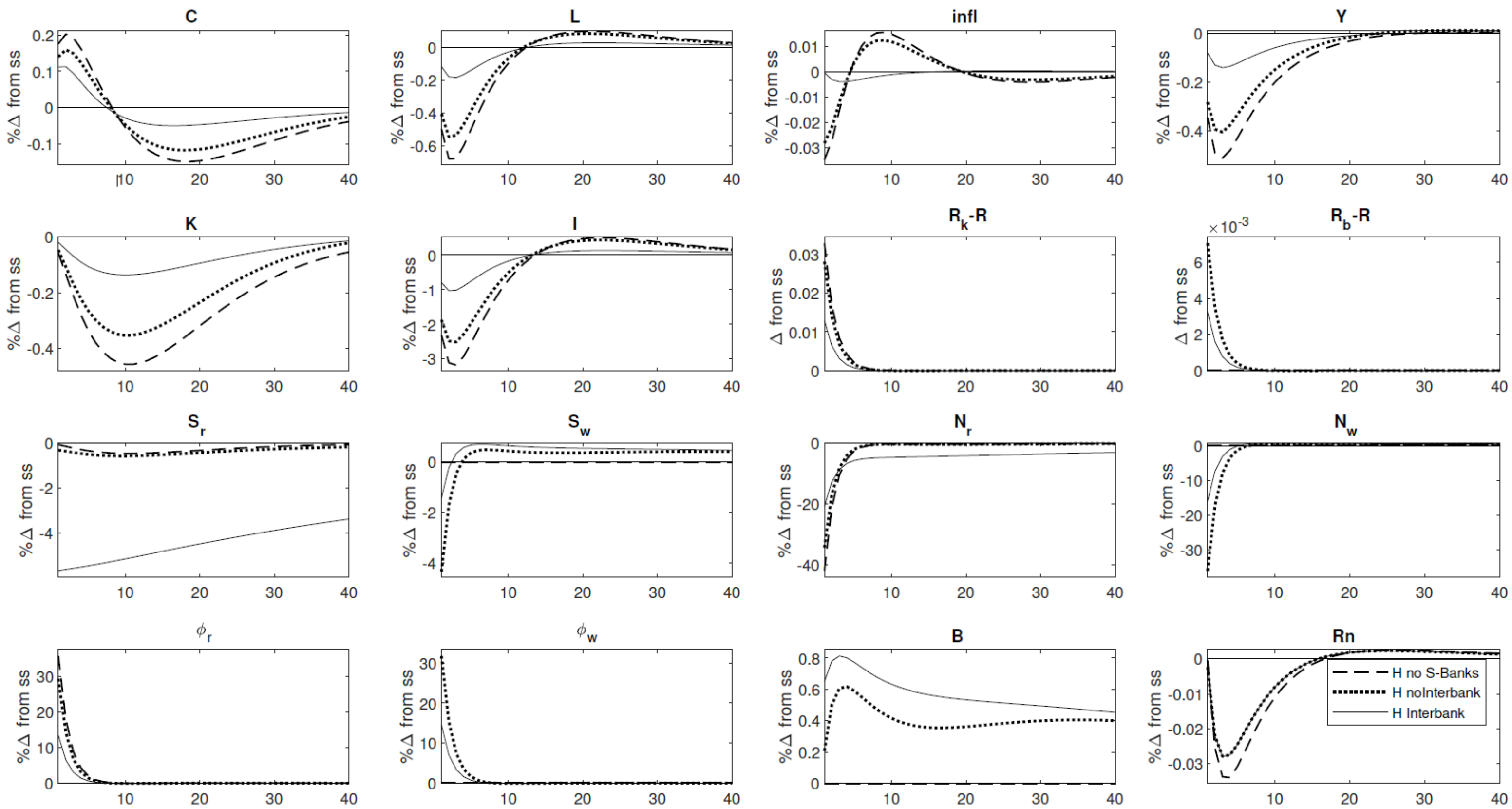


Figure 2.3: Country home: net worth shock in home

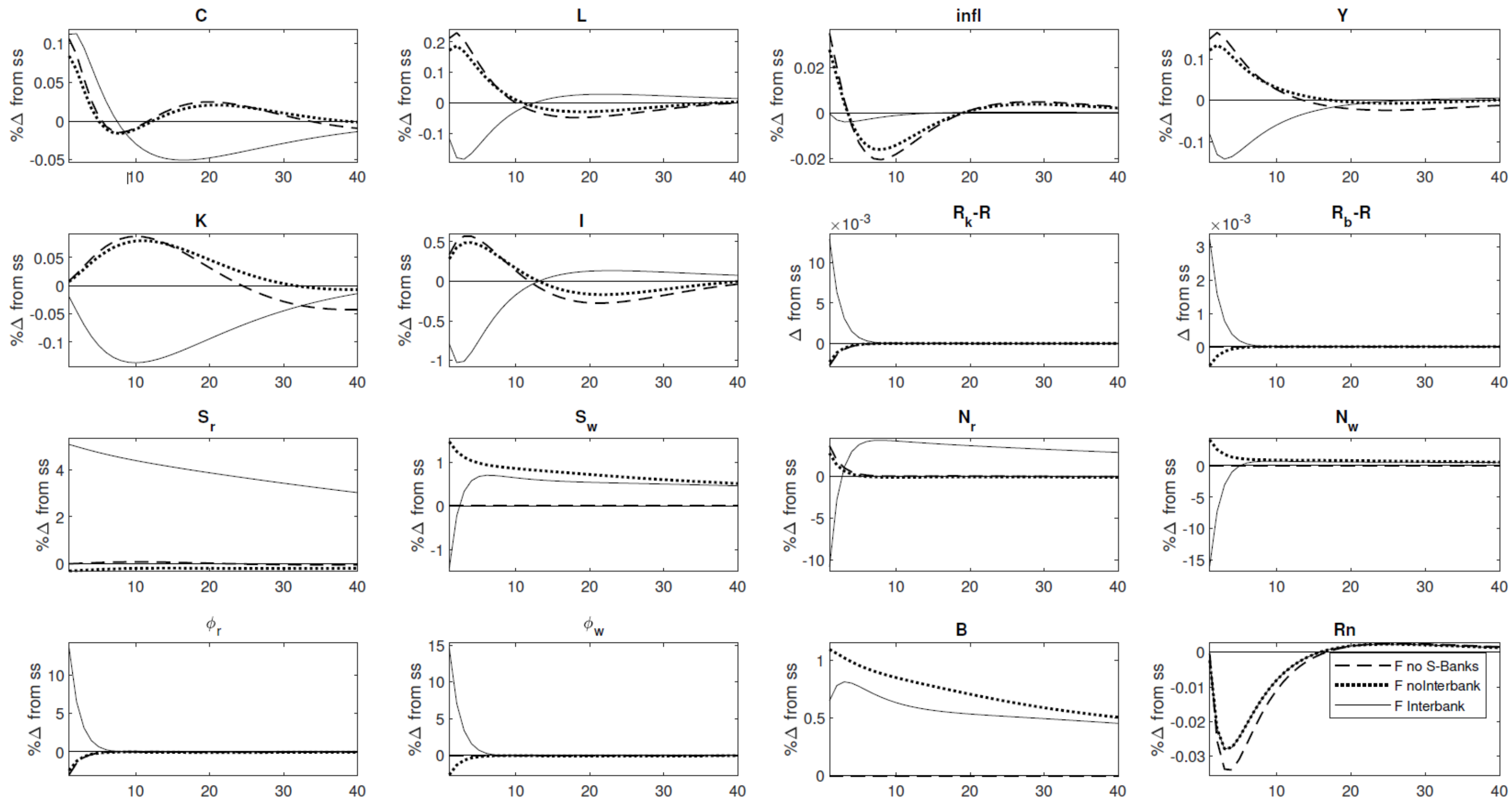


Figure 2.4: Country foreign: net worth shock in home

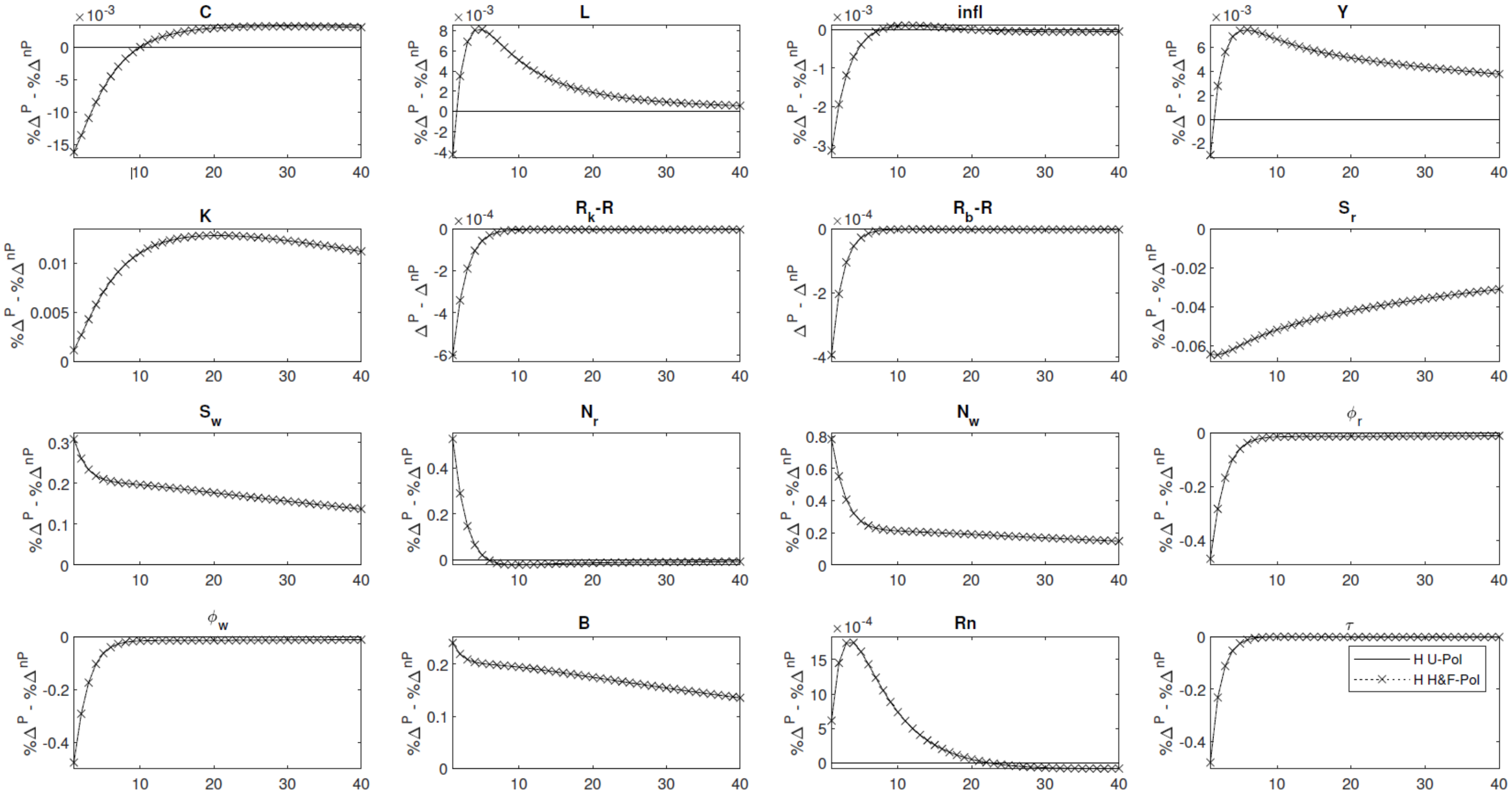


Figure 2.5: Country home: Union (U-Pol) and Country-Specific (HF-Pol) macroprudential regulation to a technology shock

