Essays on Credit, Macroprudential Regulation, and Monetary Policy

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Herrn Stefan Gebauer, M.Sc.

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Erstgutachter:
Prof. Dr. Mathias Trabandt
Professur für Makroökonomie
Freie Universität Berlin

Zweitgutachter:
Prof. Marcel Fratzscher, Ph.D.
Professur für Makroökonomie und Finanzen
Humboldt Universität Berlin

Tag der Disputation:
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To my family.

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Erklärung zu Koautorenschaften

Diese Dissertation besteht aus vier (Arbeits-)Papieren, von denen drei in Zusammenarbeit mit Koautoren entstanden sind. Der Eigenanteil an Konzeption, Durchführung und Berichtsabfassung der Papiere lässt sich folgendermaßen zusammenfassen:

- ***"Corporate Debt and Investment: A Firm-Level Analysis for Stressed Euro Area Countries"***

  Stefan Gebauer, Ralph Setzer und Andreas Westphal

  Eigenanteil: 33 Prozent

- ***"Macroprudential Regulation and Leakage to the Shadow Banking Sector"***

  Stefan Gebauer und Falk Mazelis

  Eigenanteil: 50 Prozent

- ***"Welfare-Based Optimal Macroprudential Policy with Shadow Banks"***

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Abstract

This dissertation consists of four essays that investigate the economic consequences of frictions in credit markets and the implications for macroprudential and monetary policies. The first essay addresses the following question: How do excessive debt holdings on borrower balance sheets impede economic activity? To address this question, we estimate a non-linear panel threshold model on a large-scale panel data set for euro area non-financial corporates. We account for non-linearities in the debt-investment link and find that excessive corporate leverage negatively affects firm investment if the debt-to-asset ratio exceeds 80 to 85 percent. These non-linearities are economically meaningful and robust across firm size, sector, and profitability, and were aggravated during the European sovereign debt crisis. The second and third essay address the following questions: How does the presence of unregulated shadow banks affect credit markets and the economy? What implications follow for prudential regulation and monetary policy? In the second essay, we develop a quantitative New Keynesian DSGE model for the euro area and estimate the model with full-information Bayesian techniques. We show that changes in bank capital requirements lead to credit leakage between shadow and commercial banks, and that monetary policy can partly mitigate undesired leakage to the shadow banking sector when banking regulation is tightened. In the third essay, I turn to the optimal design of macroprudential regulation when credit is intermediated by traditional banks and unregulated shadow banks. I derive welfare loss functions and show that both cyclical variations and inefficient levels of credit have welfare implications. Regulators face a trade-off related to the composition of credit when deciding on optimal regulation. I find that they lower capital requirements more strongly under optimal policy in response to adverse shocks that trigger credit leakage to risky non-banks. Furthermore, the optimal static level of capital requirements is lower once shadow banks are considered. In the fourth essay, we address the following question: How much do market participants gain from a European Deposit Insurance Scheme (EDIS)? To this end, we develop an open-economy regime-switching DSGE model with bank default and study the effectiveness of EDIS in comparison to national fiscal policies. We find that reinsurance by both national fiscal policy and EDIS is effective in stabilizing the macro economy, even though welfare gains are slightly larger with EDIS and debt-to-GDP ratios rise under fiscal policy reinsurance. We demonstrate that risk-weighted contribution to EDIS are welfare-beneficial and discuss policy trade-offs during the implementation of EDIS.

Keywords: Corporate Debt, Investment, Shadow Banking, Macroprudential Regulation, Monetary Policy, Policy Coordination, Optimal Policy, Financial Frictions, Banking Union, Deposit Insurance, Risk-Sharing

Zusammenfassung

Diese Dissertation besteht aus vier Aufsätzen, welche die ökonomischen Folgen von Kreditmarktfriktionen und deren Implikationen für die makroprudenzielle Regulierung und die Geldpolitik untersuchen. Der erste Aufsatz befasst sich mit der folgenden Fragestellung: In welchem Maße beeinträchtigen exzessive Schuldenstände in den Bilanzen von Kreditnehmern die wirtschaftliche Aktivität? Um diese Frage zu adressieren schätzen wir ein nichtlineares Grenzwertmodell mithilfe eines umfangreichen Panel-Datensatzes für nichtfinanzielle Unternehmen im Euroraum. Wir berücksichtigen Nichtlinearitäten im Zusammenhang von Unternehmensverschuldung und Investitionen und zeigen, dass exzessive Verschuldung Firmeninvestitionen negativ beeinflusst, sobald die Schuldenquote oberhalb von 80 bis 85 Prozent liegt. Diese Nichtlinearitäten sind ökonomisch relevant und haben über Unterschiede der Firmengrößen, Sektoren, und der Profitabilität hinweg Bestand. Zudem verstärkte sich der Effekt im Zuge der europäischen Schuldenkrise. Der zweite und der dritte Aufsatz beschäftigen sich mit folgenden Fragen: Wie werden Kreditmärkte und die Volkswirtschaft von der Existenz unregulierter Schattenbanken beeinflusst? Welche Schlussfolgerungen ergeben sich für die makroprudenzielle Regulierung und die Geldpolitik? Im zweiten Aufsatz entwickeln wir ein Neukeynesianisches DSGE-Modell für den Euroraum und schätzen Modellparameter mithilfe Bayesianischer Schätzmethoden. Wir zeigen auf, dass Änderungen in Kapitalvorgaben für Banken eine Verlagerung der Kreditvergabe zwischen Geschäfts- und Schattenbanken nach sich ziehen können. Im Zuge einer gestrafften Bankenregulierung kann die Geldpolitik eine solche Verschiebung jedoch teilweise mildern. Der dritte Aufsatz untersucht die optimale Ausgestaltung maroprudenzieller Regulierung, wenn Kredite sowohl von Geschäfts- als auch von unregulierten Schattenbanken vergeben werden. Dabei leite ich Wohlfahrtsverlustfunktionen ab und zeige, dass sowohl zyklische Schwankungen als auch dauerhaft ineffiziente Kreditniveaus Auswirkungen auf die Wohlfahrt haben. Für Regulierer ergibt sich ein Zielkonflikt, der mit der Zusammensetzung der Kreditvergabe zusammenhängt. Es stellt sich heraus, dass Kapitalvorgaben unter der optimalen Politik in Reaktion auf adverse Schocks stärker gelockert werden, wenn diese eine Verschiebung der Kreditvergabe zu riskanteren Schattenbanken auslösen. Zudem sinkt das optimale statische Niveau der Kapitalvorgaben, sobald Schattenbanken berücksichtigt werden. Der vierte Aufsatz befasst sich mit folgender Frage: Wie stark profitieren Marktteilnehmer von einer europäischen Einlagensicherung (EES)? Hierfür entwickeln wir ein Modell offener Volkswirtschaften, das Zustandsänderungen und Bankeninsolvenzen berücksichtigt. Wir betrachten die Wirksamkeit der EES im Vergleich zu einer Rückversicherung durch die nationale Fiskalpolitik. Es zeigt sich, dass sowohl die EES als auch die nationale Fiskalpolitik geeignet sind, die Volkswirtschaft zu stabilisieren, wenngleich die Wohlfahrtsverluste mit der EES geringer ausfallen und die Staatsschuldenquote im Szenario mit der Fiskalpolitik steigt. Wir zeigen auf, dass risikogewichtete Einzahlungen in die EES wohlfahrtsfördernd sein können und diskutieren Zielkonflikte, die sich im Rahmen der Einführung der EES ergeben können.

Schlagwörter: Unternehmensverschuldung, Investitionen, Schattenbanken, Makroprudenzielle Regulierung, Geldpolitik, Politische Koordinierung, Optimale Politik, Finanzmarktfriktionen, Bankenunion, Einlagensicherung, Risikoteilung

Contents

List of Figures

List of Tables

1 Introduction

This dissertation investigates the economic consequences of frictions in credit markets and the implications for macroprudential regulation and monetary policy. In doing so, the study tries to answer three distinct questions, where each can be broadly related to one set of economic agents active in credit markets: borrowers, intermediaries, and depositors. First, how do excessive debt holdings on borrowers' balance sheets impede economic activity? Second, how does heterogeneity among financial intermediaries affect the macro economy and what implications follow for prudential regulation and monetary policy? And finally, how much do depositors gain from adequate risk-sharing via deposit insurance schemes on the national and the European level?

1.1 Borrowers: Corporate Debt and Investment

To address the first question, chapter 3 investigates the relationship between corporate debt and investment. The empirical approach relies on firm-level data for five peripheral euro area countries over the 2005-2014 period and explicitly accounts for non-linearities in the debt-investment link. Our study adds to the existing literature which finds evidence that high debt distorts investment due to higher default risks and higher costs of financing, while low leverage levels do not negatively affect investment.[1] One concern of this literature is that the threshold between high and low leverage regimes is often determined exogenously and in an ad-hoc manner. In contrast, our empirical approach allows us to endogenously estimate debt thresholds. We show that results are sensitive to the identified thresholds and that ad-hoc threshold specifications can lead to inconclusive results.

Our estimations suggest that there are significant non-linearities in the debt-investment link: We identify leverage thresholds in the range of a debt-to-asset ratio of 80 to 85 percent. For firms with a leverage ratio above this threshold, we find strong evidence consistent with debt holding back investment. Furthermore, the impact of leverage on investment is economically meaningful. In normal times, the negative investment effect materializes only for high levels of debt. A firm with a debt-to-asset ratio of 90 percent (i.e. an excessively leveraged firm) has, ceteris paribus, 0.7 percentage point of forgone investment per year compared with a firm with a debt-to-asset ratio of 80 percent. For certain periods and subsamples the investment effects are also significant for lower levels of debt. For example, in the years after 2008, a firm with a debt-to-asset ratio of 30 percent

[1] See for instance Jäger (2003) or Goretti and Souto (2013).

had additional annual investment of 1.4 percentage points compared with a firm with a debt ratio of 60 percent, and 2.4 percentage points compared with a firm with a debt ratio of 80 percent.

Both the leverage threshold and the investment-dampening impact of high leverage are robust across various specifications. In particular, for highly leveraged firms we find a negative debt-investment relationship in all major sectors and for both profitable and unprofitable firms. There is, however, evidence for some heterogeneity across firm size. The negative investment impact of high debt is observed for micro, small and medium-sized firms (which amount to 99 percent of firms in our sample), but not for large firms. This suggests that financial constraints related to a debt overhang play a less important role for large firms.

For firms with debt levels below the threshold, the relationship between debt and investment is less robust and depends on a number of firm characteristics and the macroeconomic environment. While our full-sample estimation suggests a slight (and insignificant) positive effect of debt on investment, even low debt seems to constitute a drag on investment during the crisis period. However, the negative investment effect is still smaller than for high-debt firms. Similarly, for smaller and less productive firms, even low levels of debt have a negative impact on investment.

Overall, these results suggest still substantial deleveraging needs in peripheral countries to support a stronger investment recovery. The economic environment in peripheral countries is characterised by a large number of small firms, low productivity and relatively high financial uncertainty – factors which reduce the capacity to tolerate high levels of debt and lead to a more negative debt-investment relationship. Moreover, our results show that a debt overhang is not only reflected in a high stock of debt but also in a low capacity to service the debt. Thus, even firms with a debt-to-asset ratio below the identified threshold may be in need of deleveraging if they face high debt service obligations.

1.2 Intermediaries: Shadow Banks and Regulation

In chapters 4 and 5, the primary focus is on financial intermediaries and the adequate design of regulation. In the aftermath of the global financial crisis of 2007/2008, a broad consensus has been reached among scholars and policy makers that a *macroprudential* approach towards financial regulation should focus on systemic developments in financial markets.[2] Such regulations put a particular emphasis on swings in aggregate credit and financial market volatility, as well as on the role of financial cycles for business cycle

[2] See Borio (2011, 2009) or Borio and Shim (2007) for a detailed description of the macroprudential approach. For a review of the pre-crisis microprudential approach, see Kroszner (2010), Borio (2003), or Allen and Gale (2000).

movements. Contemporaneously, the neglected treatment or complete absence of financial intermediaries and frictions in canonical pre-crisis dynamic stochastic general equilibrium (DSGE) models has widely been criticized. In response, banking-augmented macro models have been developed and employed to assess, inter alia, the effectiveness of different macroprudential tools in the presence of financial frictions. In particular, significant progress has been made with respect to the consideration of commercial banking at the macro level, both in theoretical models and in the field of financial regulation.

In comparison, the role of non-bank financial intermediation[3] has until recently been understated in both areas. At the same time, non-bank finance has substantially gained importance in the euro area over the last two decades. Figure 1.1 shows the evolution of the total amount of outstanding credit to non-financial corporations, provided by the traditional banking system and non-bank financial intermediaries in the euro area.[4] Whereas most corporate lending is still provided by commercial banks, the share of non-bank lending has steadily increased since the implementation of the common currency and has currently reached more than 35 percent of traditional banks' lending.

1.2.1 Shadow Banks and Credit Leakage

The increasing importance of non-bank financial intermediation and the resulting relevance for financial stability has recently been recognized by supervisors. However, designing a macroprudential framework for the shadow banking sector similar to the approach introduced for commercial banks is barely feasible. While traditional banks usually intermediate funds between borrowers and savers in a universal fashion, a multitude of specialized financial corporations operating in a complex intermediation chain are usually involved in non-bank credit intermediation.[5] Therefore, shadow bank regulation is largely limited to microprudential approaches or special regulative measures that can be introduced for a set of institutions involved in credit intermediation.[6]

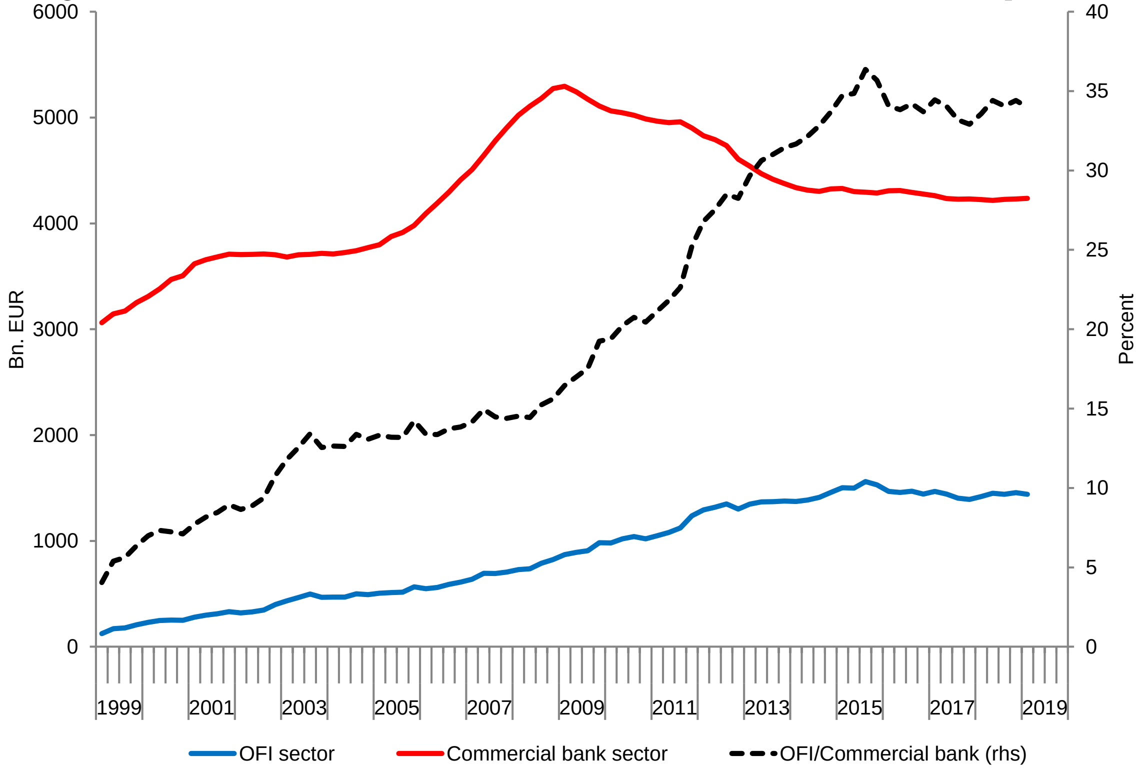
[3]In this dissertation, the terms "non-bank intermediation" and "shadow banking" will be used interchangeably to describe credit intermediation outside the regulated traditional commercial banking sector. See for instance Adrian and Jones (2018) for a discussion on terminology.