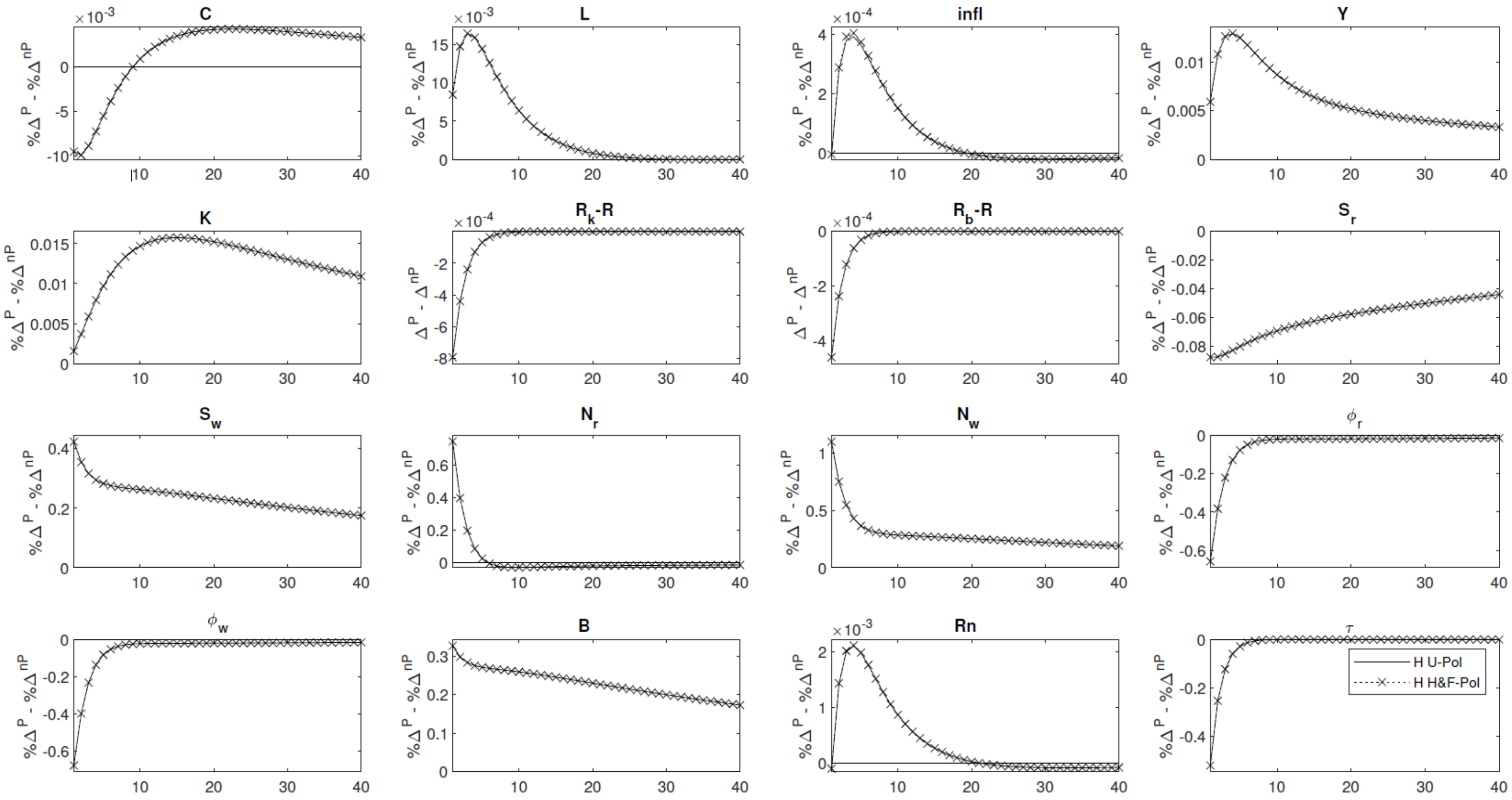


Figure 2.6: Country home: Union (U-Pol) and Country-Specific (HF-Pol) macroprudential regulation to a net worth shock

Chapter 3

On Shadow Banking and Financial Frictions in DSGE Modeling

3.1 Introduction

At the forefront of macroeconomic research on the why and wherefore of the crisis was and still is the usage of dynamic stochastic general equilibrium (DSGE) models. These models stem from the real business cycle literature but are enriched with real and nominal frictions and are thus rich in detail in depicting the economy. The behavior of agents is based on microeconomic foundations and to gain empirical fit, these models are often taken to the data (Smets et al. 2010). As these aspects make them applicable for reasonable business cycle analyses, these models became the state-of-the-art workhorse framework for the assessment of macroeconomic and especially monetary policy considerations and form an essential part of the policy making process of central banks (e.g. the ECB, the Fed or the Sveriges Riksbank). However, the classes of DSGE models used for policy analysis prior to the Great Financial Crisis (GFC) did not show sufficient signs of the vulnerability of the financial system. As they placed insignificant emphasis on the role of financial markets and frictions in financial intermediation, they were neither capable of depicting the financial (subprime) crisis that hit the U.S. economy in 2007, nor were they able to predict that it might escalate into a financial crisis on an international scale. At that time, the recent generation of DSGE models was ill-suited for making adequate monetary policy and financial stability assessments (see e.g. Christiano et al. 2018 or Gertler, Kiyotaki and Prestipino 2016). After the GFC unfolded internationally, its causes and consequences have been extensively studied. It is nowadays acknowledged that, among others, a strong nexus between the stability of financial sectors and real economic activity exists and that a combination of lax regulation and financial innovation precipitated the impact of shadow banking on the evolution of the GFC. These insights were gained not least because DSGE modeling rapidly turned to consider elaborated setups of financial intermediation, all sorts of unconventional monetary policy measures and macroprudential regulatory tools. This new generation of models now accounts for the nexus between financial sectors and the real economy, frictions in financial intermediation and financial distress causing crises of comparable impact to the GFC. Moreover, a growing body of literature considers heterogeneities in financial intermediation as reflected by shadow banking activities. Such considerations are especially important given the fact that non-bank financial intermediation like shadow banking has significant impacts on both monetary policy measures and financial stability tools. As postulated by the Bundesbank, if banking activities are increasingly conducted by non-bank entities outside the regular scope of central banks, implications occur for the monetary analysis on the one hand, and the proper and effective conduct of monetary policy and financial stability measures on the other (Deutsche Bundesbank 2014). Hence, reasonable assessments of monetary policy and financial stability measures require DSGE setups with fully-fledged financial sectors, a nexus with the real side of the economy and shocks that can cause financial distress causing repercussions comparable to the GFC.

The objective of this paper is to give a detailed review of this new generation of DSGE models. To this end, it contributes to the literature in the following ways. To begin with, it is the first attempt to give a structured review of the literature that incorporates shadow banking activities into DSGE models. We approach the topic from the angle of the economic rationale at the heart of shadow banking. Being aware of the driving forces that motivate agents to engage in this type of intermediation draws a clear picture of the factors influencing demand and supply and directs researchers' and policy makers' attention to more adequate and targeted modeling setups. We then give a short recap of the evolution of financial frictions and financial intermediation in DSGE modeling in order to draw attention to why these models failed to predict the GFC and what changed afterwards. Secondly, we present the latest progress of DSGE setups considering shadow banking activities and compare the findings with the economic rationales. We can identify two broader modeling emphases: one strand of the literature implements shadow banking as specialized institutions in the process of financial intermediation with comparative advantages over retail banks in managing financial capital, and the other strand focuses on the aspect of financial innovation where shadow banking acts as a supplier of securitized financial products. Hence, by considering "specialization" and "financial innovation", the DSGE literature touches on two important economic rationales at the heart of shadow banking activities. Based on this, we explain the core setup of the models, depict the structure of the financial sector and discuss the implications. Here, particular attention is drawn to the financial friction and the implementation of shadow banking.

The analysis allows some general conclusions. Firstly, the new generation of models that accounts for heterogeneity in financial intermediation constitutes a well-suited setup for analyzing financial distress that precipitates large-scale downturns in financial intermediation and real economic activity. These models are thus better able to simulate realistic movements in the business cycle that are of comparable magnitude to the GFC. Secondly, the considered models allow the study of amplification channels between the financial sector and the real economy that proved to be of importance during times of financial distress. Of exceptional importance are the role of leverage and liquidity and the bank capital channel. Thirdly, there remain aspects that the new generation of models do not touch on. One is the role of monetary policy and its interplay with financial regulation. As these models largely miss fully-fledged productive setups with nominal rigidities, they are unable to analyze the impact of conventional monetary policy measures. Consequently, with these new DSGE modeling attempts, researchers and policy makers are now better geared for the assessment of macroeconomic and financial stability considerations. What remains an unsolved issue, however, is the implementation of adequate modelings of conventional monetary policies. As financial stability measures and conventional monetary policy measures interact, it is of importance to analyze their interplay.

This paper is structured as follows: Section 3.2 gives a brief differentiation of shadow banking from traditional banking and provides some empirical evidence. Section 3.3 focuses on why shadow banking has become such an important part of the financial system. To this end, it considers the economic rationale and the economic consequences for financial stability measures and monetary policy. Section 3.4 starts with a recap of the evolution of financial intermediation in DSGE modeling and then turns towards depicting the latest progress of DSGE setups considering shadow banking. Section 3.5 provides a discussion of the considered models and draws implications for monetary policy and financial stability.

3.2 Regular banking, shadow banking and the GFC

Once shadow banking was held accountable for the bulk of maldevelopments in financial sectors during the last two decades, the debate on its reasons and consequences has been led by attempts to define and demarcate shadow banking from traditional banking.[1] In the second wave, there followed the endeavor to find adequate policy responses, regulatory mechanisms and supervisory tools in order to prevent a recurrence. These debates mainly focused on the impact of shadow banking on financial

[1] Since 2018 the Financial Stability Board (FSB 2019) and later on the European Systemic Risk Board (ESRB 2019) replaced the term "shadow banking" with the name "non-bank financial intermediation". According to their perception, this general wording better copes with the increasing diversity of financial intermediation that exists alongside the regular banking sector (FSB 2019). As such, the new nomenclature not only captures shadow banking and its diverse substructures but all other forms and activities of non-bank financial intermediation that emerged recently, but are not shadow banking per se (e.g. crowd funding, peer-to-peer lending, FinTech credit etc.). In the subsequent paper, we will nonetheless primarily use the term "shadow banking". If this paper refers to non-bank financial intermediation, it constitutes a perfect synonym as we do not distinguish in more detail. We are only interested in the special subset of entities that emerged prior and slightly after the crisis 2007/2008. More recent subsets of non-bank intermediation are not considered here (see e.g. Käfer 2018).

stability. We do not aim to review all these literature strands thoroughly as this has already been done by several scholars beforehand (e.g. Adrian and Ashcraft 2012). In the next subsection, we have elected to present a differentiation of shadow banking from traditional banking from the perspective of monetary policy. Three relevant properties stand out. We then briefly highlight the quantitative importance by providing empirical evidence.

3.2.1 A differentiation

In the course of the first wave of considerations, shadow banking was defined and explained by the use of different measurement approaches. This is, on the one hand, due to the variety of activities, financial institutions and entities involved, and, on the other, to structural differences in the economies and financial systems being considered. Two approaches stand out: (i) shadow banking can either be explained by means of the activities that are conducted (for the activity-based approach see e.g. IMF 2014b), or (ii) by considering the entities that carry it out (for the entitiy-based approach see e.g. Pozsar et al. 2013).

This is, however, not the only possibility to differentiate recent subsets of shadow banking from traditional banking. Along with the former distinctions there appear to be at least three crucial properties that are relevant from the perspective of monetary policy makers while also touching on financial stability aspects.