[4]Non-bank credit is defined as the aggregate loans provided by "Other Financial Intermediaries", a composite of different financial corporations other than commercial banks or institutions belonging to the Eurosystem. The OFI aggregate thus may not only include institutions universally accepted as shadow banks. However, alternative measures of "shadow bank credit" can straightforwardly be derived by marginal adjustments of OFI aggregates. See chapter 4, or Doyle et al. (2016) or Bakk-Simon et al. (2012).

[5]See for instance Adrian (2014), Adrian and Liang (2014), or Pozsar et al. (2010) for a discussion of the shadow bank intermediation chain.

[6]In Europe, the updated Markets in Financial Instruments Directive (MiFID II/MiFIR) aims at increasing transparency and investor protection in market-based finance, thereby applying to a subset of institutions under the broad definition of shadow banks used here. However, the approach primarily focuses on the harmonization of reporting and conduct of business standards and authorization requirements. Explicit capital requirements, affecting the shadow banking sector as a whole, are not part of the

Figure 1.1: Commercial and Shadow Bank Loans to Non-Financial Corporates



Note: Outstanding amount of loans of commercial and shadow banks (OFI) to non-financial coprorates (billions of euro). Source: Euro Area Accounts and Monetary Statistics (ECB).

Nevertheless, changes in regulation for the *commercial* banking sector can trigger a shift of credit intermediation towards less regulated parts of the financial system. In a scenario with only commercial banks, the trade-off the regulator faces arises from the contemporaneous stabilization of credit and economic activity:[7] Since the regulator's policy applies to the whole financial system in such a (counterfactual) scenario, changes in capital requirements affect total credit intermediation. Therefore, higher capital requirements can directly result – given that bank capital barely adjusts in the short run – in a reduction of credit intermediation, as all financial intermediaries in the economy have to reduce their assets to oblige with the regulatory requirement.[8] Lower credit intermediation potentially comes at the expense of lower economic activity, and the regulator has to decide on the optimal capital requirement level to balance the benefits of reduced lending activity and thus (potentially) higher financial stability with the cost of lower output growth.

regulatory package.

[7]See for instance Angelini et al. (2014) or Binder et al. (2018).

[8]There is ample empirical evidence that a tightening of capital regulation is usually associated with a decline in lending by financial intermediaries. See for instance De Jonghe et al. (2020), Meeks (2017), or Aiyar et al. (2016).

However, the existence of shadow banks introduces a further dimension to the trade-off the macroprudential policy maker, concerned with the regulation of traditional banking, faces. Higher capital requirements potentially lead to *credit leakage* towards unregulated shadow banks: As tighter banking regulation does not initially affect credit demand by real economic agents, higher regulation for commercial banks incentivizes borrowers to switch to shadow bank intermediaries as commercial banking becomes relatively costly.

The additional policy trade-off caused by credit leakage is furthermore shaped by structural characteristics of financial institutions. For instance, empirical evidence suggests a significant degree of market power in the euro area commercial banking sector.[9] In contrast, empirical evidence on shadow bank competition is hard to obtain, as the sector consists of highly diverse institutions operating in different market environments. However, some studies find that shadow banking can increase efficiency in financial markets by providing alternative financing sources and due to the involvement of highly specialized institutions in the intermediation process.[10] At the same time, shadow bank intermediation can increase systemic risk, as structural characteristics, economic motivations, and regulatory constraints within the diverse shadow banking sector can accelerate financial stress and macroeconomic disturbances and finally pose a threat to financial stability.[11]

How much credit tightening induced by macroprudential regulation will therefore be counteracted by the additional credit take-up of shadow banks? In the absence of macroprudential regulation of non-bank financial institutions, how can monetary policy react to limit the side effects? We adress these questions in chapter 4 where we develop and estimate a quantitative DSGE model for the euro area that features credit intermediation by different financial institutions: regulated commercial banks and unregulated shadow banks. On the aggregate level, the two intermediaries engage in similar activities, but differ along several dimensions on the micro level. First, while commercial banks can directly be reached with macroprudential tools, shadow banks are unregulated in the model. As the shadow banking sector comprises a multitude of diverse and highly specialized institutions in reality, the implementation of universal macroprudential regulation towards the sector as a whole may prove difficult. Furthermore, while – in line with empirical evidence – commercial banks exert market power, shadow banks are assumed to be subject to market forces and modeled as price takers. Without regulation, intermediating funds via these institutions is risky, and investors will limit their exposure to shadow banks endogenously.

[9] See for instance Gerali et al. (2010), Berger et al. (2004), Degryse and Ongena (2008), Claessens and Laeven (2004), or De Bandt and Davis (2000).

[10] See for instance Adrian and Ashcraft (2016, 2012) or Bundesbank (2014) for evidence how shadow banking can increase efficiency in financial markets.

[11] See for instance Adrian and Jones (2018) and the large body of references therein.

We draw on data for euro area shadow and commercial banks in a full-information Bayesian estimation exercise and employ the quantitative model for policy analyses. We document that the presence of shadow banking indeed implies a trade-off for regulators, as tighter regulation on commercial banks induces credit leakage towards the unregulated part of the financial system. We find that overall credit fluctuations are dampened in response to monetary policy and banking regulation shocks, as shadow bank credit movements counteract deviations of commercial bank lending to some degree. Furthermore, we show that monetary policy can mitigate unintended credit leakage to the shadow banking sector in response to unanticipated increases in macroprudential regulation, as changes in short-term interest rates affect both commercial and shadow bank credit. Finally, we investigate in a counterfactual analysis how the level of regulatory capital requirements would have evolved if the regulator had imposed countercyclical regulations already before the financial crisis. Whether the regulator is aware of shadow banking affects the required level of capital, suggesting the need for including non-bank credit and the leakage mechanism in the analysis of countercyclical capital requirements.

1.2.2 Shadow Banks and Optimal Policy

The analysis in chapter 4 sheds light on the credit leakage mechanism and its implications for macroprudential and monetary policies, but leaves one question unanswered: How should regulators *optimally* account for credit leakage in the design of macroprudential policies? While some degree of intermediation by efficient intermediaries might be socially desirable, policy makers have to trade off the benefits from higher financial market integration and intermediation through alternative funding sources against potential risk stemming from unregulated non-bank credit intermediation. Against this background, the degree to which activities in the shadow banking sector should be taken into account in the design of optimal regulation for traditional banks is not clear a priori.

These issues are addressed in chapter 5, where I employ a modified version of the New Keynesian model of chapter 4 to discuss welfare-optimal macroprudential regulation in the presence of unregulated shadow banks. I derive welfare loss functions and optimal policies under commitment following the LQ approach introduced in the literature on monetary policy. In doing so, the outlined approach relates to the derivation of optimal policy under the timeless perspective developed in Giannoni and Woodford (2003a,b), Benigno and Woodford (2005, 2012) and Woodford (2011).

Ultimately, the aim of deriving an optimal rule under commitment is to base policy decisions on a framework that allows for a systematic adjustment of capital requirements in response to financial market developments. Under the current policy framework in the euro area, adjustments of capital requirements are to a large extent conducted in a rather discretionary way by national regulators. However, the European Central Bank (ECB) is entitled to apply additional capital charges, including a capital conservation buffer, capital buffers for systemically important institutions, or countercyclical capital requirements.[12] However, the approach does not (yet) rely on a systematic rule according to which requirements are set, even if regulators base the adjustment of capital requirements in part on model-based inputs. Thus, chapter 5 contributes to the policy discussion on the adequate design of a quantitative framework for calibrating capital requirements in the euro area.

I find that first, shadow bank credit matters for optimal macroprudential regulation. Furthermore, not only *cyclical variations* of target variables, but also deviations of permanent credit *levels* from efficient values affect welfare. Consequently, inefficiencies in commercial and shadow bank credit markets rationalize time-invariant macroprudential policies that close the gaps between actual and efficient credit levels. In line with the principle of Tinbergen (1952), I find that two separate tools are needed to resolve inefficiencies in both credit markets. I propose a mix of permanent credit demand- and supply-side macroprudential policies that includes borrower loan-to-value (LTV) ratios and static capital requirements. The central implication from these findings is that optimal macroprudential policies for commercial banks should be designed in coordination with other policies whenever unregulated shadow banks are present in the economy. Thereby, borrower-side policies such as LTV ratios can be employed to target the share of credit intermediated by institutions that do not fall under the jurisdiction of credit-supply policies. Furthermore, monetary policy can play a role in the optimal policy mix. Short-term interest rates depict a universal tool to reach through *"all the cracks in the economy"* (Stein, 2013) and therefore affect both commercial and shadow bank intermediation.

I employ the derived welfare measures to discuss the optimal design of policies in quantitative simulation exercises. In the presence of shadow banking, the optimal permanent level of capital requirements is lower than in a comparable scenario without non-bank finance. To counteract undesirable credit leakage towards risky shadow banks, regulators optimally set requirements to 13.5 percent in steady state. In a model without shadow banking, the absence of the credit leakage trade-off results in an optimal level of bank capital requirements of 16 percent. I also evaluate optimal dynamic policies and discuss optimal regulatory responses to exogenous disturbances. I show that macroprudential regulators adjust capital requirements in a countercyclical manner in response to macroeconomic shocks and resulting movements in output and credit. They also try to mitigate credit leakage towards non-bank intermediaries. Consequently, if both credit aggregates move in the same direction after macroeconomic shocks, they adjust requirements less strongly

[12] Thereby, the ECB relies on a "scoreboard approach", where different financial indicators are evaluated to decide on the adequate level of capital requirements in a single country, see Constâncio et al. (2019).

than they would in the absence of shadow banking. In contrast, whenever macroeconomic shocks cause leakage, i.e. credit aggregates to move in opposite directions, regulators will adjust capital requirements more aggressively as in a situation without shadow banking.

1.3 Depositors: Deposit (Re-)Insurance and Risk-Sharing

The global financial crisis and the subsequent sovereign debt crisis in the euro area not only revealed the necessity for stronger macroprudential supervision and an adequate treatment of financial markets in quantitative models. Also, it highlighted the need for better integrated cross-border financial markets in Europe. For instance, the fragmentation in the financial system and the lack of adequate risk-sharing tools played a particular role in the development of a "doom loop" between banks and sovereigns prior to the crisis.[13] To increase the resilience of the European financial sector and to foster financial integration, different policy approaches have been put forward. At the core of these efforts, the European Banking Union (EBU) has been initiated as a central framework for joint banking supervision. It is substantiated by a single rulebook and comprises three pillars:[14]

1. A *Single Supervisory Mechanism (SSM)* responsible for European-wide banking supervision.

2. A *Single Resolution Mechanism (SRM)* as a European recovery and resolution framework for credit institutions.

3. A *European Deposit Insurance Scheme (EDIS)* as a European risk-sharing device to protect bank depositors.

While the implementation of the respective initiatives has been prone to delay,[15] the first two pillars have by now been fully established. However, progress on the harmonization of deposit insurance systems and the implementation of a European deposit insurance scheme (EDIS) has been slow. Under the original proposal, EDIS shall be established in three phases.[16] In phase 1, the scheme should be based on reinsurance where European funds are only required once the capacities of national schemes are exhausted. In phase 2, EDIS is intended to provide coinsurance, such that European funding would be involved immediately once payouts from deposit insurance are required in a member state. Finally, full insurance should be achieved in stage 3. However, the introduction of stages 2 and 3

[13]See Farhi and Tirole (2018) for a theoretical discussion of the doom loop in Europe.

[14]See European Commission (2020) for a detailed description of the aims and operational details of the different pillars.

[15]See Koetter et al. (2018).

[16]See European Commission (2015) for the details of the original proposal.

has raised concerns among European policy makers, such that a reinsurance scheme currently seems the most practicable approach.[17] Recent proposals therefore consider such a European deposit reinsurance mechanism, which only becomes effective once national deposit insurance funds are exhausted.[18] Accordingly, a European deposit insurance system would act as a two-tier safety net to cushion large country-specific shocks.

In chapter 6, the most recent study in this dissertation, we develop a two-country DSGE model with bank defaults and investigate the relative efficiency of such a deposit reinsurance scheme. We incorporate national deposit insurance (DI) schemes as well as trade and financial linkages, and calibrate the model for Germany (home) and the euro area excluding Germany (foreign). We then introduce EDIS as a risk-sharing device and study potential gains and losses with respect to macroeconomic and financial stability.[19]

Our model features three key elements that are important to study bank risk-taking and the performance of EDIS. First, home and foreign banks can default on their obligations and leave depositors and equity investors with losses. Second, in each country exists a national DI which collects payments from national banks. However, in times of severe financial distress, financial resources of the national DI become depleted, and either national governments or EDIS have to step in to cover depositor losses. Third, we incorporate bank-government linkages, as banks finance sovereign debt and the fiscal authority provides guarantees in case of bank insolvencies.

We use our model to evaluate the macroeconomic implications of EDIS in a situation where national deposit insurances are insufficient. To this end, we evaluate and compare different forms of reinsurance: no reinsurance, a national fiscal backstop, and EDIS. We find that if bank default risk increases in the home country, both a national backstop and EDIS perform equally well in providing reinsurance, while the latter turns out slightly more effective in stabilizing overall consumption. However, the country's debt-to-GDP ratio rises under the fiscal backstop, as insurance transfers directly affect public finances. While such an increase in government debt is avoided under EDIS, contributions to both the national DI and EDIS limit banks' margins and intermediation capacities. Financial distress is transmitted to the foreign economy, and foreign banks contribute more to cover default losses in the home economy with EDIS. Thus, bank margins also decline in the

[17] At the time, the proposal was rejected by several member states. Major concerns have been raised with respect to the treatment of risks stemming from government bond holdings and non-performing loans in the books of many European banks.

[18] See Adam et al. (2019), or Huertas (2019). Also, the German finance minister proposed a European reinsurance mechanism in a "non-paper" in November 2019. See for instance "Germany's Scholz Gives Ground on Eurozone Banking Union Plan", Financial Times, November 05, 2019.

[19] Our reinsurance scheme where EDIS would depict a second line of defense after national capacities have been exhausted also resembles closely to the proposals by a group of German and French economists (Bénassy-Quéré et al., 2018) and by the European Parliament (De Lange, 2016).

foreign economy, with resulting adverse effects for foreign lending and economic activity.

We also find that EDIS is particularly beneficial for savers in a country where national insurance funds are exhausted. Consequently, union-wide welfare gains from EDIS are largest in a scenario where national funds in both economies are insufficient to cover bank default losses. We also show that household and union-wide welfare increases in the share of contributions of risky banks. Thus, if the ultimate objective of EDIS is depositor welfare, a "polluter-pays" contribution scheme featured in recent policy proposals seems justified.

We discuss short-term costs arising when the EDIS fund is installed and only becomes operational once it has been filled up to the target level. We find that upfront contributions can temporarily lower national DIs' capacities if bank payments into EDIS are deductible. Without deductibility, demanding double contributions from banks can temporarily lower bank lending and ultimately real economic activity. Policy makers face a trade-off, as longer implementation horizons mitigate peak default rates in the short run. However, national DIs' capacities are lower for longer, which prolongs the economic contraction.

Finally, in a counterfactual exercise, we assess how EDIS would have performed in the euro area during the financial crisis. We compare EDIS with a benchmark policy, where we assume that national governments would have backed national deposit insurance schemes once their funds had been exhausted. We find that the stabilization of GDP and consumption would have been very similar under both policies. However, debt-to-GDP ratios would have been lower with EDIS. We show that the benefits of EDIS increase even more once we assume that rising sovereign bond yields are associated with declines in the value of government bond holdings by banks.

Our findings suggest that a European deposit reinsurance scheme can provide union-wide welfare gains, but policy makers face several trade-offs. First, while European risk-sharing can foster macroeconomic and financial stability, contributions in both national and European insurance schemes can limit banks' lending capacities. Thus, regulators need to design adequate contribution and deductibility schemes to avoid tensions in credit markets. Second, while the long-term benefits of EDIS are potentially large, short-term costs during the implementation phase need to be taken into account. While expanding the implementation horizon can mitigate short-run distress in financial markets, smoothing out bank contributions into the future potentially prolongs an economic downturn: If bank contributions are channeled towards EDIS for a longer time, national deposit insurance may be insufficient to cover depositor losses in times of distress, and credit costs may rise. Thus, policy makers need to make sure that EDIS, once introduced, is able to provide insurance instantaneously. Also, temporary suspensions of EDIS contributions could be considered during times of acute distress, if EDIS payments are not (yet) available.

2 Literature Review

This chapter of the dissertations provides an overview of the literature related to the content of the following chapters. Starting from the borrower side of credit markets, section 2.1 summarizes the strand of the theoretical and empirical corporate finance literature that is related to corporate leverage and its implications for firm investment activity. Then, in section 2.2, I turn to financial intermediaries and review the literature on their treatment in macroeconomic models. I put particular emphasis on how macro models are employed to discuss macroprudential regulation and its interaction with monetary policy. As the primary focus of chapters 4 and 5 lies on the role of shadow banking for such policies, I review studies that discuss the presence of non-bank financial intermediaries in macroeconomic models. I also refer to studies investigating the optimal design of macroprudential policies, as this will be the focal point of chapter 5. Finally, in section 2.3, I turn to the depositor's side of credit markets and review studies on risk-sharing and deposit insurance, issues covered in chapter 6.

2.1 Borrowers: Corporate Debt and Investment

Chapter 3 of this dissertation studies the link between firms' indebtedness and their investment activity. On the theoretical side, it is linked to the branch of the finance literature investigating the determinants of corporate balance sheets and the link between corporate finance and investment. This literature has shown that, in the presence of financial market frictions, the Modigliani and Miller (1958) theorem does not hold and firms' net worth, largely determined by investment decisions, depends on their financial structure.

According to the trade-off theory of capital structure, firms set a target leverage ratio by balancing the costs and benefits of debt. The benefits of debt include, inter alia, the tax deductibility of interest (Modigliani and Miller, 1963), the disciplining effect of debt in case of agency problems between firm managers and shareholders (Jensen and Meckling, 1976; Grossman and Hart, 1982), and the signalling role of debt regarding firm productivity, for instance if managers possess inside information about the future productivity gains of the firm (Leland and Pyle, 1977; Ross, 1977). The costs of debt relate to potential bankruptcy costs. Increasing debt holdings compared to equity raises default probabilities as the fraction of asset holdings backed by equity is decreasing. Higher default probabilities lead to financial distress, which is reflected in higher external financing premia or the rationing of credit (Myers, 1977; Stiglitz and Weiss, 1981).

The key implication of the trade-off paradigm is that firms decide on an optimal leverage ratio that solves the trade-off.[1] If their actual financial structure deviates from the targeted leverage (e.g. due to shocks to firm value), balance sheet restructuring aims at gradually moving actual leverage back to target. A firm with a leverage ratio below the target will therefore follow a different investment decision rule than one with high leverage. While low-leveraged firms face low financial constraints and can draw on "reserves of untapped borrowing power" (Modigliani and Miller, 1963) if profitable investment opportunities arise, high-debt firms are more concerned about default risks and their financial status (e.g., due to the risk of losing investment grade status). They will focus on restoring leverage targets and may give up valuable investment opportunities when internal sources of funds are not sufficient (Myers, 1984), especially in times of heightened uncertainty and financial distress.[2] In our empirical analysis, we therefore expect a non-linear debt-investment relation for firms operating below and above a leverage target or threshold.

The leverage target is influenced by several factors that have an impact on the costs and benefits of debt financing. For example, firms with a lower probability of being distressed, such as profitable or large (more diversified) firms, can be expected to be able to borrow more before the expected costs of financial distress offset the benefits of debt. Moreover, changes in general risk sentiment may impact on the leverage target through both the supply of and demand for funds (see e.g. Amador and Nagengast, 2016; Buca and Vermeulen, 2017; Cingano et al., 2016; Storz et al., 2017).

A number of empirical studies find evidence that high corporate leverage can have negative effects on investment (Vermeulen, 2002; Benito and Hernando, 2007; Martinez-Carrascal and Ferrando, 2008; Pal and Ferrando, 2010; Kalemli-Özcan et al., 2015a; Barbiero et al., 2016). These studies typically find that the investment impact of high corporate indebtedness is not uniform. Using industry level data, Vermeulen (2002) shows that leverage is more important in explaining investment during downturns and for small firms. Barbosa et al. (2007) find for Portuguese firms that the impact of corporate indebtedness on investment depends on firm size, the number of bank lending relationships, and credit default history. In contrast to Vermeulen (2002), they do not find different sensitivities of investment to debt between economic booms and busts.

In line with the trade-off theory, some studies have also argued that low leverage levels do not negatively impact on investment but that there is a threshold level of corporate debt beyond which leverage and investment are negatively associated. Using flow of funds

[1]For survey studies on corporate debt targets and financing structures see for instance Graham and Harvey (2001), Bancel and Mittoo (2004), or Brounen et al. (2004).

[2]Bernanke et al. (1999) show that the sequence of events between firm net worth, collateral and investment can lead to larger and more persistent cyclical fluctuations in the economy ("financial accelerator mechanism").

data for the US and Germany, Jäger (2003) finds that the negative impact of corporate indebtedness on investment is stronger in years of above-average debt holdings than in years of below-average leverage. Hernando and Martinez-Carrascal (2008) provide firm-level evidence on threshold effects; their results for Spanish firms indicate that a negative impact of indebtedness on investment is only present for firms with high financial pressure, i.e. for firms above the 75^{th} percentile of indebtedness. This threshold is above the one identified by Goretti and Souto (2013) who find strongly negative effects of debt on investment once the debt to equity threshold exceeds the 25^{th} percentile of the firms in their sample of euro area firms. While these studies have assumed potential debt thresholds rather arbitrarily, Ferrando et al. (2017) estimate a leverage equation from which they calculate the target level of debt. They show that firms with a conservative leverage policy (defined by a negative deviation between the actual level of leverage and the target leverage) invest more in the years following the conservative financial policy.

We add to the literature by conducting threshold analyses applying the method by Hansen (1999, 2000) to a large firm level data set and analysing the investment sensitivity of leverage above and beyond these thresholds. The study coming closest to our approach in terms of method is Coricelli et al. (2012) who apply the panel threshold model by Hansen (1999) to a subsample of Orbis data for Eastern European countries. In their study, they focus on the effect of firm leverage on productivity and leave corporate investment aside.

2.2 Intermediaries: Shadow Banks and Regulation

After the global financial crisis of 2008/2009, the neglect of financial intermediaries in pre-crisis DSGE models has widely been criticized (Christiano et al., 2018). In response, the literature on DSGE models including financial frictions and intermediaries has been growing rapidly in the past decade. Banking-augmented macro models have been developed and used to assess the effectiveness of monetary, fiscal, and macroprudential policies in the presence of financial frictions.[3] Chapters 4 and 5 of the dissertation relate to this growing literature, as the analysis on macroprudential policies is carried out with the help of banking-augmented DSGE models that feature both commercial banks and non-bank financial intermediaries.

One prominent strand of this literature employs models with a moral hazard problem located between depositors and intermediaries that implies an endogenous leverage constraint for banks. Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) introduce financial frictions based on an agency problem between banks and households. The fric-

[3] Such models have also been used to evaluate the implications of financial frictions for the transmission of unconventional monetary policy (Gertler and Karadi, 2011; Cúrdia and Woodford, 2010a,b, 2011), or for the discussion of bank runs (Gertler et al., 2016; Gertler and Kiyotaki, 2015).

tion arises as banks are allowed to divert household funds away from investment projects for private benefits. Given that households are aware of potential misconduct, the ability of banks to obtain deposit funding is limited. In Gertler and Kiyotaki (2011), the framework is furthermore augmented by allowing for liquidity risk similar to Kiyotaki and Moore (2012). However, in contrast to Gertler and Karadi (2011), the model does not incorporate nominal rigidities as the authors are particularly interested in credit market frictions and the role of credit policies instead of monetary policy effects.

A second strand of studies features models with frictions in the intermediation of funds between borrowers and banks, and emphasizes on the role of collateral borrowers have to place with lenders in return for funding. Iacoviello and Guerrieri (2017) and Iacoviello (2005) introduce housing as collateral and relate the amount of borrowing by impatient households to movements in the value of collateral. As they show, adverse developments in housing markets as well as exogenous changes in loan-to-value ratios can limit the amount of lending if debtors face borrowing constraints, and ultimately dampen consumption and investment in the economy.

Extending the approach, Gerali et al. (2010) explicitly introduce a banking sector in a canonical New Keynesian DSGE model for the euro area and locate the collateral friction between borrowers and banks. By modeling the banking sector explicitly, they are able to incorporate specific characteristics of the euro area banking sector, such as market power and sluggish adjustment of bank interest rates in response to changes in the monetary policy rate. Furthermore, introducing banks allows for an analysis of shocks emerging *within* the financial system. Estimating the model with Bayesian techniques, they find that commercial banks can on the one hand stabilize business cycles by shielding households and firms from shocks originating outside the financial sector. On the other hand, shocks to financial intermediaries can adversely affect business cycles whenever disruptions in bank balance sheets are transmitted to the real economy. Gambacorta and Signoretti (2014) employ a simplified version of the model to study the effectiveness of monetary policy in such as setup with financial frictions and a credit channel. They find that "leaning against the wind", i.e. augmenting Taylor-type monetary policy rules with a financial stability objective, is particularly effective if the economy is hit by aggregate supply shocks. Without such leaning against the wind, monetary policy turns out to be "too loose" in response to positive supply shocks, as the procyclical behavior of financial variables amplifies economic volatility.

Focusing on macroprudential regulation,[4] Christensen et al. (2011) employ a framework based on the Holström and Tirole (1997) intermediation setup with rule-based macroprudential policy makers in place. They find that countercyclical regulatory policies can stabilize the economy in response to shocks originating in the banking sector. Angelini et al. (2014) implement collateral constraints and capital requirements set according to a simple rule in an estimated New Keynesian DSGE model for the euro area. Similar to Christensen et al. (2011), they find that macroprudential policy is particularly effective in times of financial distress, i.e. when shocks affecting credit supply hit the economy.

Angelini et al. (2014) furthermore evaluate the interaction of their simple policy rule with monetary policy, and find that under certain conditions, time-varying capital requirements can be supportive to monetary policy in stabilizing economic activity. However, in "normal times", i.e. when the economy is mainly driven by real economic (supply) shocks, the benefit from capital regulation is negligible. Even worse, without adequate coordination, capital regulation can generate excess volatility in the policy instruments of regulators and the central bank. Within a class of simple policy rules, Angeloni and Faia (2013) find that the desirable combination of macroprudential and monetary policies includes countercyclical capital ratios and a response of monetary policy to asset prices or bank leverage. Gelain and Ilbas (2017) introduce a central bank and a macroprudential regulator in a Smets and Wouters (2007) New Keynesian DSGE model augmented by a Gertler and Karadi (2011) financial intermediaries. They find that in a fully cooperative scenario, a higher weight placed by the regulator on output gap stabilization – which depicts a joint policy objective – is beneficial for reducing macroeconomic volatility. In a non-cooperative setup, a higher weight on credit growth stabilization by the macroprudential regulator is beneficial. In a similar approach, Bean et al. (2010) find that a combination of monetary and macroprudential policies appears to be more effective as a means of leaning against the wind than relying on traditional monetary policy alone.

Beau et al. (2012) define four different policy regimes depending on whether financial stability depicts an explicit objective of monetary policy or not, and whether a separate macroprudential regulator is in place or not. By employing an estimated euro area DSGE model, they evaluate the impact of different shocks on inflation dynamics, and assess under which policy regime price stability is least affected by such shocks. They find that, over the business cycle, conflicts among both policy makers should be limited. In particular, shocks to housing preferences and credit, the most important sources of instability for macroprudential policy, do only marginally account for inflation dynamics in their

[4]Banking-augmented macro models are frequently employed in the evaluation of different aspects of financial stability, such as bank runs (Angeloni and Faia, 2013; Gertler and Kiyotaki, 2015; Gertler et al., 2016) or the effectiveness of (un-)conventional fiscal and monetary policies in times of financial distress (Gambacorta and Signoretti, 2014; Gertler and Karadi, 2011; Cúrdia and Woodford, 2010a,b, 2011).

model, and thus only mildly affect the conduct and the transmission of monetary policy. In addition, for the shocks explaining the largest part of inflation dynamics, it appears to be irrelevant whether monetary policy explicitly focuses on financial stability or whether a separate macroprudential regulator is in place. By deriving jointly optimal Ramsey policies, Collard et al. (2017) focus on different types of lending and show that limited liability and deposit insurance can cause excessive risk-taking in the financial sector. Silvo (2019) evaluates Ramsey-optimal policies in a New Keynesian framework augmented by Holström and Tirole (1997). In line with Angelini et al. (2014), she finds that macroprudential policies play a modest stabilizing role in response to aggregate supply shocks, but are highly effective when the financial sector is the source of fluctuations.