Firstly, shadow banking in general lacked and still lacks access to federal deposit insurance systems (see e.g. Pozsar et al. 2013 or Deutsche Bundesbank 2014). Without such a fall-back position, it turned out that the system is overly exposed to runs, fire sales and losses. Secondly, shadow banking cannot resort to liquidity enhancing operations through central banks. This makes it prone to sudden liquidity fluctuations and maturity mismatches and, in combination with the former point, susceptible to being a systemic risk for financial stability (Deutsche Bundesbank 2014). And thirdly, its structure combined with the former points mean that it is usually not able to create new means of payments (see e.g. Deutsche Bundesbank 2014 or Unger 2016). The system only transforms and restructures existing illiquid and risky assets into marketable and higher rated securities. The exemplary process is the securitization of subprime mortgages into high-rated MBS.

How do these aspects come about? To answer this, it is useful to visualize the traditional process of credit intermediation again. Banks conduct a qualitative transformation of assets (maturity, liquidity and risk transformation), usually within a single entity and with adequate information about borrowers and savers (Noeth and Sengupta 2011). Due to the susceptibility of this business, it is intensively monitored and protected by a safety net consisting of deposit insurance schemes and access to central bank liquidity operations. Taken together, these properties assign regular banking an important stake in the economy: banks can elastically create new means of payment, i.e. supply additional money in the form of demand deposits through the origination of loans (Unger 2016).

Shadow banking can then be characterized to fit to some of these functions and properties but is lacking the ones relevant from a monetary policy perspective. Albeit in a different manner, it conducts (market-based) credit intermediation by transforming long-term assets into short-term and thus money-like liabilities. The functional similarities (Bernanke 2012) hence stem from the fact that it fulfills the core banking functions of liquidity and maturity transformation. The differences, however, emerge on the structural level. Pozsar et al. (2013) visualize that shadow banking builds on a fragmented, decentralized market-based system where structured funding techniques and specialized non-bank entities and institutions are the key players.[2]

Taken together, although both systems bear functional similarities, there are properties that set shadow banking apart from traditional banking. To get a better impression of the quantitative importance during the last few decades, we will now provide some empirical evidence.

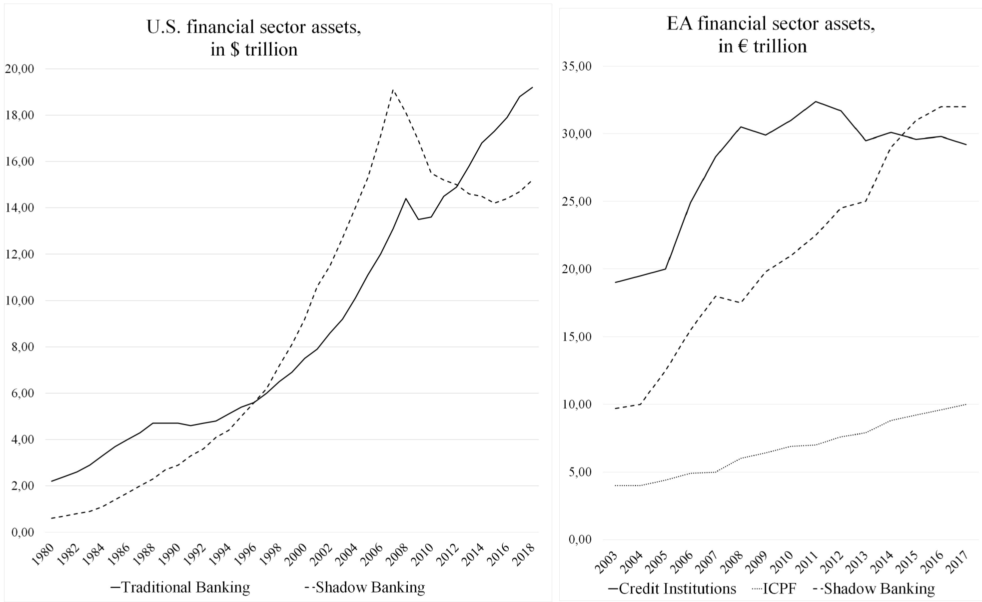
3.2.2 Quantitative importance

Measures of shadow banking differ considerably across financial systems. To pin down its activities on a global level, the macro-mapping measure of the Financial Stability Board (FSB) calculates financial assets of 21 countries and the Euro Area. According to these calculations, shadow banking assets increased from $26 trillion in 2002 to $62 trillion in 2007. This figure declined slightly to $59 trillion in 2008 after the outbreak of GFC but increased to $67 trillion in 2011 (FSB 2012, 2019). These measures account for roughly 25-27% of total financial assets in the considered sample and are roughly half the size of the respective traditional banking assets.

More accurate numbers are available at country level. For the U.S., a comparison of aggregate holdings of financial assets of the traditional and the shadow banking sector delivers valuable insights. We follow the approach of Adrian and Shin (2010) and calculate total financial assets of the traditional banking sector by summing up commercial banks, savings institutions and credit unions. Total financial assets of the shadow banking sector are composed of the government-sponsored enterprises (GSEs), agency & GSE-backed mortgage pools, finance companies, security and broker dealers and ABS issuers. Figure 1 depicts the evolution of both sectors. From the beginning of the 1980's, the volume of financial assets held by shadow banking entities increased steadily, starting to outpace the stake of traditional banking

[2] The entities involved are highly specialized and comprise e.g. structured investment vehicles, special-purpose entities and other non-bank financial institutions. They are often initiated and sponsored by banks and usually placed out of their regular balance sheet operations. Funding techniques comprise asset-backed securities (ABS), mortgage-backed securities (MBS), collateralized debt obligations (CDOs), repurchase agreements (repos) or asset-backed commercial papers (CP). The resulting money-like low-risk securities are then backed by the cash-flows from multiple different assets, which have a variety of risk classes.

around the year 1996. In 2007, just before the GFC, only 39% ($ 13 trillion) of U.S. financial assets were held by the traditional banking system, whereas the remaining 61% (roughly $19 trillion) was accounted for by the shadow banking system. Since the GFC, intermediaton by shadow banking entities decreased continuously to lower levels but picked up pace in the last three years.



Own calculations, data for U.S.: Fed Financial Accounts, EA: ECB Statistical Data Warehouse (broad SB measure)

Figure 3.1: U.S. and EA financial sector assets

How did U.S. shadow banking grew so fast during these decades? The most important stake is assigned to the evolution of structured finance, i.e. the process of securitization. As reported by Adrian and Shin (2010), the steep increase since the 1980s can be traced back to structural changes within the U.S. financial system. It was during these years that market-based intermediaries (e.g. GSEs) became the dominant players in the market for securitizing residential mortgages. Data computed by the authors show that already by the year 1990, market-based entities outpaced banks in holding residential mortgages, intensifying to a volume of roughly $7.5 trillion held by the former compared to only $3 trillion held by the latter in 2007. As a special subset, mortgages to people below credit standards, i.e. subprime mortgages, came to be known as the main effector of the GFC. Coval, Jurek and Stafford (2009) report that between 1996 and 2006, the origination of these mortgages grew from $97 billion to $600 billion, that is 22% of all outstanding mortgages in 2006. Another example is the asset-backed commercial paper (ABCP) market. Acharya and Richardson (2009) and Acharya et al. (2013) show that ABCP became the dominant money market instrument in the U.S. prior to the GFC: its volume more than doubled from \$640 billion in January 2004 to \$1.3 trillion in July 2007, then even outpacing U.S. treasury bills (\$940 billion).

In contrast, shadow banking activities in the Euro Area have a smaller stake in financial intermediation and rather picked up pace alongside the GFC, as reflected in total financial sector assets. As can be seen in Figure 3.1, at the onset of the GFC in 2007, the subset of non-bank financial entities (broad shadow banking measure: other financial institutions, investment funds and money-market funds) accounted for roughly EUR 15 trillion whereas traditional credit institutions had a stake of EUR 27 trillion. Insurance corporations and pension funds (ICPF), both not considered to be shadow entities, had a stake of roughly EUR 5 trillion. In 2015, credit institutions accounted for roughly EUR 30 trillion, ICPFs for roughly EUR 9 trillion while EUR 28 trillion was held by non-bank financial entities. Accordingly, intermediation by EA shadow banking entities doubled within a decade but still remains below the level observed in the U.S. This steady increase is mainly attributable to the subset of non-money market investment funds. Their share more than doubled in the period under consideration, reaching roughly EUR 10 trillion in 2015.

3.3 Some economics of shadow banking

Why did shadow banking became such an important part of the financial system? To give reasonable answers on this question, this section begins with the rationale for agents such as commercial banks and finance companies to engage in shadow banking and proceeds with the macroeconomic consequences. Both aspects are valuable from at least two complementary considerations. On the one hand, a proper understanding of the rationale for agents to arrange credit through shadow banking channels draws a clear picture of the factors that influence supply and demand for this type of intermediation. On the other hand then, awareness and understanding of these factors can contribute to and facilitate more targeted and predictive macroeconomic research and, in turn, enable more adequate monetary and financial stability policy measures.

Besides considerations, there are, however, aspects that concern the structural setup of recent shadow banking systems. We do not aim to explain these structural aspects as this has been done several times before (see e.g. Adrian and Jones 2018). For a non-exhaustive overview, we nevertheless collected several important "structural properties" in Table 3.1.

3.3.1 The economic rationale

In most of the explanatory attempts on shadow banking, the factors of motivation that contributed to its immense growth are a combination of cost avoidance through regulatory arbitrage, progress in financial innovation, specializations in the process

Economic rationale	**Financial stability implication**	**Monetary policy implication**	**Structural property**
Regulatory arbitrage	Risk transformation	Accuracy	Credit intermediation
Agency frictions and inf. asymmetry	High leverage	Effectiveness	Interconnectedness
Search for yield	Maturity transformation		Connection with banking sector
Financial innovation	Complexity		Network structure
Specialization	Interconnectedness		Market-based character
	Contagion		Missing insurance mechanisms

Table 3.1: Economic characteristics of shadow banking

of intermediation and misalignment problems (see e.g. Adrian, Ashcraft, Cetorelli 2013, Pozsar et al. 2013 or IMF 2014b). We go through these aspects now.

Usually, shadow banking is interpreted as being an extraordinary form of **regulatory arbitrage** (see e.g. Gorton et al. 2010, Acharya et al. 2013, Pozsar et al. 2013 or IMF 2014b). By offering a possibility to circumvent unprofitable capital and liquidity requirements, regulatory arbitrage made certain financial activities highly profitable and thereby paved the way for agents to engage in shadow banking activities. Technically, such capital and liquidity requirements are in place since financial intermediation suffers from agency frictions and misaligned incentive problems (Adrian and Jones 2018). Banks usually fail to fully internalize the costs of their risk-taking and set leverage ratios above socially optimal levels. The origins of regulatory arbitrage are then based on the fact that legal and supervisory frameworks fail to entirely capture all processes and economic relations between the economic agents involved (Fleischer 2010). Constant innovations in finance, sophisticated intermediation structures and opaque entities enable opportunities and loopholes that allow the circumvention of existing regulations with the ultimate goal of increasing profitability while shifting off risks to other parts of the financial system. Specific evidence on the hypothesis that regulatory arbitrage played a major role in shadow banking is provided by Acharya et al. (2013). The authors empirically examine the relation between commercial banks and a special subset of shadow banking entities, ABCP-conduits (asset-backed commercial paper conduits). ABCP-conduits are financial entities set up by regular banks to outsource assets and financial risk to capital markets. They are solely aimed at purchasing long-term assets from asset sellers such as the own originating bank. The conduit finances the purchase through selling short-term ABCP to investors such as money market funds. Calculations by the authors show that the volume of ABCP grew from $640 billion in January 2004 to $1.3 trillion in July 2007. They find strong arguments in favor of the regulatory arbitrage hypothesis. Such entities were more frequently used by banks that had low ratios of equity relative to assets. These banks mainly used the conduits to actively circumvent regulatory capital requirements as they enabled them to shift risky assets off their balance sheet while still investing in long-term assets and keeping regulatory capital low. Allen (2004) or Jackson (2013) report evidence that such regulatory loopholes in finance exist since the implementation of Basel I in 1988. Implemented to control and reduce bank risk-taking, the regulation unintentionally opened regulatory loopholes that encouraged banks to circumvent the measures by the use of securitized finance. These findings are supported by Acharya and Richardson (2009). They also consider misaligned regulations in Basel I+II to be crucial for regulatory arbitrage opportunities to exist. As the former authors, Acharya and Richardson trace such developments back to the lax regulation of securitization under Basel I and II. It allowed banks to barely hold regulatory capital against assets securitized through off-balance sheet entities. It thereby enabled originated loans to be shifted off the balance sheet whereas these loans would normally require to hold costly capital. Indeed, Adrian and Jones (2018) report that Basel I required zero and Basel II only little regulatory capital against exposures to ABCP-conduits or other securitization activities.