In all of the above studies, financial intermediaries are modeled as homogeneous representative agents. Acknowledging the critique on the absence of shadow bank intermediation in canonical DSGE models prior to the financial crisis and thereafter (Christiano et al., 2018), recent studies proposed different approaches to incorporate shadow banking. Gertler et al. (2016) augment the canonical Gertler and Karadi (2011) framework by introducing a heterogeneous banking system with wholesale as well as retail banks. Wholesale banks represent the shadow banking part of the financial system engaged in interbank funding, whereas retail banks collect household deposits to lend to both the wholesale banks and the non-financial sector.[5] Meeks and Nelson (2017) use a calibrated model to show how the interaction between shadow banks and commercial banks can affect credit dynamics and that securitization in combination with high leverage in the shadow banking sector can have adverse effects on macroeconomic stability. Verona et al. (2013) develop a model where shadow banks directly engage in credit intermediation between households and firms. In contrast to the models used in chapter 4 and 5, they assume that shadow banks act under monopolistic competition to derive a positive spread between the lending rate of shadow banks and the risk-free rate. They show that incorporating shadow banks increases the magnitude of boom-bust dynamics in response to an extended period of loose monetary policy. Mazelis (2016) develops a model including traditional banks, shadow banks, and investment funds and studies the relevance of different types of credit for macroeconomic volatility. He concludes that a more equity-based financial system can mitigate the credit crunch during recessions when the economy is stuck at the effective lower bound of nominal interest rates (ELB).

Closest to the analysis in chapter 4, Begenau and Landvoigt (2016) and Fève and Pierrard (2017) evaluate how the existence of shadow banks can alter the effectiveness

[5] The notion of a wholesale banking sector has already been introduced in Gertler and Kiyotaki (2015). Furthermore, Gertler and Kiyotaki (2011) discuss interbank borrowing. However, no distinct separation between wholesale and retail banks has been undertaken in these studies.

of capital requirements. Studying the United States (US), the former study shows that tightening regulation for commercial banks can result in a shift of intermediation away from safer commercial banks towards unregulated and more fragile shadow banks, such that the net benefit of raising capital requirements for commercial banks only depends on the initial level of fragility in the financial system. Similarly, Fève and Pierrard (2017) estimate a real business cycle model with US data and identify a leakage of intermediation towards shadow banks. They conclude that the degree of stabilization due to higher capital requirements for commercial banks can be dampened when more funds are channeled via the shadow banking sector. Aikman et al. (2019) discuss the role of credit intermediation by market-based financial institutions that do not represent traditional banks for optimal coordination between monetary and macroprudential policies. All of these studies evaluate different aspects of the shadow banking sector, rely to a different degree on calibration and estimation techniques to match time-series data for the US and the euro area with model-implied dynamics, and discuss the interaction of the shadow banking sector with the rest of the economy in different ways. However, they lack a welfare-based discussion of optimal capital regulation for commercial banks whenever shadow banks are present.

To my knowledge, the study in chapter 5 is therefore the first to discuss the optimal design of macroprudential policies in the presence of shadow banking in a dynamic general equilibrium framework. In doing so, it not only strongly connects to the studies on financial frictions and financial intermediaries in DSGE models discussed so far, but also to two additional strands. First, several recent studies in the theoretical banking literature use static or partial-equilibrium models to discuss how the introduction of shadow banking alters optimal capital regulation for commercial banks (Ordonez, 2018; Farhi and Tirole, 2017; Plantin, 2015; Harris et al., 2014). Despite differences in microfoundations for the interaction between shadow bank and commercial bank lending and assumptions on regulatory coverage, they find that the existence of shadow banks significantly alters the optimal level of capital regulation. However, these studies do not discuss general equilibrium effects and dynamic policy responses to macroeconomic disturbances.

Second, it relates to the discussion on welfare-optimal macroprudential policies and their analyses with macroeconomic models. Only few studies derive optimal macroprudential policies on welfare-theoretic grounds, i.e. by deriving welfare functions from first-principle, in DSGE models with financial frictions. More often, optimal macroprudential policy analyses rely on a "revealed preferences" approach to define macroprudential objectives (Binder et al., 2018; Silvo, 2019; Angelini et al., 2014; Collard et al., 2017; Gelain and Ilbas, 2017; Angeloni and Faia, 2013; Bean et al., 2010). Based on real-world discussions among policy makers and statements of macroprudential authorities, it is usually assumed that these institutions are primarily concerned with the stabilization of credit and business cycles. Therefore, credit measures as well as measures of economic activity usually enter ad-hoc loss or policy functions used for welfare analyses in these studies, whereas such functions are not derived from first principles. Furthermore, these studies do not take the existence of shadow banks explicitly into account. In contrast, Cúrdia and Woodford (2010b) and De Paoli and Paustian (2017) find that credit frictions enter welfare-based loss functions for macroprudential policy. Ferrero et al. (2018) discuss coordination between macroprudential and monetary policy and derive a welfare-based loss function that provides scope for active macroprudential policy to overcome imperfect risk-sharing in their model due to household heterogeneity. Aguilar et al. (2019) derive welfare loss functions in a model featuring endogenous bank default as in Clerc et al. (2015) and study different macroprudential rules for the euro area.

2.3 Depositors: Deposit (Re-)Insurance and Risk-Sharing

Chapter 6 relates to several strands of research on bank risk-sharing and the adequate international coordination of banking policies. First, we contribute to the macroeconomic literature on bank risk-sharing in open economy models. Earlier contributions already embed banking sectors in two-country settings. Some assume a representative global bank to study international spill-over effects of country-specific shocks and their amplification by international banks (Mendoza and Quadrini, 2010; Kollmann et al., 2011; Kollmann, 2013). We deviate from this approach by allowing for heterogeneous degrees of risk across countries' individual banking sectors. To this end, our study closely relates to Dedola et al. (2013), they develop a two-country banking model à la Gertler and Kiyotaki (2011) with agency costs. In their approach, the degree of financial frictions is assumed to be equal across both countries. However, our model instead builds on Mendicino et al. (2018), who rely on a closed-economy model that features bank default and a deposit insurance scheme. They focus on optimal dynamic bank capital regulation, and while their deposit insurance reflects a direct transfer scheme between households, our framework features a deposit fund financed by banks that compensates households in case of bank default. We extend a modified version of their model to the open economy, and explicitly allow for heterogeneity in bank riskiness across both countries.

Only few studies have introduced (European) deposit insurance schemes in macroeconomic models,[6] and if so, design of such frameworks and its relative performance against

[6] However, the optimal design of centralized banking supervision has been studied extensively in the theoretical banking literature. Both the optimal degree of transfer of responsibilities to a union-wide regulatory agency and coordination issues between supranational and national regulators have been discussed. Inter alia, the focus has been on banking supervision (Colliard, 2018; Carletti et al., 2016; Beck and Wagner, 2016; Boyer and Ponce, 2012), bank resolution (Górnicka and Zoican, 2016), as well as on bank bailouts and recapitalization (Foarta, 2018). Whereas evidence on the efficiency of supranational

other forms of risk-sharing has not been studied in great detail. Furthermore, these studies do not analyze deposit insurance designed as a European reinsurance scheme. Dubois (2017) evaluates the implementation of a joint deposit insurance scheme in a two-country model with bank runs, and finds that such a framework potentially increases steady-state consumption and reduces volatility in real economic activity, with ultimately positive welfare effects. While we abstract from bank runs, international banks are subject to endogenous default risk in our model. This allows us to analyze moral hazard and welfare even during non-crisis times. In addition to the introduction of a full-fledged insurance fund, our analysis also compares the macroeconomic effects of a European deposit reinsurance to different risk-sharing scenarios.

Second, we contribute to the broader literature on the design and implications of deposit insurance schemes. On the theoretical side, Diamond and Dybvig (1983) show in their seminal paper that adequately designed deposit insurance schemes can prevent bank runs and reduce liquidity risks, which lowers the likelihood and depth of financial crises and resulting adverse effects for the real economy. However, these benefits are balanced by costs associated to moral hazard, as insurance fosters bank risk-taking behavior (Lambert et al., 2017; Anginer et al., 2014; Bernet and Walter, 2009; Cooper and Ross, 2002). Furthermore, deposit insurance can lead to a decline in market discipline and adverse selection, as the share of undisciplined and incompetent bankers rises once depositors' incentives to monitor bankers and banks incentives to behave disciplined decline (Acharya and Thakor, 2016; Merton, 1977). Empirically, Demirgüç-Kunt and Huizinga (2004) and Demirgüç-Kunt et al. (2014) document the rapid increase in the number of countries that implemented deposit guarantee schemes given their effectiveness in reducing bank runs and liquidity risks. However, there is vast empirical evidence on how deposit insurance can indeed lead to more moral hazard and risk-taking (Pennacchi, 2006; Wheelock and Kumbhakar, 1995), a decline in market discipline (Demirgüç-Kunt and Huizinga, 2004; Calomiris and Jaremski, 2019, 2016; Wheelock and Kumbhakar, 1995), and ultimately to greater instability in financial markets (Demirgüç-Kunt and Detragiache, 2002). With respect to EDIS, Carmassi et al. (2018) employ bank-level data to estimate EDIS exposure to bank failures and contributions, and study the implications of different EDIS designs and risk-weighted contribution schemes. They find that appropriately designed risk-weighted contributions to EDIS are crucial to achieve a balance between adequate insurance and cross-subsidization between national banking systems. Such cross-subsidies are smaller in a full-fledged EDIS than in a "mixed deposit insurance scheme" more similar to the reinsurance variant we study in chapter 6 if contributions to EDIS are non-deductible.

regulation is mixed, the findings indicate that some degree of shared responsibilities via a supranational regulatory regime is welfare-beneficial.

Third, we connect to the theoretical literature that has recently investigated the doom loop between sovereigns and banks. Farhi and Tirole (2018) discuss different channels through which bad news about government and banking sustainability can induce re-nationalization in financial markets and argue that banking unions can act as commitment devices for fragile debtor countries. Similarly, Acharya et al. (2014) model the increase in bank solvency risk in response to increasing sovereign risk and show by relying on credit default swaps (CDS) data that bank bailouts increased sovereign credit risk over the course of the European debt crisis. Consequently, Acharya and Steffen (2016) conclude that both banking and fiscal unions are needed as risk-sharing devices to break the link between weak sovereigns and banks. As a link between both approaches, Brunnermeier et al. (2016) use a two-country bank-sovereign model to propose a risk-sharing mechanism in which banks are incentivized to hold senior tranches of syndicated government bonds backed by euro area member states (ESBies). However, empiricaland theoretical evidence suggests that risk-sharing occurs via different channels (Asdrubali et al., 2018, 1996), so that well-designed fiscal policies alone cannot completely mitigate credit or sovereign default risks. Other channels such as capital and credit markets also play a significant role in effective risk-sharing (Hoffmann et al., 2019; Furceri and Zdzienicka, 2015; Afonso and Furceri, 2008; Sørensen and Yosha, 1998).

3 Corporate Debt and Investment: A Firm-Level Analysis for Stressed Euro Area Countries

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4 Macroprudential Regulation and Leakage to the Shadow Banking Sector

Macroprudential policies are often aimed at the commercial banking sector, while a host of other non-bank financial institutions, or shadow banks, may not fall under their jurisdiction. We study the effects of tightening commercial bank regulation on the shadow banking sector. We develop a DSGE model that differentiates between regulated, monopolistic competitive commercial banks and a shadow banking system that relies on funding in a perfectly competitive market for investments. After estimating the model using euro area data from 1999 – 2014 including information on shadow banks, we find that tighter capital requirements on commercial banks increase shadow bank lending, which may have adverse financial stability effects. Coordinating macroprudential tightening with monetary easing can limit this leakage mechanism, while still bringing about the desired reduction in aggregate lending. In a counterfactual analysis, we compare how macroprudential policy implemented before the crisis would have dampened the business and lending cycles.

4.1 Introduction

The global financial crisis of 2007/2008 triggered a substantial debate about the adequate design of financial regulation. As of today, a broad consensus has been reached among scholars and policy makers that sound financial market regulation requires a particular focus on macro developments in financial markets.[1] Such a macroprudential approach towards financial regulation focuses on systemic developments like swings in aggregate credit or financial market volatility, as well as on the role of financial cycles for business cycle movements.[2] While a lot of macroprudential policies focus on the commercial banking sector,[3] consistent and comprehensive regulation of the non-bank financial sector has proven to be more difficult to attain. Given the diverse nature of financial firms involved in

This chapter is joint work with Falk Mazelis.

[1]See Borio (2003), Kroszner (2010), or Allen and Gale (2000) for a review of the pre-crisis microprudential approach of guaranteeing financial stability by supervising single institutions alone.

[2]See Borio and Shim (2007), or Borio (2009, 2011) for a detailed description of the macroprudential approach.

[3]Rules laid down in the latest round of Basel accords on banking regulation (*Basel III*) strongly focus on supervisory and regulatory tools targeting macro developments in credit and risk-taking, such as rules on interbank lending, cyclical adjustments of capital requirements, and supervision on bank interconnectedness.

non-bank credit intermediation, their regulation falls into the court of various regulatory authorities. However, understanding the interaction between commercial bank regulation and non-bank finance is crucial for the assessment of macroprudential policies, as non-bank institutions might take up some of the lending if banks cut back on intermediation in the wake of tighter regulation.[4]

In this chapter, we analyze the implications of considering non-bank financial intermediaries, or *shadow banks*, in the conduct of macroprudential regulation for the commercial banking sector. In practice, the shadow banking sector comprises a set of diverse institutions conducting highly specialized tasks in the financial system. On the macro level, however, the shadow banking sector intermediates funds in a similar fashion to the commercial banking system, but without being subject to macroprudential policies. In this chapter, we therefore address the following questions: How much of the credit tightening induced by macroprudential regulation will be counteracted by shadow banks? In the absence of macroprudential regulation of non-bank financial institutions, how can monetary policy react to limit the side effects?

To answer these questions, we derive a New Keynesian DSGE model with savers and borrowers, and two types of financial institutions that intermediate funds between these two groups: commercial banks and shadow banks. Both types of intermediaries are based on distinct microeconomic foundations that allow for structural differences with respect to regulatory coverage and market structure in the two sectors. We then apply Bayesian techniques and rely on economic and financial data for the euro area to estimate the parameters of our model.

This chapter contributes to the literature in several ways. On the technical side, we derive a heterogeneous financial system by combining elements of two canonical frameworks for modeling financial frictions in DSGE models: Our commercial banking sector is based on the work by Gerali et al. (2010), whereas our shadow banking sector is modeled similar to the financial sector in Gertler and Karadi (2011). This is the first study to model both approaches in one consistent setting with heterogeneous financial markets.[5] The second contribution is the inclusion of data on euro area shadow bank lending in the estimation procedure, which has so far been limited to other jurisdictions. Third, we contribute to the policy discussion around unintended consequences of macroprudential measures and interaction with monetary policy: The presence of shadow banks can affect the setting of

[4] See Cizel et al. (2019).

[5] The updated version of the ECB's New Area Wide Model (NAWM II) depicts another example of a model where elements of both the Gerali et al. (2010) and the Gertler and Karadi (2011) framework are combined, see Coenen et al. (2019). However, the "wholesale" and "retail" banks motivated by the two frameworks are part of a representative bank holding group in this model, whereas both bank types will be separate entities in our setup.

macroprudential policy, even if not directly enforceable on all financial intermediaries.

Effective and targeted macroprudential policy is often considered to be the first-best response in reaction to financial instability concerns.[6] We challenge this view in the face of a growing and still sparsely regulated non-bank financial sector in the euro area (see figure 1.1), and the resulting potential for macroprudential and monetary policy coordination. Our approach is therefore intended as a caveat to work that considers financial stability issues of the aggregate financial sector or commercial banking sector only instead of differentiating between banking and non-bank finance. As discussed in section 1.2.1, changes in macroprudential regulation for banks can trigger *credit leakage* towards unregulated institutions, and neglecting such changes in the composition of credit can impede the efficacy of such policies.[7]

The policy tool we consider in this study is capital requirement regulation, which under Basel III represents a key macroprudential tool regulators can apply to the commercial banking system to prevent excessive leverage and risk-taking. Countercyclical capital requirements can be raised to avoid excessive credit growth in boom times, and lowered whenever credit developments are subdued. In a policy exercise, we assess to what extent coordinating monetary and macroprudential policies can limit credit leakage, while still bringing about the desired reduction in aggregate lending. We also evaluate how regulators taking shadow banking into account or not would have set countercyclical requirements in the euro area since the start of the single currency, had such tools been already in place.

In the following section, the full DSGE model is introduced. Section 4.3 introduces the data we use and discusses the econometric procedure we employ to derive estimates of key parameters of the model. In section 4.4, we use our model to simulate the effects of neglecting shadow bank intermediation in macroprudential policy, before we conclude in section 4.5.

4.2 A New Keynesian DSGE Model

In this section, we introduce shadow banking into a DSGE model akin to the euro area banking model developed by Gerali et al. (2010) and Gambacorta and Signoretti (2014).[8] In appendix A.1, we furthermore develop a stylized two-period model and describe the implications of shadow banks for the effectiveness of commercial bank regulation in detail.

[6]See for instance Rubio and Carrasco-Gallego (2015).

[7]Increasing intermediation by non-bank financial institutions does not *per se* depict an undesirable development. In some circumstances, technological advances as well as lower dependency on regulatory and institutional provisions of non-bank financial institutions can increase the efficiency in the intermediation process and increase overall welfare in the economy (Buchak et al., 2018; Ordonez, 2018). However, higher shares of intermediation being conducted by unregulated shadow institutions, which may exploit regulatory arbitrage, potentially increases risks to financial stability, which is our concern here.

[8]The complete non-linear DSGE model is presented in appendix A.2.

In the DSGE model, patient households serve as savers and provide funds to impatient entrepreneurs that act as borrowers.[9] Households cannot directly provide funds to borrowing entrepreneurs, but have to place deposits in financial intermediaries that then provide loans to firms, which use the funds for production.[10] However, households can allocate savings between two types of intermediaries: shadow banks and commercial banks. Commercial banks face regulatory capital requirements, whereas shadow banks are not obliged by regulation to back a minimum of assets with equity. As in Gerali et al. (2010), commercial banks exert market power when setting interest rates on loans and deposits and adjust these rates incompletely in response to policy changes.

In contrast to commercial banks, shadow banks act under perfect competition. They are neither subject to macroprudential regulation, nor do they have recourse to government support schemes such as deposit insurance and central bank liquidity facilities. Consequently, saving in shadow banks is more risky from the household perspective. Default risk can thus result in a positive spread between the rates households demand from shadow banks compared to commercial banks. To capture the dependence of shadow banks on market funding, we draw on the incentive constraint in Gertler and Karadi (2011). We assume that the lack of regulation is akin to the risk that shadow bankers can divert a share of funds, defaulting on the remaining liabilities in the process. Whenever the benefits from doing so exceed the returns from behaving honestly, shadow bankers face an incentive to disappear from the market and leave investors with losses on their investments. Households are aware of this risk and limit their funding to an amount that motivates the shadow banker of continuing operations rather than diverting a share and defaulting on the rest. The implicit default risk the household faces when placing funds in shadow banks thus results in a spread between shadow bank and commercial bank deposit rates, as households demand higher compensation when placing funds in these institutions.

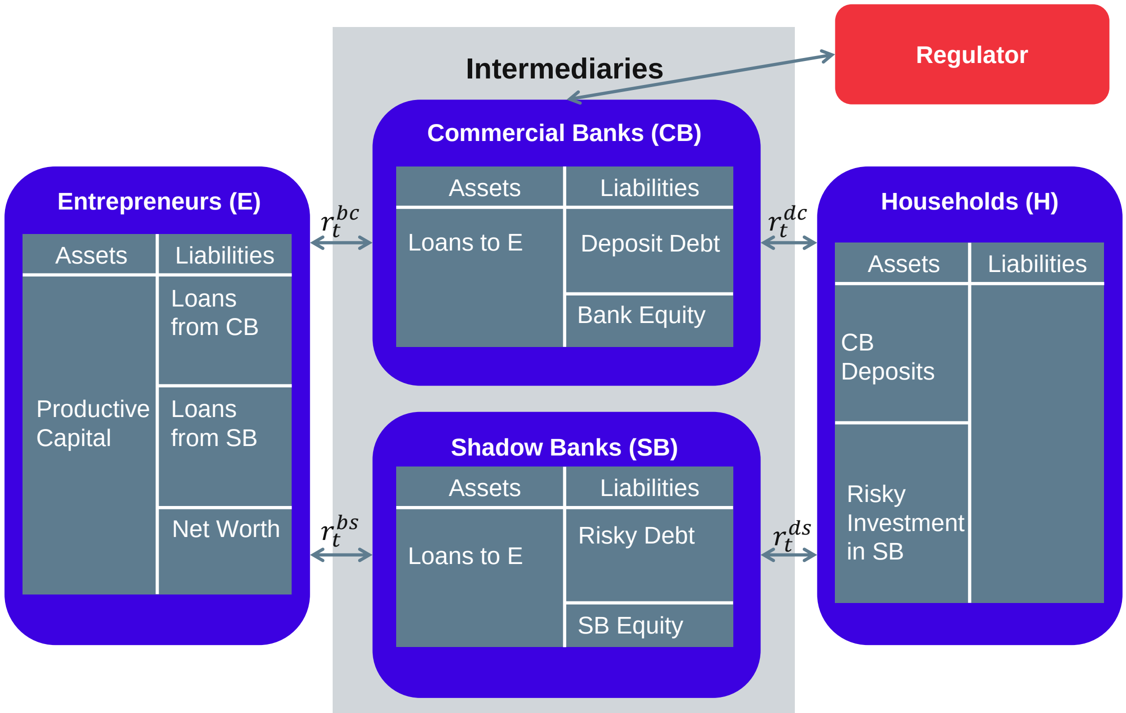
On the loan market, regulation only applies with respect to commercial banks, as entrepreneurs have to fulfil an externally set loan-to-value (LTV) ratio when demanding funds from commercial banks. Consequently, entrepreneurs can only borrow up to a certain amount of their collateral value at hand, which is given by the stock of physical capital that they own and use for production purposes. However, they can use their remaining collateral for borrowing from shadow banks.[11] An overview of the relationships between

[9]We distinguish both agents by different values for the discount factors used in the utility functions.

[10]As in Gambacorta and Signoretti (2014), we assume that all debt contracts are indexed to current inflation. In this respect, we deviate from the framework in Gerali et al. (2010) and Iacoviello (2005) by eliminating the *nominal debt channel* from the model. This channel potentially affects the redistribution of funds between borrowers and savers and thus macroeconomic developments in response to unexpected changes in the price level, which we do not consider here.

[11]Details on the microfoundation of the entrepreneurs' credit constraints and the superiority of commercial bank credit are provided in appendix A.1.

Figure 4.1: Relationship Between Intermediaries, Savers and Borrowers



Note: Overview of model relationships between agents involved in financial intermediation.

savers, borrowers and the two intermediaries is given in figure 4.1.

Households provide labor to entrepreneurs and either consume or save in financial intermediaries. Entrepreneurs produce intermediate goods and sell them on a competitive market to retailers that differentiate, repackage and sell them in a monopolistically competitive market. The resulting final goods price thus includes a markup on the marginal cost. Furthermore, capital goods producers are introduced to derive a market price for capital. The central bank conducts monetary policy by setting the nominal short-term interest rate according to a Taylor rule.[12]

In the baseline model, macroprudential regulation is determined exogenously, before we introduce a macroprudential regulator that follows a countercyclical policy rule for capital requirements in section 4.4. In this respect, our baseline model used in the estimation procedure of section 4.3 reflects the regulatory framework in the euro area in place before the introduction of Basel III. Under the preceding Basel II regulations, countercyclical adjustments of capital requirements for commercial banks were not set systematically.

[12]In this model, we abstract from any unconventional monetary policy and assume that the economy is not at the effective lower bound (ELB) of nominal interest rates.

4.2.1 Households

The representative patient household i maximizes the expected utility

$$\max_{c_t^P(i), l_t^P(i), d_t^{P,C}(i), d_t^{P,S}(i)} E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\varepsilon_t^z \log[c_t^P(i) - a^P c_{t-1}^P] - \frac{l_t^P(i)^{1+\phi^P}}{1+\phi^P} \right] \quad (4.1)$$

subject to the budget constraint

$$c_t^P(i) + d_t^{P,C}(i) + d_t^{P,S}(i) \leq w_t l_t^P(i) + (1+r_{t-1}^{dC}) d_{t-1}^{P,C}(i) + (1+r_{t-1}^{dS}) d_{t-1}^{P,S}(i) + t_t^P(i) \quad (4.2)$$

where $c_t^P(i)$ depicts current consumption and lagged aggregate consumption is given by c_{t-1}^P. Working hours are given by l_t^P and labor disutility is determined by ϕ^P. Preferences are subject to a disturbance ε_t^z affecting consumption. The flow of expenses includes current consumption and real deposits to be made to both commercial and shadow banks, $d_t^{P,C}(i)$ and $d_t^{P,S}(i)$. Resources consist of wage earnings $w_t^P l_t^P(i)$ (where w_t^P is the real wage rate for the labor input of each household), gross interest income on last period deposits $(1+r_{t-1}^{dC}) d_{t-1}^{P,C}(i)$ and $(1+r_{t-1}^{dS}) d_{t-1}^{P,S}(i)$, and lump-sum transfers t_t^P that include dividends from firms and banks (of which patient households are the ultimate owners).

4.2.2 Entrepreneurs

Entrepreneurs use labor provided by households as well as capital to produce intermediate goods that retailers purchase in a competitive market. Each entrepreneur i derives utility from consumption $c_t^E(i)$, which it compares to the lagged aggregate consumption level of all entrepreneurs. They maximize expected utility

$$\max_{c_t^E(i), l_t^P(i), b_t^{E,C}(i), b_t^{E,S}(i)} E_0 \sum_{t=0}^{\infty} \beta_E^t \log[c_t^E(i) - a^E c_{t-1}^E] \quad (4.3)$$

subject to the budget constraint

$$\begin{aligned} &c_t^E(i) + w_t l_t^P(i) + (1+r_{t-1}^{bC}) b_{t-1}^{E,C}(i) + (1+r_{t-1}^{bS}) b_{t-1}^{E,S}(i) + q_t^k k_t^E(i) \\ &\qquad \leq \frac{y_t^E(i)}{x_t} + b_t^{E,C}(i) + b_t^{E,S}(i) + q_t^k(1-\delta^k) k_{t-1}^E(i) \end{aligned} \quad (4.4)$$

with δ^k depicting the depreciation rate of capital, q_t^k the market price for capital in terms of consumption, x_t determining the price markup in the retail sector, and a^E determining entrepreneur habit.[13]

[13] We set a^E equal to the estimated value for household habit formation, see table 4.2.

Entrepreneurs face a constraint on the amount they can borrow from commercial banks which depends on the value of collateral the firm holds. The collateral value of the entrepreneurs is determined by their expected physical capital stock in the period of repayment $(t+1)$, which is given by $E_t\{(1-\delta^k)k_t^E\Pi_{t+1}\}$.[14] Whereas a regulatory LTV ratio m_t^E applies for funds borrowed from commercial banks, shadow bank funding is not prone to regulation. As outlined in detail in appendix A.1, due to a positive spread between interest rates charged for shadow bank and commercial bank loans, entrepreneurs have an incentive to borrow from commercial banks first and turn to shadow bank lending only whenever the possible amount of commercial bank funds, determined by $m_t^E k_t^E(i)$, is reached. Further borrowing can be obtained from shadow banks by using capital holdings not reserved for commercial bank funds, $(1-m_t^E)k_t^E(i)$. Thus, the two respective borrowing constraints are given by

$$(1+r_t^{bC})b_t^{E,C}(i) \leq m_t^E E_t\{q_{t+1}^k(1-\delta^k)k_t^E(i)\} \tag{4.5}$$

$$(1+r_t^{bS})b_t^{E,S}(i) \leq (1-m_t^E)E_t\{q_{t+1}^k(1-\delta^k)k_t^E(i)\} \tag{4.6}$$

where the LTV ratio for commercial banks m_t^E is set exogenously by the regulator and follows an exogenous AR(1) process.

We follow Iacoviello (2005) and assume that the borrowing constraints bind around the steady state such that uncertainty is absent in the model.[15] Thus, in equilibrium, entrepreneurs face binding borrowing constraints, such that equations 4.5 and 4.6 both hold with equality.

4.2.3 Financial Intermediaries

Both commercial banks and shadow banks intermediate funds between households and firms. While they both engage in intermediation in a similar fashion, we assume the two types of agents to be structurally different along various dimensions.

First, we assume that commercial banks are covered by banking regulation, which implies that they have to fulfill requirements on the amount of capital they have to hold compared to the size of their balance sheet. Second, they are eligible for central bank liquidity assistance and government guarantees such as deposit insurance schemes.[16] Thus, for households and firms, commercial banks depict safe deposit institutions, given that

[14] In Iacoviello (2005), entrepreneurs use commercial real estate as collateral. However, we follow Gerali et al. (2010) by assuming that creditworthiness of a firm is judged by its overall balance sheet condition where real estate housing only depicts a sub-component of assets.