Besides cost avoidance motives through regulatory loopholes, the regulatory framework and the process of financial intermediation in itself facilitated the exploitation of frictions in the interaction between the agents involved. Commonly known from microeconomics, **agency frictions** and **informational asymmetries** are inherent in and influence the efficiency of the intermediation process. In shadow banking systems, such frictions evolve easily and exist manifold as its opaque and complex structure is susceptible to misalignments and disincentives (Adrian and Jones 2018). Accordingly, the usage and targeted exploitation of such frictions for reasons such as profit maximization might be seen as another rationale behind the existence of shadow banking. As one example, Adrian and Jones (2018) highlight that disincentives and misalignments stemming from agency frictions become significantly distinct in the process of securitization. The complex system of intermediation combined with opaque and multilayered securitized financial instruments fuels informational frictions by obscuring the true quality of the underlying assets or loan pools. Since it converts subprime loans ("the lemons") into high-rated securities it is exemplary of informational asymmetries and agency problems between the involved players. In this respect, Ashcraft and Schuermann (2008) highlight seven frictions inherent in the process of mortgage securitization among agents. These frictions mainly stem from informational asymmetries and especially comprise adverse selection and agency frictions. This view is further supported by Coval, Jurek and Stafford (2009) who give impressive insights into the economics of structured finance. The authors pinpoint that the process of securitization obscured and underestimated the true risks of underlying loan pools, leading to vast amounts of risky assets being transformed into seemingly risk-free and high-yielding securitized products.

These frictions are to a great extent promoted by the usage of **financial innovations** in the process of credit intermediation. Although innovations in financial markets started much earlier, they picked up pace alongside the upswing in shadow banking. As such, the existence of financial innovation can be seen as a further rationale of shadow banking. It is especially structured finance that explains the large increase in financial innovation in combination with the shadow banking system. Calculations by Coval, Jurek and Stafford (2009) show that the structured finance market increased heavily in the years to prior the crisis and then significantly dropped, with $25 billion of structured products issued quarterly in 2005, $100 billion issued quarterly in 2007 and only $5 billion issued in the first quarters of 2008. Coval, Jurek and Stafford (2009) and Adrian and Jones (2018) link this rapid growth, among other factors, with misalignments and disincentives in the business of rating agencies. Due to increased market demand for rated assets and a drive for expanding ratings to structured and securitized products, agencies fostered a "rating inflation" for securitized assets, thereby spurring on the securitization business and the expansion of shadow banking activities.

Closely linked to these aspects is the role of **specialization** in the process of financial intermediation (Adrian, Ashcraft and Cetorelli 2013, Pozsar et al. 2013). The decomposed intermediation structure of shadow banking usually involves entities that are highly specialized and geared to a certain function in the intermediation chain (e.g. structured investment vehicles or special-purpose entities). Although traditional banks could usually provide these services by themselves, it is the combination of economies of scale, cost avoidance through regulatory loopholes and exploitation of agency frictions that makes a separation into different entities more efficient.

As a logical consequence of the above points follows the rationale that channeling credit through the shadow banking system serves, among others, the purpose of maximizing profits. Accordingly, the **search for yield** effect is another factor of motivation. Several authors such as Coval, Jurek and Stafford (2009) or the IMF (2014b) claim that securitized products attracted investors due to their triple-A rating that combined apparently low risks with high yields. Those high yields combined with ample liquidity and relatively low market interest rates during the early 2000s spurred excessive demand by investors in the US and other parts of the world. This view is further supported by Goda, Lysandrou and Stewart (2013) and Goda and Lysandrou (2014). These papers see a causal relation between the relatively low nominal long-term yields in major US bond markets in the years prior to the crisis and the exceptionally stark increase in the demand for securitized products such as CDO. According to the authors, investors were eagerly searching for high-yielding assets and triple-A rated securities that resembled triple-A rated corporate or government bonds were welcome alternatives.

3.3.2 The economic consequences

The macroeconomic consequences emerge on two different levels. On the one hand, channeling credit through the shadow banking system causes significant risks to financial stability, both on a country and on a global level. On the other hand, additional suppliers of liquidity alongside the regulated banking sector can potentially alter the transmission channels of monetary policy, impact on its efficiency and forecast accuracy.

Financial stability Implications

In a statement before the Financial Crisis Inquiry Commission in 2010, then-chairman of the Fed Ben Bernanke (2010) discussed the causes of the crisis and distinguished crisis triggers and systemic vulnerabilities. He summarized that triggers are particular events or shocks that initiate a crisis (one example are the significant losses on subprime mortgage loans) whereas vulnerabilities are the financial system's structural weaknesses, that often emerge as "products of private sector-arrangements" and enable, facilitate and propagate the triggering shocks.

In this differentiation, shadow banking clearly falls into the latter category as it evolved as a major source of vulnerabilities for the financial system. These vulnerabilities derive from the structure of shadow banking in combination with the aforementioned motivating factors (Adrian and Jones 2018). Extensive risk and maturity transformation through shadow banking entities with high levels of leverage set the stage for risks to emerge in this sector. The opaque structure and interconnectedness with the official banking sector in combination with missing regulations and supervision then imply significant risks to the stability of the entire financial system. Adrian and Jones (2018) point out that such factors can act as stress accelerants in times of financial downturns and facilitate a transmission of shocks. This, in turn, can initiate cascade effects between the regular and shadow banking sector and, most likely, spill over to the real economy and other parts of the global financial system. The FSB (2019) highlights the importance of such transmission effects as well. Although they identify linkages between the sectors as a means to diversify risk on the one hand, they indicate the problem of too high a level of interconnectedness that induces contagion effects across sectors and economies on the other. The latter point can cause procyclical movements in asset prices and credit supply not only in good times, but facilitate downturns as well, thereby making financial crises more likely. Where regular banking is then protected through liquidity lines and a well-developed system of regulation, shadow banking is not. In the absence of such adequate regulations, shadow banking constitutes a large risk to the stability of the financial system.

Monetary policy implications

Besides financial stability considerations, shadow banking bears increased significance and challenges for the proper conduct of monetary policy. In its monthly report series for March 2014 the Bundesbank identifies two central issues of importance. If banking activities are increasingly conducted by non-bank entities outside the regular scope of central banks, implications occur for the monetary analysis on the one hand, and the proper and effective conduct of monetary policy measures on the other.

As regards the former point, the Bundesbank hints at challenges that shadow banking activities constitute for the analysis and informational content of monetary and credit indicators. Such indicators play a vital role in the decision-making procedure of central banks as they are particularly important for assessing the developments of consumer prices, the real economy and hence medium term changes to price stability. Ordinarily, central banks gather such information on the basis of balance-sheet data of the regular banking sector and are thus able to compile a relatively adequate picture of financial sector activities and the price level. However, if non-bank entities in the unregulated shadow sector start to increasingly take over banking functions, the informational adequacy of balance-sheet data of the regular banking sector is distorted and may lose its representative character for financial activities and monetary developments. This in turn impairs the monetary analysis and can, at a later stage, reduce the effectiveness of monetary policy measures.

The latter point rather concerns the direct transmission effects and hence the effectiveness of monetary policy measures. In light of increased shadow banking activities with the private and public sector, regular banking is constantly losing its role as primary financial intermediary between the central bank on the one hand and the non-financial sector on the other. In this regard, the Bundesbank in particular emphasizes the monetary transmission channels through which monetary policy measures such as interest rate changes are transmitted from regular banks to the real economy. Important to mention are the interest rate channel through which changes in main interest rates are transmitted to the real economy and thereby influence spending and investment, or the credit channel through which bank credit supply is influenced via interest rate changes. If, however, shadow banking entities increasingly substitute regular banking activities investors and private households start to rely on funding from alternative shadow banking sources and regular bank funding and loan origination loses ground. As a consequence, the conventional transmission channels become less important and the effectiveness of monetary policy measures weakens; monetary policy stimuli increasingly lose their stabilizing character for price developments and hence the economy.

3.4 Shadow banking and financial frictions in DSGE modeling

This section starts with a brief explanation of the evolution of financial frictions in monetary DSGE models as we believe this is key to understanding the workings of the models that we go through in the next part. Based on the considerations from section 3.3.1 and 3.3.2, we then extensively review DSGE models that feature shadow banking and illustrate their key analytical modeling blocks.

3.4.1 Financial frictions in DSGE modeling

The role of financial frictions in DSGE modeling can be separated into two eras whereby the turning point is marked by the GFC.[3]

Before the crisis, DSGE modeling placed insignificant emphasis on the role of financial frictions and financial markets which is one of the reasons why these models did not foresee the global consequences of financial disturbances in the U.S. economy. At that time, a widespread opinion was that financial sectors run smoothly and are thus of less importance for business cycles. Several assumptions explain this misjudgment of which we focus on two.[4] One traces back to the work of Modigliani and Miller (see Stiglitz 1969) and postulated a separation of the macro sphere from financial aspects. In their theorem on the "irrelevance of financing structure", they proposed that given an efficient market, the external value of a firm is not affected by its financing structure, i.e. the amount of equity or net worth. By uncoupling the market value from financing aspects and capital markets, Modigliani and Miller likewise uncoupled real economic activity from financial sectors (Claessens and Kose 2017). Another assumption has been highlighted by Christiano et al. (2018) and refers to the fact that until the GFC, postwar recessions in the U.S. and Europe did not seem to be caused by frictions and disturbances in financial markets and only had small effects on business cycles. Although crises happened (e.g. the savings and loan crisis or the tech Bubble), their consequences remained local and the stake of financial markets in their development remained negligible (Christiano et al. 2018). That is why research focused on frictions other than those in financial markets.

These insights resulted in DSGE models that largely neglected financial sectors and financial frictions and rather focused on elaborated modelings of the real side of the economy to explain business cycle fluctuations. The type of frictions con-

[3] A detailed review on the evolution of financial frictions is extensively laid out by Quadrini (2011), Duncan and Nolan (2017) or Claessens and Kose (2017).

[4] Another assumption rests on the hypothesis of efficient capital markets by Fama (1970). For a detailed overview see Claessens and Kose (2017).

sidered were real and nominal rigidities and usually placed in non-financial sectors. We want to sketch two important advances in the following: one is the literature on the financial accelerator mechanism and the other highlights the attempts to develop plausible model environments to generate impulse responses that were able to explain the observed fluctuations in real variables during that time (e.g. the widespread models of Smets and Wouters 2003 or Christiano et al. 2005).

As regards the financial accelerator mechanism, two approaches guided further research in the field of monetary DSGE modeling. The first traces back to the seminal papers of Gertler and Bernanke (1989), Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999). The second follows the setup developed by Kiyotaki and Moore (1997). Both strands add realism to the model world by implementing microeconomic frictions (asymmetric information stemming from principal-agent relations and enforcement problems) that result in credit market imperfections for non-financial agents (borrowers). This opens up a financial accelerator mechanism whereby small shocks are amplified and propagated throughout the economy, affecting equilibrium conditions.

In the Bernanke/Gertler-strand, the financial accelerator essentially works through the concept of the external finance premium, which is the cost to a borrower between raising funds externally and the opportunity costs of internal funds, i.e. own cash flows (Bernanke 2007). This external finance premium is likely to be positive as lenders typically put effort into monitoring their borrowers due to the existence of asymmetric information about investment projects. These monitoring efforts are factored into the corresponding interest rate. And since lenders acknowledge that borrowers have "skin in the game", i.e. sufficient net worth or liquidity, the concept assumes an inverse relation between the premium and the financial engagement or balance sheet of borrowers (Claessens and Kose 2017). Hence, the better the financial position of borrowers in the project, the easier lenders are able to monitor them and the lower are the monitoring costs to overcome uncertainty due to informational asymmetries. This costly state verification-mechanism and the relation to the external finance premium is based on Townsend (1979). It is this nexus that creates the financial accelerator mechanism. Once a negative productivity shock starts to worsen the balance sheet positions of firms (borrowers), their external cost of finance increases as their net worth/liquidity deteriorate. The external finance premium increases, worsens their cost of funds and thus reduces investment. Hence, it is the cost of credit that is constrained here. This amplifies and propagates the initial shock over several periods. Bernanke (2007) points out that the financial accelerator mechanism is, in principle, applicable to any shock affecting borrowers balance sheet items.

The second approach to model the financial accelerator is by Kiyotaki and Moore. In this approach, asymmetric information make it difficult for lenders to fully enforce debt repayment from borrowers and that is why lenders require collateral against their outstanding funds. To show their engagement in a project, borrowers must maintain enough collateral in the form of assets. This, in turn, introduces an upper borrowing limitation based on the value and availability of collateral. Accordingly, borrowers only receive the amount of funds they are able to collateralize with their assets as this enables lenders to take recourse to their funds in case of bankruptcy (Claessens and Kose 2017). The financial accelerator effect emerges due to the linkage of asset prices as collateral for loans. Once any shock reduces asset prices, the borrowers' collateral value decreases, reduces creditworthiness and hence access to liquidity. This, in turn, reduces investment and amplifies the initial shock over several periods (Claessens and Kose 2017). Here, it is not only the cost of credit that changes, but also the availability.

As regards the class of models using real and nominal frictions to generate impulse responses able to explain the observed fluctuations in real variables, the Smets and Wouters (2003)-model and the Christiano et al. (2005)-model evolved as a foundation for DSGE models used for monetary policy analysis. Due to space constraints, we restrict attention to the former. Smets and Wouters (2003) developed an estimated DSGE model for the euro area with a fully-fledged productive sector, stickiness in price and wage setting, and various shocks. The economy consists of households, final and intermediate good firms. Monetary policy is implemented via a standard Taylor-rule and the government runs expenditures financed via debt (bonds). Households maximize utility consisting of consumption (final goods) and leisure (drawing disutility from supplying labor). As labor is differentiated over households, they act as wage-setters and can realize a degree of market power when setting wages (Smets and Wouters 2003). This stickiness in nominal wages is based on the approach of Calvo (1983). Above, households are owners of the capital stock and rent out capital services to intermediate goods producers, which combine acquired capital and labor to an intermediate good. Monopolistic competition in the intermediate goods market allows firms to maximize profits by setting prices over marginal costs. Their price setting behavior follows the Calvo-mechanism: firms can only reset their price once receiving a random signal, they otherwise index prices to past inflation. Final goods are produced under perfect competition using the intermediate good as input, and then sold to households. A Taylor-type reaction function for the interest-rate setting of monetary policy closes the model. Their model entails ten structural shocks (such as productivity, cost-push, monetary policy etc.) and is estimated to fit key macroeconomic variables (GDP, consumption etc.) in the Euro Area. Given these parameter estimations, they analyze the impulse responses to the shocks and their contribution to the business cycle fluctuations. As their model includes several features (sticky prices and wages, imperfect competition, capital accumulation with adjustment costs) that deliver a reasonable empirical fit, the features of the production side have become standard in recent DSGE modeling.

It was only due to the crisis that DSGE models started to consider frictions in financial intermediation as a source and amplifier for financial linkages and business cycle fluctuations. Quadrini (2011) gives valuable advice on why such frictions are to be implemented in financial intermediation except for they played a major role in the GFC. Firstly, they have a cyclical property meaning that credit flows and lending standards are highly pro-cyclical and thus reinforce shocks. Secondly, they are a channel linking financial flows to real economic activity. This is why thirdly, they cause stark amplification effects of non-financial shocks. Based on these insights, post-crisis DSGE modeling started to combine the approved features of the real side of the economy already known from e.g. Smets and Wouters (2003) or Christiano et al. (2005) with sophisticated modelings of financial sectors, financial frictions and fitted modifications of the financial accelerator mechanism. This new class of models now accounts for elaborated financial intermediation subject to financial frictions and the possibilities of financial crises (see e.g. Schwanebeck 2018). Beyond that, they cover recent unconventional monetary policy measures (see e.g. Gertler and Karadi 2011) as well as macroprudential and regulatory tools (see e.g. De Paoli and Paustian 2017 or Poutineau and Vermandel 2017). In general, these modeling developments roughly follow two broader lines.

One strand has been mainly pushed forward by Mark Gertler, Peter Karadi and Nobuhiro Kiyotaki. These types of models feature rich financial sectors where banks are specialized intermediaries between borrowers and savers and usually act in perfect competition. Frictions in financial intermediation result from an agency problem between bankers and creditors (firms) that gives rise to endogenously determined balance sheet constraints of bankers. Once shocks hit the model, a BGG-type financial accelerator mechanism depresses financial intermediation and thereby economic activity. Noteworthy examples in this direction are Gertler and Karadi (2011), Gertler and Kiyotaki (2011, 2015), Gertler, Kiyotaki, Queralto (2012), or Dedola et al. (2013). Closely connected to this strand is the approach of Iacoviello (2005, 2015). In his seminal paper (Iacoviello 2005), he combines the BGG-financial accelerator with collateral constraints in the sense of Kiyotaki and Moore where the eligible collateral is real estate (housing). Firms (here entrepreneurs) borrow from households and the maximum amount of borrowing is dependent on the collateralizable amount of real estate (housing). In Iacoviello (2015), he extends the setup such that financial capital now flows through banks that are constrained in their ability to supply credit to entrepreneurs.

The second direction departs from the assumption of perfect competition and implements banking in a monopolistic competitive environment. The type of frictions usually remain identical: agency problems and a BGG-financial accelerator catalyze real or financial shocks and transmit them through the economy. However, monopolistic competition now allows banks a certain degree of market power in their business environment. It assumes that although banks offer similar financial products, each is a variety with slightly different characteristics. This degree of market (pricing) power enables banks to set prices (here interest rates) above marginal costs (here interest on deposits) and generates positive lending spreads that result in (inefficient) profits. As pointed out by Andrés and Arce (2012), there is ample empirical evidence suggesting that monopolistic power in banking is a source for positive lending spreads. Among other factors, this seems to be caused by transaction and switching costs that induce a lock-in effect for customers (Gerali et al. 2010). Noteworthy examples are Gerali et al. (2010), Andrés and Arce (2012) and Poutineau and Vermandel (2015, 2017).

3.4.2 Shadow banking in DSGE modeling

This section reviews the existing publications in the DSGE literature that consider financial intermediation through shadow banking systems.[5] For this approach, we draw on the findings from section 3.3.1, and use the specified aspects there to sort the publications based on their respective method to implement shadow banking. With this approach, we are able to identify two explicit modeling emphases the literature focused on so far: shadow banking is either modeled as a form of specialization in the process of intermediation or as a manufacturer of securitized finance. Table 3.2 shows the segmentation. It is important to mention here that one could likewise sort along the policy problems addressed within the paper as their content emphasized differs, ranging from monetary policy considerations through to financial stability and regulatory issues. We, however, sort along the special modeling characteristics of the considered setup. That is why in the subsequent sections, we illustrate the method used to implement shadow banking and only in section 3.3.5 carve out the implications of the model for monetary policy and financial stability considerations, as described in section 3.3.2.

Specialization

Section 3.3.1 highlighted the aspect of shadow banking being a form of specialization in the financial intermediation process. A strand of literature captures this aspect by considering shadow banks to be specialized entities with comparative advantages in their financial activities.

The publication by **Gertler, Kiyotaki and Prestipino (GKP 2016)** focuses on this aspect of shadow banking. Their paper is motivated by the fact that disruptions in shadow banking markets triggered and aggravated the GFC. Their objective is to reasonably model shadow banking activities (labeled wholesale banking) and macroeconomic fragility implemented via (un)anticipated runs on the banking sector within a mainstream DSGE setup.

[5] Besides these publications, a number of working papers exist that we do not consider here. Mazelis (2016) studies a model with shadow banking were monetary policy is constrained by the zero lower bound, Kirchner and Schwanebeck (2017) examine unconventional monetary policy measures in the face of shadow banking, Fève et al. (2019b) study shocks to credit supply by shadow and retail banks to explain the U.S. economy during the GFC, Gebauer and Mazelis (2019) analyze the impact of tighter financial regulations for commercial banks on shadow banking.

Specialization	**Financial innovation**
Gertler, Kiyotaki, Prestipino (2016)	Meeks, Nelson, Alessandri (2017)
Verona, Martins, Drumond (2013)	Nelson, Pinter, Theodoridis (2018)
	Fève, Moura, Pierrard (2019a)

Table 3.2: Modeling emphasis

For that purpose, they extend the framework of Gertler and Kiyotaki (2011) and especially the model on banking instability and bank runs of Gertler and Kiyotaki (2015) to feature a rich interaction between retail and wholesale banks on the one hand, and implement the possibility of (un)anticipated bank runs on wholesale banks on the other hand. The setup is condensed to focus on financial interaction and comes without a fully fledged productive sector and nominal rigidities. The key features are as follows: households and financial intermediaries populate an economy with a nondurable and a durable good, of which the latter is capital. Agents can hold/invest in capital directly and, together with the nondurable good, use it for the production of new capital and goods. Acquiring capital, however, requires agents to borrow funds (non-financial loans) from banks and holding it is costly at the margin due to capital management costs. Here, households are supposed to posses inferior competencies and thus face higher management costs as opposed to financial intermediaries. It is this comparative advantage of financial intermediaries in managing capital/assets that motivates their existence in the model. The resulting flow of funds has financial intermediaries channeling financial capital from savers to investors, i.e. households place deposits in banks which, in turn, originate non-financial loans. Besides, intermediaries can resort to an interbank market.

In this setup, financial intermediation is modeled along the lines of Gertler/Karadi/Kiyotaki: banks maximize their bank value by accumulating retained earnings (net worth). It evolves as the difference between returns from loans and the costs for deposits; and borrowing from other banks. As long as the intermediary can earn a positive premium on its assets, it pays to make additional loans and retain any positive premium to maximize net worth until the time he has to exit. As will become apparent, the financial friction will introduce an endogenous constraint on the borrowing ability of bankers and thereby exacerbate shocks.