[15] Iacoviello (2005) discusses the deviation from the certainty equivalence case in appendix C of his paper.

[16] Even though not explicitly modeled, the assumption of an existing insurance scheme lies behind the idea of shadow bank deposits being more risky than deposits placed with commercial banks.

they are both covered by regulation and have access to government support schemes. We furthermore assume market power in the loan and deposit markets for commercial banks,[17] and model it using the same Dixit-Stiglitz framework as employed in Gerali et al. (2010). Thus, in both loan and deposit markets, commercial banks are able to charge some markup on loan rates and pay deposit rates conditional on a markdown. In line with Gerali et al. (2010), we model commercial banks by distinctively separating a single bank into three units: two retail branches responsible for retail lending and retail deposits, respectively, and one wholesale branch that manages the bank capital position. While the two retail branches operate under monopolistic competition, we assume lending and deposit taking between retail and wholesale units to operate perfectly competitively.

Shadow banks, in contrast, face no regulatory burden but in turn are not covered by structural support schemes. Consequently, the shadow banking sector increasingly depends on creditor trust, which is captured by a moral hazard problem that governs the degree of leverage of shadow bank institutions. Whereas commercial banks' charter values as well as their funding opportunities via central banks provide a buffer in case of illiquidity, shadow banks are exposed to funding pressures that can lead to instantaneous exit from the market. At the same time, reduced regulatory burdens in the establishment of shadow banking operations supports regular inflow to this market. As a consequence, while we assume commercial banks to be infinitely lived in our model, we allow for frequent entry to and exit from the shadow banking system.

Commercial Banks

In the following, we discuss the maximization problem of the wholesale unit of the commercial bank as the capital requirement set by regulators applies directly to this branch of the commercial bank.[18] The maximization problems of the monopolistically competitive retail loan and deposit branches straightforwardly follow Gerali et al. (2010), and we report these problems in appendix A.2.4.

The wholesale branches of commercial banks operate under perfect competition and are responsible for the capital position of the respective commercial bank. On the asset side, they hold funds they provide to the retail loan branch, b_t^C, and these retailers ultimately lend the funds to entrepreneurs as credit $b_t^{E,C}$. As retailers act under monopolistic competition, the retail rate r_t^{bC} comprises a markup over the wholesale loan rate r_t^C. On the liability side, the wholesale unit combines commercial bank net worth, or capital, k_t^C, with wholesale deposits, d_t^C. The latter are provided by the retail deposit branch, but originally

[17]The existence of market power in the euro area was indicated in various empirical studies, see for instance Fungáčová et al. (2014) or De Bandt and Davis (2000).

[18]Thus, the modeling of the wholesale unit closely resembles the commercial bank outlined in the two-period model in appendix section A.1.1.

stem from deposits households place in the retail branch ($d_t^{P,C}$). The capital position of the wholesale branch is also prone to a regulatory capital requirement ν_t^C. Moving away from the regulatory requirement imposes a quadratic cost to the bank, which is proportional to the outstanding amount of bank capital and parameterized by κ_k^C. The wholesale branch maximization problem can be expressed as

$$\max_{b_t^C,\, d_t^C} \; r_t^C b_t^C - r_t^{dC} d_t^C - \frac{\kappa_k^C}{2}\left(\frac{k_t^C}{b_t^C} - \nu_t^C\right)^2 k_t^C \tag{4.7}$$

subject to the the balance sheet condition

$$b_t^C = k_t^C \varepsilon_t^{Kb} + d_t^C. \tag{4.8}$$

where ε_t^{Kb} is an exogenous shock to bank capital. The first-order conditions yield the following expression:

$$r_t^C = r_t^{dC} - \kappa_k^C \left(\frac{k_t^C}{b_t^C} - \nu_t^C\right)\left(\frac{k_t^C}{b_t^C}\right)^2. \tag{4.9}$$

As the commercial bank has access to central bank funding in the model, we assume that the rate paid on wholesale deposits gathered from the retail deposit unit of the commercial bank (and so originally from households and firms) has to be equal to the risk-free policy rate, r_t. Thus, via arbitrage,

$$r_t^{dC} = r_t$$

such that the spread between the loan and deposit rates on the wholesale level is given by

$$r_t^C = r_t - \kappa_k^C \left(\frac{k_t^C}{b_t^C} - \nu_t^C\right)\left(\frac{k_t^C}{b_t^C}\right)^2. \tag{4.10}$$

This expression indicates that the marginal benefit from further lending, the spread earned on intermediation at the margin, has to be equal to the marginal costs from doing so in equilibrium. This marginal cost increases whenever the deviation of commercial bank capital holdings from the regulatory requirement increases. Assuming symmetry between banks and reinvestment of profits in banks, aggregate bank capital K_t^C is accumulated from retained earnings only:

$$K_t^C = (1 - \delta^C) K_{t-1}^C + J_{t-1}^C \tag{4.11}$$

where J_t^C depicts aggregate commercial bank profits derived from the three branches of the bank, see Gerali et al. (2010). Capital management costs are captured by δ^C.

Shadow Banks

In contrast to the commercial banking sector, shadow banks do not operate under monopolistic competition. Given the flexibility and the heterogeneity of the shadow banking system, we assume shadow banks operate under perfect competition. Also, instead of being constrained by regulation, shadow banks' ability to acquire external funds is constrained by a moral hazard problem that limits the creditors' willingness to provide external funds. To avoid excessive equity capital accumulation – and eventually exclusive financing via equity rather than debt – shadow bankers are assumed to have a finite lifetime: Each shadow banker faces an i.i.d. survival probability σ^S with which he will be operating in the next period. This exit probability functions in the maximization problem of the shadow bankers as an additional discount factor, which ensures that they are always net debtors to the households. To make up for the outflow, every period new shadow bankers enter with an initial endowment of w^S they receive in the first period of existence, but not thereafter. The number of shadow bankers in the system is constant.[19]

For the shadow banker, as long as the real return on lending $(r_t^{bS} - r_t^{dS})$ is positive, it is profitable to accumulate capital until he exits the intermediation sector. Thus, the shadow bank's objective to maximize expected terminal wealth, $v_t(j)$, is given by

$$v_t(j) = \max E_t \sum_{i=0}^{\infty} (1-\sigma^S)\sigma^{S^i} {\beta_S}^{i+1} k_{t+1+i}^S(j). \tag{4.12}$$

We introduce a moral hazard problem that leads to the possibility of positive spreads earned by shadow banks.[20] We allow for the possibility that shadow banks divert a fraction of available funds, θ^S, and use them for private benefits at the beginning of each period. Households can consequently only recover the leftover share $(1-\theta^S)$ afterwards. However, diverting funds and "running away" is equivalent to declaring bankruptcy for the shadow bank, such that it will only do so if the return of declaring bankruptcy is larger than the discounted future return from continuing and behaving honestly:

$$v_t(j) \geq \theta^S q_t^k b_t^{E,S}(j). \tag{4.13}$$

Equation 4.13 depicts the incentive constraint the shadow banker faces when trying to acquire funds from households.[21] As we assume some shadow bankers to exit each period

[19] The complete derivation of the shadow bank problem and a deeper discussion of the approach used is presented in appendix section A.2.4.

[20] See appendix section A.1.2.

[21] Compared to equation A.1.37 in the two-period model of appendix A.1, the interest rate term on the right-hand side is missing here. In the full DSGE model, we do not have fixed shadow bank capital, but interest returns from the previous period are booked into shadow bank capital at the end of a respective period. In the infinite-horizon case, the timing of events is such that at the beginning of any period t,

and new bankers to enter the market, aggregate capital k_t^S is determined by the capital of continuing shadow bankers, $k_t^{S,c}$, and the capital of new bankers that enter, $k_t^{S,n}$

$$k_t^S = k_t^{S,c} + k_t^{S,n} \tag{4.14}$$

and combining the expressions for $k_t^{S,c}$ and $k_t^{S,n}$ derived in appendix A.2 yields the following law of motion for shadow bank capital:

$$k_t^S = \sigma^S[(r_{t-1}^{bS} - r_{t-1}^{dS})\phi_{t-1}^S + (1 + r_{t-1}^{dS})]k_{t-1}^S + \omega^S q_t^k b_{t-1}^{E,S}. \tag{4.15}$$

The shadow bank balance sheet condition

$$q_t^k b_t^{E,S}(j) = d_t^{P,S}(j) + k_t^S(j) \tag{4.16}$$

in combination with the demand for shadow bank credit by borrowers given by equation 4.6 determines shadow bank lending $b_t^{E,S}(j)$ and ultimately shadow bank savings, $d_t^{P,S}(j)$.

Finally, we assume a non-negative spread between the interest rates earned on shadow bank deposits, r_t^{dS}, and on the deposits households can place with commercial banks, r_t^{dC}, which is again determined by the parameter τ^S, with $0 \leq \tau^S \leq 1$. In appendix section A.1.1, we provide a microfoundation for the existence of a positive spread, and use the results to incorporate a relationship between the two deposit rates similar to the relation stated in equation A.1.4 in the two-period model:

$$1 + r_t^{dS} = \frac{1 + r_t^{dC}}{1 - \tau^S \varepsilon_t^\tau}. \tag{4.17}$$

As in the two-period version of the model, the parameter τ^S determines the spread between the gross rates on both deposit types and is implicitly related to the default probability of shadow banks. As a shortcut, we calibrate τ^S and assume the existence of a spread shock ε_t^τ following an autoregressive process to motivate exogenous swings in the spread on interest rates earned on the two deposit types.

shadow banks use net worth $k_t^S(j)$ together with deposits $d_t^{P,S}(j)$ to lend out financial claims $b_t^{E,S}(j)$. Afterwards, the shadow banker decides whether to run away or not. In case of behaving honestly, he receives net returns $r_t^{bS} - r_t^{dS}$ on intermediation at the end of period t, and these returns are then part of the capital stock in the next period, $k_{t+1}^S(j)$.

4.2.4 Monetary Policy and Market Clearing

The central bank sets the policy rate according to a Taylor-type rule given by

$$(1 + r_t) = (1 + r)^{(1-\phi^r)}(1 + r_{t-1})^{\phi^r} \left(\frac{\pi_t}{\pi}\right)^{\phi^\pi(1-\phi^r)} \left(\frac{y_t}{y_{t-1}}\right)^{\phi^y(1-\phi^r)} \varepsilon_t^r \tag{4.18}$$

where the weights on inflation and output growth are given by ϕ^π and ϕ^y, respectively. The steady-state policy rate is given by r and ε_t^r defines a white noise monetary policy shock.

The market clearing condition is given by the aggregate resource constraint

$$Y_t = C_t + q_t^k(K_t - (1 - \delta^k)K_{t-1}) + \frac{\delta^k K_{t-1}^b}{\pi_t} + AC_t \tag{4.19}$$

with AC_t determining the overall adjustment costs and composite consumption given by $C_t = c_t^P + c_t^E$.

4.3 Estimation

4.3.1 Data

All real economic variables used in the estimation exercise are drawn from the European System of Accounts (ESA 2010) quarterly financial and non-financial sector accounts, provided by the European Central Bank (ECB) and Eurostat.[22] For the real economy, we include information on real gross domestic product, real consumption, real investment, and consumer price as well as wage inflation. Information on commercial bank balance sheets – commercial bank deposits held by private households and commercial bank loans granted to the non-financial corporate sector – is gathered from the data set in "Monetary Financial Institutions" (MFIs) collected by the ECB. Data on commercial bank interest rates on household deposits and firm loans are drawn from different sources within the ECB Statistical Data Warehouse and harmonized in line with the procedure recommended by Gerali et al. (2010). We also use the short-term EONIA rate as a quarterly measure of the policy rate. For shadow bank variables, we use information provided in the ECB data base on different monetary and other financial institutions, as discussed in detail in appendix A.3.

We apply full-information Bayesian techniques to estimate some of the model parameters. Our baseline sample covers the period between 1999:Q1 and 2013:Q4, as we assume that the effective lower bound (ELB) on nominal interest rates in the euro area was reached

[22]See appendix A.3 for a detailed description of the data set.

in 2014.[23] Furthermore, as the effective implementation of the Basel III framework under the Capital Requirements Directive IV (CRD IV) of the European Union took place from 2014:Q1 onward, we estimate our baseline model reflecting the regulatory landscape under Basel II for the period before the implementation of the new framework.[24]

In total, we use eleven time series,[25] and we apply the Metropolis-Hastings algorithm to derive draws from the posterior distribution, by running five chains with 500,000 draws each in the baseline estimation. We evaluate convergence in the estimation by considering the approach of Brooks and Gelman (1998). We furthermore check for the identification of parameters following Ratto and Iskrev (2011).

4.3.2 Calibration and Prior Distributions

Table 4.1 depicts calibrated parameters. In most cases, we apply the calibration used by Gerali et al. (2010). We adjust parameters on the loan (deposit) rate markup (markdown) for commercial bank lending ε^{μ} (ε^{d}) to match the mean spreads in our extended sample. As the loan rate markup (deposit rate markdown) is given by $\frac{\varepsilon^{\mu}}{\varepsilon^{\mu}-1}$ ($\frac{\varepsilon^{d}}{\varepsilon^{d}-1}$), we set parameters to match the average annualized loan rate spread (deposit rate spread) with respect to the EONIA of 240 basis points (35 basis points) in our extended sample.[26]

In addition, by incorporating shadow banks and macroprudential regulation in the model, we introduce five new parameters: τ^{S}, θ^{S}, σ^{S}, ω^{S}, and β_{S}. Given our broad definition of shadow banks, finding empirical equivalents to shadow bank deposit returns is not straightforward. The shadow bank aggregate we consider covers institutions with highly diverse investment portfolios, different types of investors placing funds, and ultimately highly varying returns on the specific activity they are engaged in. We calibrate τ^{S} such that the implied default probability of shadow banks is approximately five percent per quarter and the resulting annualized spread between shadow bank and commercial bank deposit rates is approximately two percentage points in steady state.

Furthermore, we ensure in the calibration that the share of shadow bank intermediation in total intermediation is approximately one-third in steady state and that the size of the

[23] See for instance Coeuré (2015) for a discussion of the beginning of the ELB period in the euro area. We conduct a robustness analysis using a different sample period in appendix A.4.

[24] In the euro area, the implementation of Basel III is governed by the Capital Requirements Directives IV (CRD IV) and the subsequent Regulation on Prudential Requirements for Credit Institutions and Investment Firms (CRR), which came into force on January 1, 2014. Thus, as euro area countries did not implement the policy measures put forward under Basel III before the beginning of 2014, we are effectively covering the pre-Basel III era of banking regulation in the euro area with our sample for the baseline estimation.

[25] See charts in figure A.5 of appendix A.3.

[26] In Gerali et al. (2010), the retail deposit rate spread is stated to be 125 basis points. However, we include the period after 2008 in our sample, where bank market power was adversely affected by the global financial crisis and the debt crisis in Europe and thus lending and deposit margins for commercial banks were reduced significantly.