The innovative feature in GKP (2016) is a heterogeneity in the banking sector. It is separated into retail and wholesale banking and the main difference arises in the way banks manage capital and are exposed to the financial friction. As regards the former point, financial intermediaries incur capital management costs whereby wholesale banks are considered to incur the lowest costs. Due to their specialization in the management of their respective assets (here capital), they are able to offer capital services at a lower cost compared to other agents. The role of shadow banks being specialized entities in the process of financial intermediation is thus crucial to the model (see section 3.3.1). As regards the latter point, financial frictions are implemented with the use of a moral hazard problem between banks and their creditors (households and other banks). Based on the positive premium that the banker earns when supplying credit, he might be inclined to expand lending indefinitely. The financial friction now endogenously limits the ability of both retail and wholesale banks to raise funds from creditors. It relates the borrowing capacity to the constraint that for both banks to receive funds, the going bank value V_t^j must exceed a fraction of assets that is considered to be divertable by bankers.[6]

The authors condense the friction in the following incentive constraints, where $j = r, w$ (retail and wholesale, respectively), FL are loans to firms, BF interbank funds and θ, ω, γ ($\theta, \omega, \gamma \in (0,1)$):

$$V_t^j \geq \theta[FL + \omega BF], \text{ where } b_t^j > 0 \tag{3.1}$$

$$V_t^j \geq \theta[(FL + \gamma(-BF))], \text{ where } b_t^j < 0. \tag{3.2}$$

As the source and use of funds differ among banks, so does their exposure to the friction. Eq. (3.1) relates to a borrowing bank within the interbank market ($BF > 0$). It can more easily divert the fraction θFL, that is loans to firms, as compared to the fraction $\theta\omega BF$, that is assets funded with interbank funds. The reason is that GKP assume that banks posses superior qualifications in monitoring counterparties as compared to when households monitor banks they supply deposits to. Hence, assets governed by $\theta\omega$ constitute better collateral for outsiders. Eq. (3.2) shows the case of lending banks within the interbank market ($BF < 0$) and states that the fraction $\theta\gamma BF$, that is loans to other banks, is harder to divert as compared to the fraction θFL. Here, loans among banks are assumed to be easier to monitor for outsiders (households) since interbank lending is said to reduce idiosyncratic risk in loan origination (banks are supposed to perfectly know their counterpart). In these relations the parameters ω and γ are essentially important. They determine the attractiveness of interbank affairs and thereby pin down the relative size of the wholesale banking sector. Variations in ω and γ change the collateral value of interbank assets and, accordingly, their relative attractiveness to retail deposits or

[6]Once banks collected assets, they might be on the take instead of proceeding to maximize the bank value during the time they are active. When doing the former, banks divert a fraction of their assets to return it to their respective household and use it personally. This potential fraud induces households to be only willing to supply additional funds to banks if they see an incentive for banks to remain in business, hence to maximze V_t^j.

non-financial loans. GKP choose $\omega + \gamma > 1$, implying a situation with a plausible amount of interbank relations alongside loan origination by retail banks. Further, they focus on the scenario that has retail banks receiving deposits and, besides non-financial loans, supplying interbank loans ($BF < 0$). Wholesale banks have no access to deposits, they are dependent on funds from their sponsoring retail banks ($BF > 0$). With the help of variations to ω, the authors then try to visualize the process of securitization. Variations to ω change the collateral value of interbank borrowing and thereby the strength of the financial friction. This impacts on the leverage ratio of intermediaries and affects the lending behavior of both retail and wholesale banks. Reducing ω increases the collateral value of interbank borrowing for wholesale banks which in turn reduces their leverage ratio and extends their non-financial lending capacity. As more capital is channeled through wholesale banks, the economy finds itself in a more efficient steady state (wholesale banks incur the lowest capital management costs).

In this model, the financial accelerator works through the effect of the incentive constraint on the ability of financial intermediaries to supply the economy with financial capital. It is especially the existence of the wholesale sector that acts as an additional amplifier. As a shock hits the balance sheet of intermediaries, the value of their assets declines and automatically tightens/worsens the agency friction, i.e. the incentive constraint. Credit spreads rise, making finance more expensive. Wholesale banks, being higher leveraged than traditional banks, are especially hard hit and to recover, both deleverage and cut back on lending.

The content emphasis of the paper is on the interaction of financial intermediation and the consequences of (un)anticipated bank runs for financial stability. In their experiments, the authors use productivity shocks as a trigger for financial crises and assume (un)anticipated runs on wholesale banking. A run happens when sponsors of wholesale banks suddenly decide to not roll over funding lines (interbank credits). As this erodes a major source of funding for wholesale banks, they are forced to liquidate assets and start a firesale, causing a significant drop in asset prices. The starting point, however, is a negative shock to productivity that starts the well-known financial accelerator mechanism. Due to a reduction in the price of capital, it feeds through the balance sheet of both retail and wholesale banks. As their asset position worsens, the agency friction deteriorates and the collateral constraint tightens, i.e. the access to finance is impaired. Through the high level of leverage, wholesale banks worsen the effect of the initial drop in asset prices and thereby exacerbate the financial accelerator. After such a shock, the economy slowly moves bank to its steady state. What matters here is the amount of leverage held by wholesale banks. As this depends on ω, the size of wholesale banking acts as a financial amplifier. Given this, the authors then introduce two government policies: in the scenario of ex-post intervention, the central bank acts as lender of last resort while in the ex-ante intervention scenario, macroprudential policy limits the risk exposure of banks. In the former scenario, the central bank intervenes in credit markets with large scale asset purchases when the expected return on assets exceeds the cost of borrowing. GKP can show that it is the mere anticipation of intervention that weakens the impact of the crisis as it reduces the probability of runs. In the latter scenario, GKP assume leverage restrictions on wholesale banks such that an upper limit on their leverage ratio exists. Again, the policy is effective in preventing a run and thereby calms down the recessionary effects. However, as the leverage restrictions impair the ability to leverage and thereby slow down credit supply, the policy decelerates the recovery of the economy.

A second contribution that focuses on the aspect of specialization in financial intermediation is the publication by **Verona, Martins and Drumond (VMD 2013)**. The paper assesses the applicability of different DSGE model environments for analyzing business cycle fluctuations given too low and too long interest rate policies. Based on recent events, they are especially interested in whether misaligned interest rate settings in the US during the early 2000s, among other factors, facilitated a macroeconomic boom-phase that was followed by the well-known bust phase starting in late-2006. For their examination, the authors run different DSGE model setups. Their baseline version follows the framework of Christiano, Motto, Rostagno (2010) and includes a financial sector with the BGG-financial accelerator mechanism. For comparison, another version is missing the latter two characteristics.

The models feature the typical agents known from e.g. Smets and Wouters (2003) such as households, capital producers, intermediate and final goods firms, entrepreneurs, financial intermediaries and the government. Financial intermediaries exist because they provide the productive sector (entrepreneurs) with credit to finance investment projects. Financial frictions arise as these projects are risky though not freely observable by the bank; this bears monitoring costs. This sort of asymmetric information requires a contract that enables the bank to have recourse to its funds in case of bankruptcy of the firm. This costly state-verification causes the bank to charge an interest rate premium depending on the net worth of the firm. As such, it is countercyclical and induces the typical BGG-financial accelerator.

In the first step, the authors pinpoint the effect of banking and financial frictions in explaining boom-bust phases in economic and financial activity given anticipated and unanticipated shocks to the policy rate (technically materialized by either holding the interest rate constant with a sequence of (unexpected) shocks over several periods (unanticipated), or by announcing a policy path for several periods (anticipated)).

In a second step, the authors extend the model with a shadow banking system (labeled investment banks). In this extension, investment banks exist because entrepreneurs are now separated along two risk dimensions: one group being risky and the other being safe. Based on empirical data showing that safe firms rather resort to bond financing via investment banks, the risky ones are dependent on bank finance and the safe ones acquire funding in the form of bonds from the shadow banking system. Being safe means having sufficient net worth to be able to always repay debts and never default. The consequence is a lower interest rate on external finance. Accordingly, shadow banks exist because of their specialized competencies in supplying parts of the financial system with safe assets. A main difference is that VMD move away from the assumption of perfect competition á la Gertler/Karadi/Kiyotaki. The shadow banking system is populated by monopolistic competitive investment banks who are suppliers of slightly differentiated financial assets (bonds) and thereby have a degree of market power. This allows them to set bond interest rates in a profit maximizing manner. The measure of market power is depicted in the elasticity of demand for financial assets (bonds) and is endogeous in that it moves with the business cycle.

Banks maximize

$$\max_{R_{t+1}^{coupon}(z)} \Pi_{t+1}^{IB}(z) = \{[1 + R_{t+1}^{coupon}(z)]BI_{t+1}^{LR,l}(z) - [1 + R_{t+1}^{e}]BI_{t+1}^{LR,l}(z)\} \tag{3.3}$$

subject to the (low risk) entrepreneurial demand for funds

$$BI_{t+1}^{LR,l}(z) = \left(\frac{1 + R_{t+1}^{coupon}(z)}{1 + R_{t+1}^{coupon}}\right)^{-\varepsilon_{t+1}^{coupon}} BI_{t+1}^{LR,l}. \tag{3.4}$$

Accordingly, investment banks set the profit-maximizing interest rate R_{t+1}^{coupon} on bonds issued to entrepreneurs above the risk free rate R_{t+1}^{e} they pay on returns to households, taking as given the entrepreneurial demand for funds. For the objective of the paper, the spread in bond finance is essential for the model dynamics. It is the difference between the bond rate and the risk free rate

$$spread_{t+1} \equiv R_{t+1}^{coupon} - R_{t+1}^{e} = \frac{1}{\varepsilon_{t+1}^{coupon} - 1}(1 + R_{t+1}^{e}) \tag{3.5}$$

where $\varepsilon_{t+1}^{coupon}$ is the time-varying interest rate elasticity of the demand for funds. As VMD conclude that bond spreads typically move with business cycles, the authors set up two versions whereby the reaction of $\varepsilon_{t+1}^{coupon}$ derives from different states of the economy. VMD consider that during normal times, the interest rate elasticity follows the equation $\varepsilon_{t+1}^{coupon} = \varepsilon_{t+1}^{normal} = \bar{\varepsilon} + \left(Y_t - \bar{Y}\right)$. Here, the movement of $\varepsilon_{t+1}^{normal}$ is based on the output gap $\left(Y_t - \bar{Y}\right)$ and a constant $\bar{\varepsilon}$. Deviations of current output from its potential cause changes to $\varepsilon_{t+1}^{normal}$ and force a countercyclical reaction of (3.5). In the second version, that is during times of overoptimism identified through higher entrepreneurial net worth, the elasticity follows $\varepsilon_{t+1}^{coupon} = \varepsilon_{t+1}^{optimistic} = \varepsilon_{t+1}^{normal} + (1 + \varkappa_t)$ with $\varkappa_t$ being an AR(1) process of type $\varkappa_t = \rho_{\varkappa}\varkappa_{t-1} + (1 - \rho_{\varkappa})\left[\bar{\varkappa} + \alpha_2(NR_{t+1}^{LR,l} - N^{LR,l})\right]$. The elasticity $\varepsilon_{t+1}^{optimistic}$ now moves with $\varkappa_t$ reflecting optimism. Due to $\alpha_2(NR_{t+1}^{LR,l} - N^{LR,l})$ in the AR (1) process, $\varkappa_t$ is driven by its sensitivity to changes in entrepreneurial net worth (deviations from its steady-state level). Accordingly, interest rate spreads in VMD evolve endogenously, as the elasticity of the demand for funds depends on the state of the economy.

After calibrating the model to U.S. data, the authors run several experiments to analyze the model setups in terms of their applicability for explaining boom-bust phases caused by (un)anticipated interest rate regimes, during normal and overly optimistic times. Their model is able to show that setups with financial frictions, at least in their parametrization, fail to produce downturns in response to monetary policy shocks that are large enough to replicate the bust-phase starting in 2007. Once enriching the setup with a shadow banking system, the model fit changes. During normal times (the spread reacts countercyclically to the output gap), VMD find that the existence of shadow banking adds realism to the model as core macro variables such as output, investment and the price of capital react more in line with empirical findings. During optimistic times and when agents do not anticipate the policy path, VMD find that their model predicts buildups in the price of capital and excessive credit that correspond to empirical findings prior to the GFC.

Financial innovation (securitization)

In section 3.3.1, we already identified financial innovation, especially that of securitization, to be an important rationale for the existence of shadow banking. A strand of literature is capturing this aspect by allowing shadow banks to manufacture securitized assets as collateral in the financial intermediation process.

Meeks, Nelson and Alessandri (MNA 2017) is among the most important and trend-setting paper in this model direction. The objective of their paper is to properly account for the macroeconomic implications of the interaction between shadow banking and regular banking. In particular, MNA are interested in the consequences of business cycle and financial shocks for aggregate activity and credit supply during normal and crises times in order to allow for more accurate policy advice. Central to their model is a comprehensive interaction between regular and shadow banking that is based on the process of securitization in credit provision. In principle, their model is a version of components specific to their model and components from the Gertler/Karadi/Kiyotaki-strand.

The structure of their model is as follows: households enjoy utility from consumption and are composed of workers, bankers and brokers. The model features a productive sector where firms produce final output and capital producers transform final goods into capital goods. In this environment, the former need to purchase capital for production from the latter which, in turn, introduces the role for financial intermediaries to exist since the acquisition of physical capital requires firms to receive loans from banks. As is standard in this strand of literature, financial intermediaries maximize their bank value by accumulating net worth that evolves as the difference between returns on assets and costs for liabilities.

The innovative feature in MNA (2017) is the role of securitization in credit provision and the associated segmentation of banking into commercial banks and shadow banks (brokers). The latter exist as their specialized competencies in transforming illiquid loans into tradeable and better pledgeable assets (ABS-portfolios) adds substantial efficiency to the process of intermediation. The role of shadow banks being manufacturers of ABS in the process of financial intermediation is thus crucial to the model. The authors thereby manage to implement an important aspect of recent shadow banking systems (see section 3.3.1). The economic function and the resulting flow of funds is as follows: commercial banks have a comparative advantage in originating loans to firms FL and, for that purpose, combine household deposits and net worth. Besides, they acquire portfolios of ABS m_t^c from the shadow banking system. Shadow banks, however, do not originate loans, they rather hold loan pools composed of loan bundles formerly originated by commercial banks. The acquisition is funded with net worth and manufactured ABS-portfolios m_t^b. When manufacturing portfolios of ABS, shadow banks use two securitization schemes: "risk-sharing" and "risk-taking securities". The former has its returns fed by the cash flows of the loan pools and risk is shared among both investors and shadow banks. The latter rather constitutes a fixed and noncontingent claim and is as such more comparable to bank-like debt products. According to MNA, this differentiation adds substantial realism to the model as both schemes were predominant at the onset of the GFC. As regards the leverage ratio of both intermediaries, MNA consider shadow banks to be more highly leveraged than commercial banks. The difference is caused by lower net worth of shadow banks, simply operating with higher leverage.

The financial friction in the model is the well-known agency problem in the sense of GKP (2016) and Gertler and Karadi (2011). It limits the volume of funds intermediaries are able to receive from their creditors. Accordingly, the possibility of banks to divert a fraction of assets for own purposes opens up the need of incentive comparability between their bank value and the divertable assets. The incentive constraints for commercial and shadow banks read

$$V_t^c \geq \theta_c[FL + (1-\omega_c)m_c^t] \text{ where } [\theta_c, \omega_c] \in (0,1), \tag{3.6}$$

$$V_t^b \geq \theta_b[m_t^b + n_t^b]. \tag{3.7}$$

Eq. (3.6) introduces an important feature of the model. Here, MNA consider that the process of securitization actively destroys idiosyncratic risk inherent in loans and, by pooling and tranching a variety of loans, creates a safer and thus more pledgeable asset. For creditors (households), this process guarantees a safer claim and thus a better collateral. As in GKP 2016, MNA use two diversion parameters for this relation. Loans FL are governed by θ_c only whereas ABS-portfolios m_c^t by $\theta_c\omega_c$ and as such are harder to divert. The effect is as follows: the more ABS banks hold, the more trustworthy their business appears to outsiders, the more relaxed their funding constraint (3.6) becomes and, accordingly, the higher their lending capacity becomes. Eq. (3.7) reflects these relations for shadow banks. Here, MNA capture the feature that it is not households that monitor shadow banks, but rather their sponsors, the commercial banks. MNA suppose that this fact guarantees in itself higher trust as banks have comparative advantages in monitoring their counterparts and that is why $\theta_b < \theta_c$, i.e. the divertable fraction of assets is higher for commercial as for shadow banks.

These relations then bring about the typical financial accelerator mechanism. As in GKP, it works through the effect of the incentive constraint on the ability of financial intermediaries to supply the economy with financial capital.

The content emphasis of the paper of MNA is to account for business cycle comovements between output, credit by traditional and shadow banks, and for the behavior of the latter during a liquidity crisis. In their quantitative analysis, the exogenous disturbances that cause the crisis are twofold and target the incentive constraints (3.6) and (3.7). Firstly, (3.7) is hit by a positive shock to θ_b that reduces the collateral value of assets held by shadow banks. In the second scenario, a negative shock to ω_c in (3.6) reduces the pledgeability of shadow assets (ABS) held by commercial banks. Both scenarios depict a "securitization" crisis like the one experienced at the onset of the GFC where assets held and produced by the shadow banking system suddenly lose in value. Here, it is the impact on the incentive constraint that makes both shocks trigger a financial accelerator effect. The changes in θ_b and ω_c cause (3.7) and (3.6) to tighten as the respective assets are loosing in collateral value. Both types of bankers, interested in maximizing their bank value while confronted with tighter incentive constraints, now have to restructure their business. The effect is a contraction in securitized shadow assets (as shadow banks reduce supply) and bank loans (as commercial banks strengthen their position in ABS as they now require more of it). Since both disturbances directly hit the financial sector, financial activity comes to a halt, the supply of funds for the productive sector is impaired and consumption, investment and output drop significantly.

In the second step, MNA go through the possibility of official backstops by the government to moderate the effects of the securitization crisis. To this end, the government can purchase loans or securitized assets in exchange for government debt, the latter being a perfect substitute for deposits. In both instances, the government appears as an additional intermediary in markets with the benefit of being 100% creditworthy, i.e. with no financing constraints. MNA find that direct loan purchases are more effective in reducing macroeconomic volatility than interventions in shadow banking markets.

Nelson, Pinter and Theodoridis (NPT 2018) is the next publication to be considered in this subcategory. Their main contribution is to enter into the discussion of whether US interest rate decisions prior the GFC fueled misguided balance sheet expansions of commercial banks and the shadow banking system. Awareness of such opposing effects of monetary policy measures adds to the question of whether monetary policy should be used universally to lean against imbalances to achieve financial stability goals, or whether measures need to vary depending on which part of the financial system is affected.

As the point of departure, NPT (2018) estimate VAR models to control for the impact of monetary policy decisions on changes in financial sector's balance sheets. Their estimations show that during the period from 1966-2007, a tightening of monetary policy tended to reduce assets held by commercial banks. Due to the higher cost of funding, they reduced lending to the economy. In contrast, assets such as mortgage securities held by the shadow banking system increased. The authors ascribe this countercyclical impact to a circumvention strategy of commercial banks. By redirecting parts of their lending to the shadow banking system, commercial banks effectively avoided higher funding costs.

In a second step and based on the empirical findings, the authors deploy a DSGE model to replicate the empirical evidence. The structure of their model closely follows MNA (2017). Since the effects are identical to MNA (2017), we do without explanations here.

The content emphasis of the paper is on the ability of monetary policy to fully control for imbalances in the economy to achieve financial stability goals, or whether the measures need to vary depending on the part of the financial system that is affected. In their quantitative analysis, NPT run a contractionary monetary policy shock and compare the resulting impulse response functions with the previously found empirical facts of the VAR model. Their analysis shows that the theoretical model comes close to the empirical data, even for a wide range of parameter values. As the increase in the monetary policy rate puts downward pressure on overall lending, it reduces asset prices and increases the funding costs for commercial banks. A financial accelerator effect sets in whereby decreasing asset prices put pressure on the balance sheet of commercial banks, who, in turn, have to reduce net worth to account for the losses. Simultaneously, commercial banks are eagerly searching for collateral in order to keep their intermediation business active and further on maximize the going bank value. Now, acquiring ABS offered by the shadow banking system helps to attenuate the downward pressure on commercial banks' balance sheet. Holding more of these assets relaxes the incentive constraint (3.6) and allows to extend credit. Accordingly, commercial banks increase demand for ABS and shadow banking expands.

The third publication that embeds shadow banking with the use of securitization is the paper by **Fève, Moura, Pierrard (FMP 2019a)**. The aim of their paper is to examine different forms of macroprudential regulation and their impact on financial sector stability and business cycle movements. Central to their model is an interaction between regular and shadow banking that is based on securitization in credit provision. To identify two structural model parameters, the authors use Bayesian methods and estimate the model on quarterly U.S. data for the period from 1980-2016.

The structure of their model is as follows: households' utility consists of consumption, holdings of deposits (driven by a liquidity motive) and labor supply. The latter is demanded by a representative firm and, given a standard Cobb-Douglas function, combined with capital into the final good. For renting capital for production, the firm borrows financial capital from the banking sector, what introduces the reason for financial intermediaries to exist. The banking sector is composed of traditional banks and shadow banks. The former combine deposits and net worth to hold two types of assets: loans to firms and ABS from shadow banks. Traditional banks then simply maximize profits with respect to deposits, loans and ABS. Shadow banking is modeled in an overlapping generation structure with shadow bankers living for 2 periods. FMP treat shadow banks as special-purpose vehicles created by traditional banks to outsource capital. Accordingly, the balance sheet of shadow banks comprises loans to firms funded with issued ABS. Profits evolve as the difference between income from loans and interest paid for the issuance of ABS. As FMP assume free market entry, a zero profit condition ensures a constant number of shadow banks.

From the maximization of traditional banks, they derive a crucial condition that governs the interaction between traditional and shadow banks. $\Gamma' \frac{1}{q_t l_t} + E_t \epsilon^a_{t+1} = E_t \Lambda_{t,t+1}(r^a_t - r^d_t)$ depicts the spread between ABS returns and the deposit rate and shows that the spread equals portfolio-adjustment costs Γ (limit the ability of the bank to substitute between both assets) plus $E_t \epsilon^a_{t+1}$, depicting a shadow wedge, i.e. an ABS default shock based on an AR(1) process. Hence, since there are no monitoring or regulation costs in holding ABS, its demand is solely driven by its premium over holding deposits and a default shock. With a linearized approximation of the equation, the authors can show that an increase in the return on ABS directly increases traditional banks' demand for the very same. An increase in the shadow wedge, however, increases the required return on ABS and reduces holdings of the very same.

In the model of FMP, shadow banks do not increase the efficiency of credit intermediation by relaxing financial frictions (as in GKP or MNA), shadow banks rather act as a circumvention strategy for traditional banks as they are unregulated. Macroprudential regulation in FMP follows a capital requirement on bank capital n_t. Especially, n_t is constrained downwards by a fraction of risk-weighted assets $\bar{\eta}$ that consists of $q_t l_t$ only as abs_t are not included. The tool then gets $x_t = n_t - \bar{\eta} q_t l_t$. To circumvent the possibility that banks only hold unweighted abs_t, FMP calibrate its equilibrium return lower as that of bank loans.[7]

FMP then compare a world with fixed shadow credit to the benchmark case with active shadow banks. By means of a positive productivity shock, they find shadow banking to be an amplifier of business cycle movements. Following the shock, traditional banks want to increase lending but likewise need to increase capital at the instigation of the regulators. Due to a substitution with unregulated ABS, banks can limit the costs implied by the macroprudential tool and increase credit more

[7] FMP circumvent the implemention of the regulation tool due to computational challenges and use a shortcut. If a bank holds less capital than required, it is subject to a penatly cost that is proportional to th emerging capital gap. The cost function reads $\Theta_t(x_t) = -\theta_1 \ln(1 + \theta_2 x_t)$ with costs being decreasing and convex in x_t.

strongly. The reaction of output and investment is intensified.