Table 4.1: Calibrated Parameters

Parameter	**Description**	**Value**
τ^S	Deposit Rate Spread Parameter	0.05
θ^S	SB Share of Divertible Funds	0.2
σ^S	SB Survival Probability	0.944
ω^S	SB Start-Up Funding $\frac{\omega^S}{1-\sigma^S}$	0.002
ν^C	Steady-State Capital Requirement	0.08
ϕ^P	Inverse Frisch Elasticity of Labor Supply	1
β_P, β_S	Discount Factor Households, Shadow Banks	0.9943
β_E	Discount Factor Entrepreneurs	0.975
m^E	Steady-State LTV Ratio vs. Commercial Banks	0.3
α	Capital Share in Production Function	0.2
ε^d	Deposit Rate Markdown $\mu^d = \frac{\varepsilon^d}{\varepsilon^d-1}$	-0.9
ε^μ	Loan Rate Markup $\mu = \frac{\varepsilon^\mu}{\varepsilon^\mu-1}$	2
ε^y	Goods Market Markup $x^y = \frac{\varepsilon^y}{\varepsilon^y-1}$	6
ε^l	Labor Market Markup $x^l = \frac{\varepsilon^l}{\varepsilon^l-1}$	5
δ^k	Depreciation Rate Physical Capital	0.025
δ^C	Bank Capital Management Cost	0.1049
χ_ν	Policy Rule Sensitivity Parameter	7
ρ^ν	Policy Rule AR Coefficient	0.9

Note: Calibration following in part Gerali et al. (2010) and Gertler and Karadi (2011).

average shadow bank loan portfolio is one-third the size of shadow bank assets. These values are comparable to statistical figures derived in empirical studies on the euro area shadow banking sector based on similar data (Bakk-Simon et al., 2012; Malatesta et al., 2016) and resemble average values in our data set. The latter calibration allows us to treat σ^S as a transformed parameter in the estimation, and the resulting post-estimation value is given by 0.944. Our value of θ^S, the share of divertible funds, turns out to be lower than the calibrated value in Gertler and Karadi (2011), where the authors settled on a value of 0.381 in the calibration of the US model.[27] Furthermore, we set the steady-state commercial bank capital requirement, ν^C, equal to 8 percent, which resembles the overall level of capital-to-asset holdings demanded from commercial banks under Basel II. The steady-state LTV ratio for commercial banks m^E is calibrated following Gerali et al. (2010), implying relatively strict regulation on collateral and a significant scope for shadow bank lending based on collateral criteria.

For the prior distributions, we mostly follow Gerali et al. (2010) for the parameters originally estimated in their study. As we apply a Calvo (1983) pricing framework[28] instead

[27] An economic interpretation of the lower share that intermediaries can divert in the euro area could be given by a higher degree of creditor protection.

[28] Under pricing à la Calvo (1983), the entrepreneurs in each industry can fix monetary prices for their goods only in some periods, and the probability with which a certain firm can adjust its price in the next

of Rotemberg (1982), we rely on a prior distribution similar to those introduced by Smets and Wouters (2003, 2007) for the Calvo parameter θ^p. We choose a slightly tighter prior distribution for the Taylor-rule parameter on inflation and change the distribution on the respective output parameter to a Beta distribution compared to the Normal distribution used in Gerali et al. (2010). We thus give preference to a prior distribution that does not, even theoretically, allow for negative values of the parameter.

Table 4.2 reports prior and posterior distributions for structural parameters as well as parameters describing exogenous processes. As in Gerali et al. (2010), we take the posterior medians as parameter estimates, and report estimates derived in their study for comparability.

For the parameter that governs the cost of deviation from the capital requirement, κ_C, we assume a uniform distribution ranging from 0 to 25. Since this parameter is difficult to identify in an observable empirical counterpart, the non-informative nature of this prior in principle allows sufficient flexibility for the posterior to assume a broad range of values depending on the highest likelihood of the entire model and parameter set.

We finally use the same priors for all exogenous process parameters, including the parameters related to the newly introduced shock to the spread between shadow bank and commercial bank returns (ε_t^τ), as can be seen in table 4.2.

4.3.3 Posterior Distributions

In table 4.2 we also report summary statistics of the posterior distributions for the model parameters. We furthermore provide marginal densities of the prior and posterior distributions for the structural parameter estimates in figure A.6 in appendix A.3.

Even though the mode of the posterior for the Calvo parameter turns out to be slightly lower than the estimate derived in Smets and Wouters (2003), price stickiness is a significant feature in the model. The posterior mode for the investment adjustment cost parameter κ^i turns out to be of similar magnitude as the parameter derived in Smets and Wouters (2003), whereas Gerali et al. (2010) report a larger value for this parameter.

Sluggish interest rate adjustment appears particularly strong in the market for commercial bank deposits, indicated by high posterior mode and median values for the deposit rate adjustment cost parameter κ^d. Furthermore, loan rates adjust more rapidly to changes in the policy rate compared to commercial bank deposit rates. Commercial banks therefore appear to react to changes in monetary policy by a more flexible adjustment of loan rates in response to competition from shadow banks which operate under perfect interest-rate pass-through, compared to a situation where shadow banking is absent.

period is given exogenously. Thus, only a subset of firms adjusts prices in each period, and consequently the overall price level adjusts only gradually in response to exogenous disturbances.

Table 4.2: Prior and Posterior Distributions

		Prior Distribution			**Posterior Distribution**				**GNSS (2010)**
		Distribution	**Mean**	**Std.Dev.**	**5 Perc.**	**Median**	**95 Perc.**	**Mode**	**(Median)**
Structural Parameters									
θ^p	Calvo Parameter	Beta	0.5	0.10	0.83	0.87	0.90	0.86	-
κ^i	Investment Adjustment Cost	Gamma	2.5	1.0	2.98	3.98	5.14	3.67	10.18
κ^d	Deposit Rate Adjustment Cost	Gamma	10.0	2.5	10.00	13.26	16.72	12.62	3.50
κ^{bE}	Loan Rate Adjustment Cost	Gamma	3.0	2.5	4.84	8.34	14.23	7.56	9.36
κ_k^C	CCR Deviation Cost	Uniform	0.0	25.0	0.01	10.05	21.32	24.71	11.07
ϕ^π	TR Coefficient π	Gamma	1.5	0.25	1.44	1.87	2.30	1.75	1.98
ϕ^y	TR Coefficient y	Gamma	0.20	0.05	0.14	0.24	0.34	0.20	0.35
ϕ^r	Interest Rate Smoothing	Beta	0.75	0.10	0.84	0.88	0.91	0.88	0.77
a^P, a^E	Habit Formation	Beta	0.50	0.10	0.70	0.77	0.84	0.77	0.86
Exogenous Processes (AR Coefficients)									
ρ^τ	Deposit Rate Spread	Beta	0.8	0.1	0.62	0.81	0.95	0.85	-
ρ^z	Consumer Preference	Beta	0.8	0.1	0.82	0.87	0.92	0.87	0.39
ρ^a	Technology	Beta	0.8	0.1	0.31	0.42	0.52	0.42	0.94
ρ^{mE}	Entrepreneur LTV	Beta	0.8	0.1	0.91	0.94	0.97	0.95	0.89
ρ^d	Deposit Rate Markdown	Beta	0.8	0.1	0.27	0.36	0.46	0.36	0.84
ρ^μ	Loan Rate Markup	Beta	0.8	0.1	0.51	0.63	0.75	0.64	0.83
ρ^{qk}	Investment Efficiency	Beta	0.8	0.1	0.33	0.46	0.58	0.49	0.55
ρ^y	Price Markup	Beta	0.8	0.1	0.25	0.36	0.47	0.37	0.31
ρ^l	Wage Markup	Beta	0.8	0.1	0.64	0.71	0.77	0.71	0.64
ρ^{Kb}	Commercial Bank Capital	Beta	0.8	0.1	0.93	0.96	0.99	0.97	0.81
Exogenous Processes (Standard Deviations)									
σ^τ	Deposit Rate Spread	Inverse Gamma	0.01	0.05	0.002	0.007	0.016	0.005	-
σ^z	Consumer Preference	Inverse Gamma	0.01	0.05	0.008	0.011	0.014	0.011	0.027
σ^a	Technology	Inverse Gamma	0.01	0.05	0.025	0.029	0.033	0.028	0.006
σ^{mE}	Entrepreneur LTV	Inverse Gamma	0.01	0.05	0.006	0.008	0.009	0.007	0.007
σ^d	Deposit Rate Markdown	Inverse Gamma	0.01	0.05	0.002	0.002	0.002	0.002	0.032
σ^μ	Loan Rate Markup	Inverse Gamma	0.01	0.05	0.002	0.002	0.003	0.002	0.063
σ^{qk}	Investment Efficiency	Inverse Gamma	0.01	0.05	0.001	0.002	0.002	0.002	0.019
σ^r	Monetary Policy	Inverse Gamma	0.01	0.05	0.001	0.001	0.002	0.001	0.002
σ^y	Price Markup	Inverse Gamma	0.01	0.05	0.001	0.002	0.002	0.001	0.598
σ^l	Wage Markup	Inverse Gamma	0.01	0.05	0.035	0.041	0.047	0.040	0.561
σ^{Kb}	Commercial Bank Capital	Inverse Gamma	0.01	0.05	0.003	0.003	0.004	0.003	0.031

Note: Results are based on 5 chains with 500,000 draws each based on the Metropolis-Hastings algorithm. GNSS (2010) refers to the results reported in Gerali et al. (2010). We calibrate the entrepreneur habit parameter a^E to the same value as estimated for household habit, a^P.

As indicated in the previous section, the uniform prior for the commercial bank capital requirement adjustment cost parameter κ_k^C was selected due to a weak identification problem, and the resulting estimated median turns out to be slightly lower than in Gerali et al. (2010).[29] Parameters related to monetary policy are broadly in line with results derived for instance in Gerali et al. (2010) and Smets and Wouters (2003), with our estimated posterior modes for the Taylor rule parameters ϕ^π, ϕ^y and ϕ^r taking on values in-between the estimated parameters derived in these studies. Finally, household habit formation is slightly weaker than in Gerali et al. (2010). For all shock processes, persistence turns out to be relatively high, with the processes for commercial bank deposit rate markdown shocks and price markup shocks depicting exceptions.

4.4 Policy Analyses

We use our estimated model to evaluate whether disregarding credit intermediation via the shadow banking sector in macroprudential policy decisions has quantitative implications for policy decisions and the macro economy. In this context, we discuss potential implications for policy coordination between central banks and macroprudential regulators. Furthermore, in a counterfactual analysis, we assess how regulators would have set capital requirements under a countercyclical policy rule in the fashion of the Basel III regulatory framework had it been in place throughout the existence of the common currency. To do so, we introduce a policymaker following a countercyclical rule in the pre-Basel III model and simulate the development of capital requirements over the course of the monetary union. We thereby evaluate the implications from policy rules with different target variables. Furthermore, we discuss to what extent the level of implied capital requirements would have changed if regulators took not only commercial bank credit, but overall credit into account.

4.4.1 Macroprudential Regulation

In the following analyses, we discuss different regulatory regimes, depending on the degree of shadow bank consideration. We therefore implement, in the estimated Basel II model, different types of regulators that follow countercyclical rules for adjusting commercial bank capital requirements. We take key elements of the Basel III framework into account: countercyclical adjustment of capital requirements in response to swings in the credit cycle and the primary focus on commercial banking in the application of macroprudential policy. As indicated above, before the implementation of Basel III, the requirement on total capital holdings was 8 percent, and no countercyclical adjustment of requirements

[29] We conducted a sensitivity analysis to evaluate the robustness of the estimation and found that model dynamics are unchanged when this parameter is varied.

was intended. We raise the steady-state capital requirement for all regulator types from 8 percent to 10.5 percent[30] and change the capital requirement equation in the model from an exogenous AR(1) process to a regulation-specific countercyclical rule described in more detail below. We leave the rest of the calibration and estimated parameters unchanged, as they were derived from the estimation using the true regulatory setup and economic data before the implementation of Basel III.

We discuss two different versions of the Basel III macroprudential regulator – in addition to the case without countercyclical capital regulation as under Basel II – that can apply capital requirements only to commercial banks, but cannot enforce regulation on the shadow banking system. The difference between these types emerges from the degree to which shadow banking is considered when setting capital requirements for commercial banks. We define a *moderate* regulator that only takes variation in commercial bank credit into account when setting capital requirements for commercial banks. In comparison, a *prudent* regulator considers overall credit, which includes both commercial and shadow bank credit.[31]

We distinguish between four target variables that indicate the credit cycle: credit levels, credit growth, as well as the level and the growth rate of the credit-to-GDP ratio.[32] The regulator thus raises the capital-to-asset ratio ν_t^C above the steady-state level of capital requirements ν^C whenever the respective measure deviates positively from its steady-state value, and vice versa.

The Moderate Regulator

We first evaluate the policy setting of a moderate regulator that only focuses on developments in commercial bank credit when setting capital requirements for commercial banks. The policy rules the moderate regulator follows in each scenario resemble the rule derived in Angelini et al. (2014) where deviations of the respective credit measure from steady state are targeted:

[30] The Basel III capital requirement consist of different buffers banks have to hold: 8 percent (minimum Tier 1+2 capital) plus 2.5 percent (capital conservation buffer), yielding 10.5 percent for total capital.

[31] Under Basel III, the specific credit measure that should be applied is not stated explicitly in the regulatory statutes, and the primary focus of regulators lies on credit intermediated by commercial banks.

[32] The choice of target variables is inspired by the common measures employed in the DSGE literature on capital requirements. See for instance Rubio and Carrasco-Gallego (2016), Bekiros et al. (2018), Angelini et al. (2014), Angeloni and Faia (2013), and Christensen et al. (2011).

$$\begin{aligned}
&\text{Credit Growth Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \Delta \widehat{B}_t^M + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.20)\\
&\text{Credit/GDP Growth Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \Delta \widehat{Z}_t^M + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.21)\\
&\text{Credit Level Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \widehat{B}_t^M + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.22)\\
&\text{Credit/GDP Level Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \widehat{Z}_t^M + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.23)
\end{aligned}$$

where

$$\widehat{B}_t^M = b_t^{E,C} - b^{E,C}$$
$$\widehat{Z}_t^M = \frac{b_t^{E,C}}{Y_t} - \frac{b^{E,C}}{Y}$$

and Δ indicates the difference of a variable compared to its one-period lag. The reaction parameter χ_ν determines the degree of policy sensitivity, and we calibrate it to a value of 7, which is broadly in line with the parameter values derived in Angelini et al. (2014). Furthermore, we allow for exogenous shocks ε_t^ν to the capital requirement, and assume an autoregressive shock process and smoothing in the adjustment of capital requirements, governed by parameter ρ^ν which we calibrate at a value of 0.9.