As their content emphasis is on regulation, they then introduce a countercyclical capital buffer following $\eta_t = \bar{\eta} + \kappa_\eta(\frac{\Delta b_t}{y_t} - \frac{\bar{\Delta b}}{\bar{\Delta y}})$ with Δb_t being a measure of credit growth and κ_η the sensitivity parameter. The tool now moves countercyclically with deviations of credit growth relative to output from a steady-state level. Three versions of that scheme exist: the regulator either keeps requirements constant, countercyclical on traditional loans only, or countercyclical on traditional and shadow banking loans (symbolizing Basel I, II and III, respectively). Their results show that, once unregulated, shadow banking enables regulatory cost arbitrage for traditional banks and reduces the effectiveness of macroprudential policies. If shadow and traditional banking are regulated, business cycles fluctuations can be attenuated.

3.5 Discussion and implications

With the occurrence of the GFC, long-neglected attention shifted to the role played by failings in regulatory frameworks and the ensuing consequences on the structure of the financial system. Due to these developments, the literature on financial intermediation in DSGE modeling has made significant progress over the last decade. The models considered in section 3.4.2 introduce new approaches of how to extend existing setups in order to consider heterogeneities in financial sectors where retail and shadow banks act as financial intermediaries between savers and borrowers. As the latter are usually firms in the productive sector, this new model generation is able to establish a comprehensive nexus between the financial and the real side of the economy. By introducing such interlinkages, these models are now able to bridge a gap between the observed empirics before and during the GFC on the one hand, and a lack of sufficient DSGE modeling on financial intermediation in place at the onset of the GFC on the other. This progress allows the empirical observation that both real and financial sector shocks can cause financial distress that jeopardizes the stability of the financial system, spills over to economic activity and causes harsh and long-lasting business cycle downturns.

The models considered allow several conclusions. A first general one refers to the ability to show that once financial intermediation is extended by a shadow banking sector, the effects of both real and financial shocks hitting the economy are larger and more protracted than in comparable baseline scenarios without shadow banking sectors. Shadow banking acts as a powerful amplification mechanism. The explanatory power rests upon the implementation of frictions in financial intermediation and the resulting nexus between changes in asset prices caused by real or financial sector shocks and the balance sheet conditions of financial intermediaries. This is amplified by the fact that shadow banks are more highly leveraged than retail banking. Shocks that reduce asset prices and thereby force intermediaries to reduce net worth hit shadow banks relatively harder than retail banks. The financial friction amplifies the effect on credit (or ABS) supply of shadow banks and puts additional downward pressure on economic activity. Especially the models of MNA and GKP are well-suited setups to look back on and reappraise these occurrences. Both are rich in detail in modeling the shadow banking and the financial sector. Accordingly, the models are better able to generate business cycle movements that are comparable to the ones observed during the recent GFC.

The second general conclusion refers to the explanatory power of these models regarding considerations on financial stability and macroprudential policies. The GFC made obvious that there is a strong nexus between the stability of the financial system and real economic activity. That is why in the years following the crisis, policy makers and research on financial regulation turned towards a macro perspective in banking supervision. With the regulations as laid down in the framework of Basel III, a set of new macroprudential policies has been introduced that are aimed at the stability of the financial system and its resilience during financial distress. These policies are mainly directed towards the balance sheet exposures of financial intermediaries and aim at their risk-taking, leverage restrictions and (countercyclical) capital buffers.[8] In the DSGE literature, these measures are usually covered by implementing capital requirements and analyzing their impact on macroeconomic stability. The measures are then based on a policy rule that reacts to variations in financial indicators such as credit or loan aggregates, credit and lending spreads, output growth, or any relation of these variables. Such measures have been found to work well in dampening fluctuations in bank equity/capital and other macroeconomic variables with the effect of increased financial and macroeconomic stability. The models of GKP and FMP explicitly account for financial stability in combination with shadow banking and implement macroprudential policies. GKP assume leverage restrictions on wholesale banks in the form of an upper limit on their leverage ratio. FMP introduce a countercyclical capital buffer with three versions symbolizing Basel I, II and III, respectively (see section 3.4.2 for closer explanations). Their results show that macroprudential policies are effective in attenuating fluctuations of the business cycle and thereby foster financial stability. As pointed out by GKP, the effects of these measures stem from the fact that they weaken the financial accelerator effect. As the policies moderate the drop in net worth of financial intermediaries, they can counteract the negative effects stemming from the initial shock. A stabilization of net worth softens the financial friction and thereby dampens the contraction in credit supply by financial intermediaries. The side effect, however, comes in the form of regulatory arbitrage (if the shadow banking sector remains unregulated) and a slowdown of credit supply after a crisis whereby these policies tend to decelerate the recovery of the economy. However, what these considerations ignore is the interaction of financial stability measures with (conventional) monetary policy measures.

Besides these general conclusions, there are aspects that relate to the specific strengths and weaknesses of these models. Among the strengths are e.g. the aware-

[8] For a literature review on macroprudential policies see Galati and Moessner (2012).

ness of new types of amplification channels between regular banking and the shadow banking system or modeling advances that now allow the incorporation of financial sector efficiency due to specialization and financial innovation. The weaknesses touch upon aspects that the models do not cover but that are of importance from the viewpoint of policy makers.

As regards the amplification mechanisms, the bank capital channel and the role of leverage and liquidity are of exceptional significance. As outlined by Claessens and Kose (2017), balance sheet positions such as net worth are of importance for the proper conduct of credit supply through financial intermediaries. Once shocks reduce asset prices and intermediaries adjust for losses by reducing net worth, their access to funds (such as deposits) worsens and reduces their lending capacity. The source of this interaction in the models considered is the implementation of financial frictions such as agency problems and the resulting incentive constraints that bring about financial accelerator mechanisms and cause a spiral of worsening financial conditions and downward pressure on economic activity. Once asset prices deteriorate, intermediaries reduce net worth and their access to funding is impaired as their incentive constraints tighten. Given tighter incentive constraints, intermediaries cut back on lending to the real sector and investment and output drop. Another amplification channel brought to light by the GFC is the role of leverage and liquidity of financial intermediaries (Claessens and Kose (2017)). In prosperous times, high levels of leverage allow higher borrowing capacities and as such can have positive impact on economic activity. However, the downside of high leverage is that balance sheets and hence net worth of intermediaries are overly exposed to shocks that cause asset prices to fluctuate. Once disruptions in financial or economic activity cause assets to devaluate, the reaction of financial intermediaries is to cut back on lending in order to comply with leverage restrictions. This, in turn, depresses economic activity. The papers considered, especially GKP and MNA, capture this nexus. Both calibrate leverage ratios (assets to net worth) of shadow banking to be twice as high as for retail banks and the effects of shocks are amplified by the degree of leverage. Asset prices drop and the direct effect is to reduce net worth which is accompanied by a tightening of incentive constraints. Shadow banks, showing higher leverage ratios, are more exposed to this mechanism.

Besides this, these modeling advances now allow the incorporation of specialization and financial innovation. Alongside the negative impact on financial stability, specialization and financial innovation clearly comprise positive aspects in that both can increase the efficiency and extend the borrowing capacity of the financial sector. The models of GKP and MNA are able to pinpoint that these effects set in once accounting for shadow banking activities. In MNA, the shadow banking system transforms illiquid loans into tradeable assets and as such helps to manufacture economically valuable collateral that extends the lending capacity of financial intermediaries. In the model of GKP, the effect of specialization (financial innovation) is captured through changes in the agency friction (collateral constraint) between retail and shadow banks, condensed in the parameter ω. In the steady state of the model, several variables react to changes (here a reduction) in this parameter with the consequence that the overall amount of capital channeled through the shadow banking system is larger and the economy equilibrates in a more efficient steady state.

However, there remain aspects that the models considered do not cover but that are of importance from the viewpoint of policy makers. A key argument here is that the policy measures available to central banks lose in efficiency once financial intermediation is increasingly conducted by non-bank institutions such as the shadow banking system that are out of reach of central bank activities. To evaluate such interlinkages and the impact of monetary policy decisions on real variables in DSGE setups, the crucial model condition is the presence of nominal frictions (nominal rigidities) in the price setting behavior of firms and the presence of monopolistic competition. Once firms have a degree of market power when setting prices, prices do not change immediately when market demand changes. Since this price stickiness generates a nexus between nominal and real aggregates, monetary policy has real impacts. The most popular approach to consider stickiness in nominal prices (and wages) is the method of Calvo (1983). In this approach, prices (or wages) are set in a staggered manner as the ability to reset prices (or wages) is an exogeneous probability that is signalled randomly to a fraction of firms (or households). The remaining fraction keeps prices constant. Due to this stickiness in nominal price setting, monetary policy can use the nominal interest rate to steer the real rate and hence impact on real economic activity. In the DSGE setup, nominal rigidities require an elaborated modeling of the real side of the economy in the sense of e.g. Smets and Wouters (2003) or Christiano et al. (2005). However, several of the models considered are real business cycle models extended with financial frictions but abstract from nominal rigidities. This applies for GKP, FMP and MNA. The two former models omit to model a fully-fledged productive sector that features the typical web of firms needed to implement nominal rigidities. In the model of MNA, a more elaborated productive sector exists as the production of capital is outsourced to capital producers. However, the absence of nominal rigidities permit the study of conventional monetary policy. Given the circumstance that central banks conduct conventional tools simultaneously to unconventional measures and macroprudential tools, a proper policy analysis needs to evaluate the effects of applying such measures synchronously.

Another aspect relates to the structure of bank balance sheets in the considered models. In the wake of the crisis, it became obvious that the capitalization of the banking sector was insufficient to account for the immense losses in asset values and the abrupt illiquidity of private borrowers (BIS 2010). The regulatory response to these maldevelopments was the introduction of new supervisory measures as laid down in the BASEL III regulations. In contrast to BASEL II, the new regulations aim for a better resistance of the banking sector to shocks that cause a depreciation in asset values and thereby threaten the solvency of banks (BIS 2010). The requirements comprise a more detailed segmentation of relevant supervisory equity capital into tier 1 capital (segmented into common equity tier 1 capital and additional tier 1 capital) and tier 2 capital. These new regulations intend to increase the quality of equity capital, reduce bank leverage and excessive levels of liquidity (BIS 2010). In the models considered, the balance sheet of banks usually consists of the asset side with credit to firms (and possibly other financial intermediaries) and liabilities composed of deposits and net worth/equity. Implementations of regulatory macroprudential tools then usually take advantage of capital requirements or leverage restrictions that draw on bank net worth. However, given this rather simple structure of balance sheets, the models miss a detailed depiction of the different equity tiers of banks. This is, however, important in order to give a neat depiction of macroprudential policies in the sense of Basel III. Some recent advancements in this direction are Gertler et al. (2012) or Nelson and Pinter (2018) who allow banks to issue outside equity along with net worth.

Finally, the advancements in DSGE modeling over the last decade yielded more realistic model environments that allow elaborated analyses on the causes and consequences of financial distress and business cycle fluctuations. As these models account for the interaction between financial sectors and the real economy, they are able to track that even small financial or real shocks can precipitate a financial crisis of international dimension that is followed by sharp declines in real economic activity. Given these new modeling setups, research and policy making is now better able to estimate and assess the effects of shocks and thereby implement more accurate policy measures.

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Since the occurrence of the Great Financial Crisis (GFC) in 2007/2008, our understanding of (macro) economics changed fundamentally. The evolution of the GFC revealed fundamental changes in the structural composition of financial systems in that traditional retail banking services, especially in the U.S., shifted progressively into a market-based banking system called the shadow banking system. Consequently, policy makers were forced to adapt the existing toolkit in two ways: implementing unconventional monetary measures to stimulate markets and introducing macroprudential measures as laid down in the BASEL III-framework geared towards the resilience and stability of the financial sector. This thesis addresses these aspects by using state-of-the-art closed- and open-economy dynamic stochastic general equilibrium models to analyze the impact of shadow banking on the business cycle and on the interaction with monetary and macroprudential policy measures.

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