The Prudent Regulator

In addition, a prudent regulator is introduced that takes lending by the shadow banking sector into account when setting capital requirements for commercial banks. Despite the lack of a unifying regulatory framework for shadow banks, we assume that the prudent regulator is able to derive estimates of non-bank credit intermediation. The regulator therefore considers not only commercial bank credit, but movements in *overall* credit.[33] The policy rules stated in equations 4.20 to 4.23 are thus altered for the prudent regulator such that:

$$\begin{aligned}
&\text{Credit Growth Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \Delta \widehat{B}_t^P + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.24)\\
&\text{Credit/GDP Growth Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \Delta \widehat{Z}_t^P + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.25)\\
&\text{Credit Level Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \widehat{B}_t^P + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.26)\\
&\text{Credit/GDP Level Rule:} && \nu_t^C = (1-\rho^\nu)\nu^C + (1-\rho^\nu)\chi_\nu \widehat{Z}_t^P + \rho^\nu \nu_{t-1}^C + \varepsilon_t^\nu && (4.27)
\end{aligned}$$

[33] The ECB has stressed the importance to consider both commercial bank *and* overall credit in their "scoreboard approach" for macroprudential regulation. See for instance Constâncio et al. (2019) for a review of the ECB's approach towards macroprudential policy and the role of market-based finance in regulatory statutes.

where

$$\widehat{B}_t^P = (b_t^{E,C} + b_t^{E,S}) - (b^{E,C} + b^{E,S})$$
$$\widehat{Z}_t^P = \frac{b_t^{E,C} + b_t^{E,S}}{Y_t} - \frac{b^{E,C} + b^{E,S}}{Y}.$$

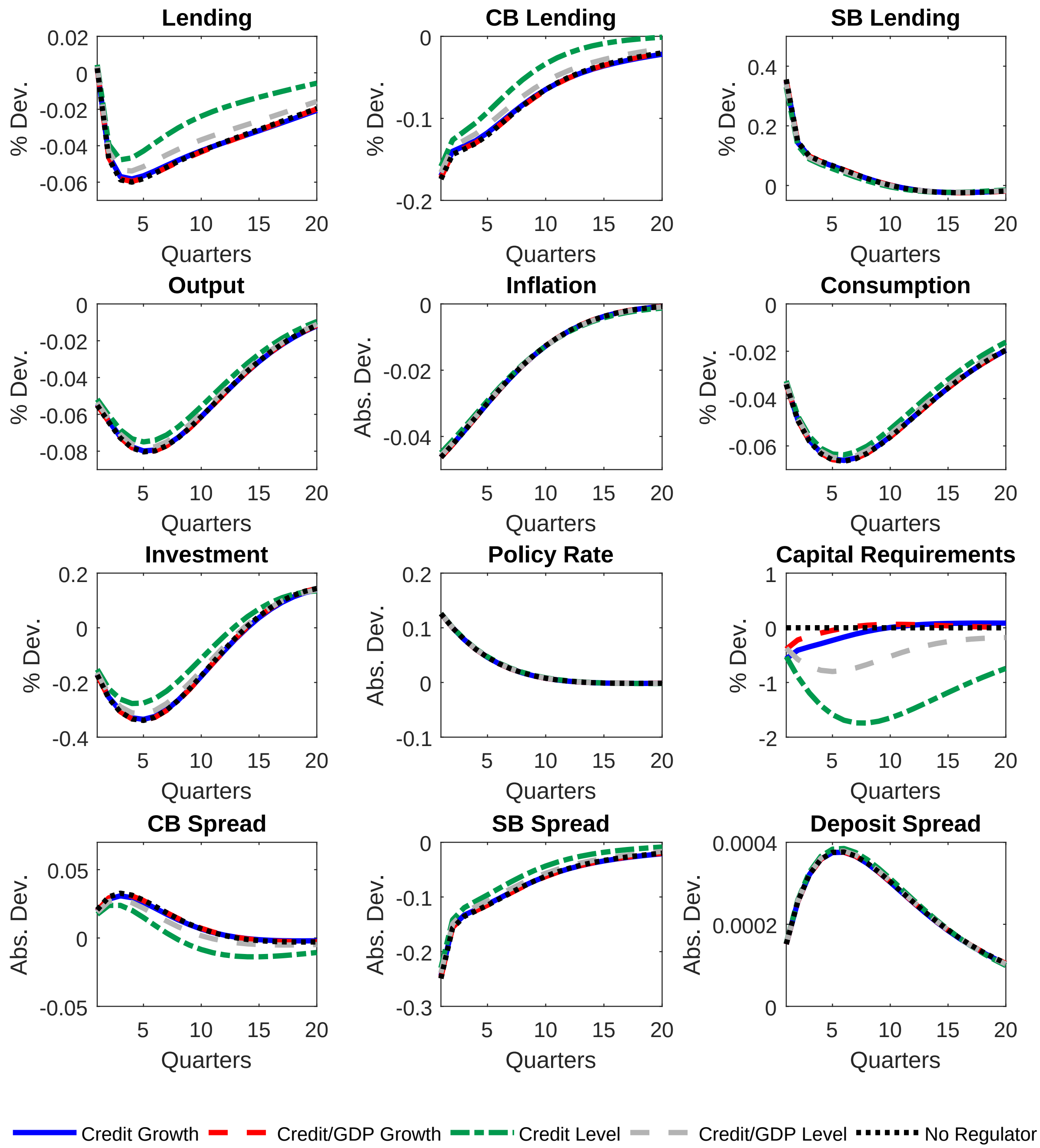
4.4.2 Impulse Response Analysis

In the following, we derive impulse responses for two policy shocks: a standard monetary policy shock and a shock to commercial bank capital requirements. We analyze the first shock to evaluate whether our model is able to replicate stylized facts from the large literature on monetary policy shocks, and to study potentially differing reactions of commercial bank and shadow bank intermediation. We then evaluate the impact of an unanticipated increase of capital requirements to shed light on credit leakage towards shadow bank intermediation in response to tighter commercial bank regulation. We finally discuss the potential of coordination between monetary and macroprudential policies to avoid potentially unintended side effects of tighter commercial bank regulation, i.e. credit leakage towards the shadow banking sector.

Monetary Policy Shock

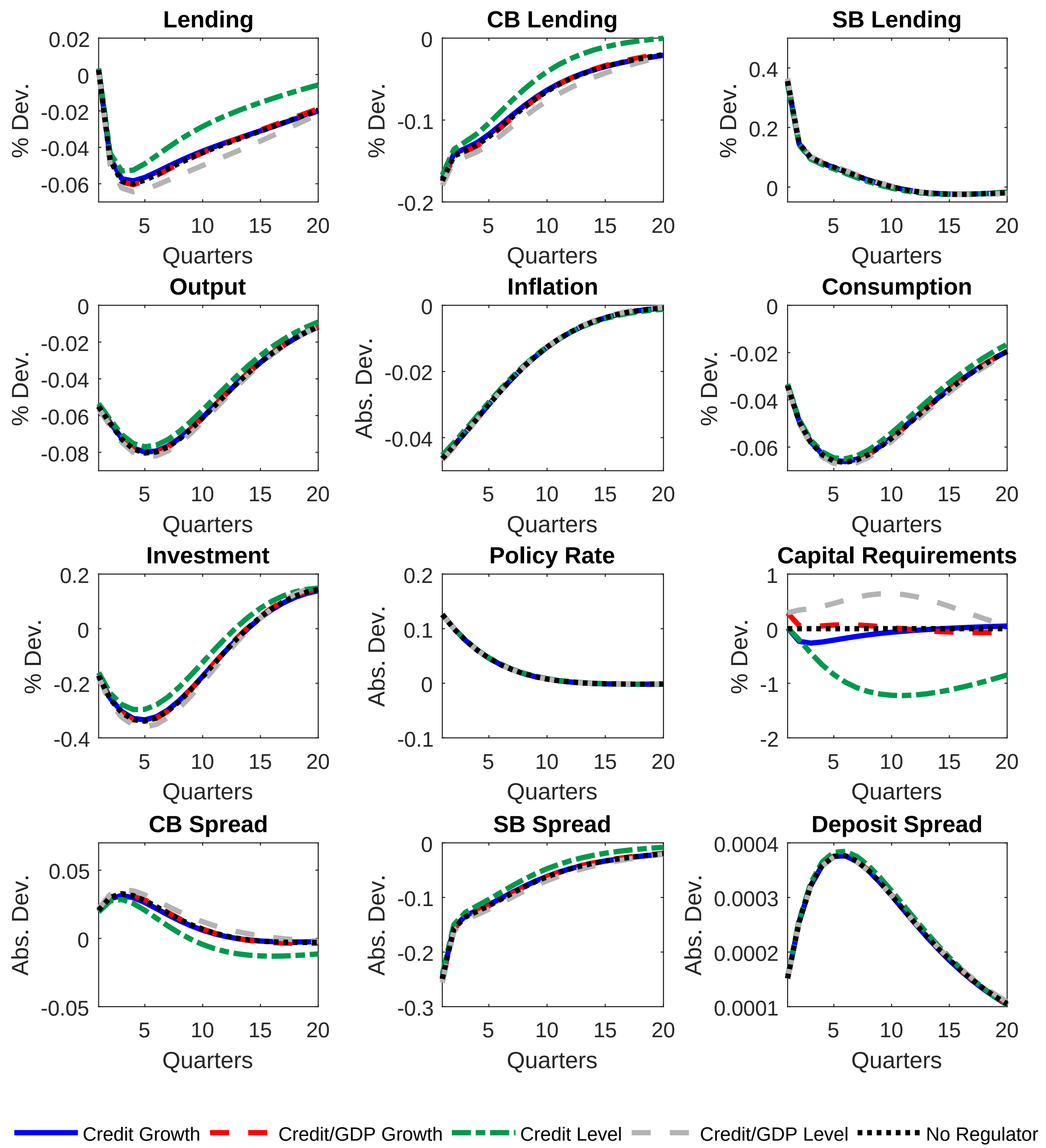
Several empirical studies have identified different reactions in credit intermediated within and outside the regular banking system in response to monetary policy shocks. Igan et al. (2017) find that some institutions (money market mutual funds, security broker-dealers) increase their asset holdings after a monetary policy tightening, whereas issuers of asset-backed securities (ABS) decrease their balance sheets. Pescatori and Sole (2016) use a vector autoregression (VAR) framework including data on commercial banks, ABS issuers, and other finance companies as well as government-sponsored entities (GSEs). They find, inter alia, that monetary policy tightening decreases aggregate lending activity, even though the size of the non-bank intermediary sector increases. Similarly, Den Haan and Sterk (2011), using US flow-of-funds data, find that non-bank asset holdings increase in response to monetary tightening, even though overall credit declines or stays relatively flat. Mazelis (2016) distinguishes between commercial banks depending on deposit liabilities, highly levered shadow banks which depend on funding from other intermediaries, and investment funds that draw funding from real economic agents directly. He finds that, whereas commercial bank credit remains relatively flat after monetary tightening and is reduced only in the medium term, shadow banks and investment funds increase lending in response to monetary policy tightening in the short term. Nelson et al. (2018) find similar results when looking at aggregate balance sheets, even though their definition of shadow banks differs from the one in Mazelis (2016). For European banks, Altunbas et al. (2009) show that institutions engaged to a large extent in non-bank activities, such as securitization, are less affected by monetary policy shocks.

Figure 4.2: Impulse Responses: Monetary Policy Shock – Moderate Regulator



Note: Impulse responses to a one-standard-deviation monetary policy shock. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

Figure 4.3: Impulse Responses: Monetary Policy Shock – Prudent Regulator



Note: Impulse responses to a one-standard-deviation monetary policy shock. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

We report the reaction of model variables to an unanticipated increase in the policy rate by 12.5 basis points in figures 4.2 and 4.3. In line with standard findings, output and its subcomponents – consumption and investment – decline in a hump-shaped manner and inflation falls in response to tighter monetary policy. Total lending is reduced as credit costs increase due to higher interest rates, while aggregate demand deteriorates. Bank intermediation spreads increase, as monopolistic competitive banks raise lending rates to generate profits, which compensates for the decline in lending volume.[34] However, higher commercial bank loan rates increase lending costs for borrowing firms. The collateral constraint 4.5 indicates that the amount of borrowing firms can obtain from commercial banks is limited by the LTV ratio m_t^E and the value of non-depreciated physical capital $q_{t+1}^k(1-\delta^k)k_t^E(i)$. Due to this borrowing limitation, an increase in the borrowing cost firms face when acquiring loans from commercial banks $1+r_t^{bC}$ causes a decline in the quantity of commercial bank loans $b_t^{E,C}(i)$.

On the margin, borrowers will find it profitable to switch to alternative sources of funding. Shadow banks face higher refinancing costs due to an increasing risk premium, reflected in the widening of the deposit rate spread. They are extending loan supply and accept a decline in the intermediation spread on impact to generate profits. Thus, the decline in commercial bank lending is partly counteracted by an increased intermediation and leverage of shadow banks. Whereas commercial bank credit falls by approximately 0.18 percent in response to higher interest rates in all scenarios, shadow bank credit increases by approximately 0.35 percent. We therefore confirm empirical evidence on the presence of credit leakage towards shadow banks in response to tighter monetary policy in our model.

For the moderate regulator, the decline in credit and real activity is larger for rules based on growth rates (solid blue and dashed red lines in figures 4.2 and 4.3) than for level rules (dashed green and gray lines). Policy makers relying on level rules lower capital requirements more aggressively in response to a monetary tightening, and thus the overall decline in lending is mitigated. For all types of rules, a moderate policymaker only concerned with developments in the commercial banking sector lowers capital requirements to a larger extent than the prudent counterpart when confronted with higher interest rates. Quantitatively, a moderate regulator cuts capital requirements by half a percent on impact, which depicts a reduction of roughly five basis points compared to the steady-state level of capital requirements. While the requirements are quickly readjusted back to the steady-state level under growth-based rules, capital requirements are eased by up to 1.8 percent, or 19 basis points under the credit level-based rule.

The easing of capital regulation is significantly less pronounced under the prudent regulator (figure 4.2). Strikingly, a regulator considering both commercial bank and shadow bank credit would actually increase capital requirements in our stylized simulation exercise whenever the rule is based on the credit-to-GDP (growth) gap. The significant increase in shadow bank credit, and a relatively strong decline in GDP – the denominator of the

[34] This finding is consistent with studies relying on a homogeneous description of the financial sector, see for instance Gerali et al. (2010).

credit-to-GDP ratio – in response to higher interest rates is sufficient to trigger a slight increase in capital requirements. In turn, the reduction in overall credit is even more pronounced in the prudent regulation case with credit-to-GDP as in the moderate regulator case, and compared to the benchmark situation of no countercyclical policy maker. Also, the reduction in aggregate demand and output is slightly more pronounced in the case of a prudent macroprudential regulator.

We take this finding as indication that a different treatment of shadow banks in policy considerations can lead to different policy prescriptions in response to macroeconomic shocks, with respective consequences for macroeconomic developments and financial stability. Ultimately, the response by regulators depends on the primary objective of macroprudential policy. As we do not explicitly take the effect of shadow banking on financial stability into account, the results here indicate that a regulator concerned with excessive lending by unregulated shadow banks – and a *potentially* resulting increase in financial instability – would prescribe a different policy for commercial banks when developments in the shadow banking sector are taken into considerations.[35]

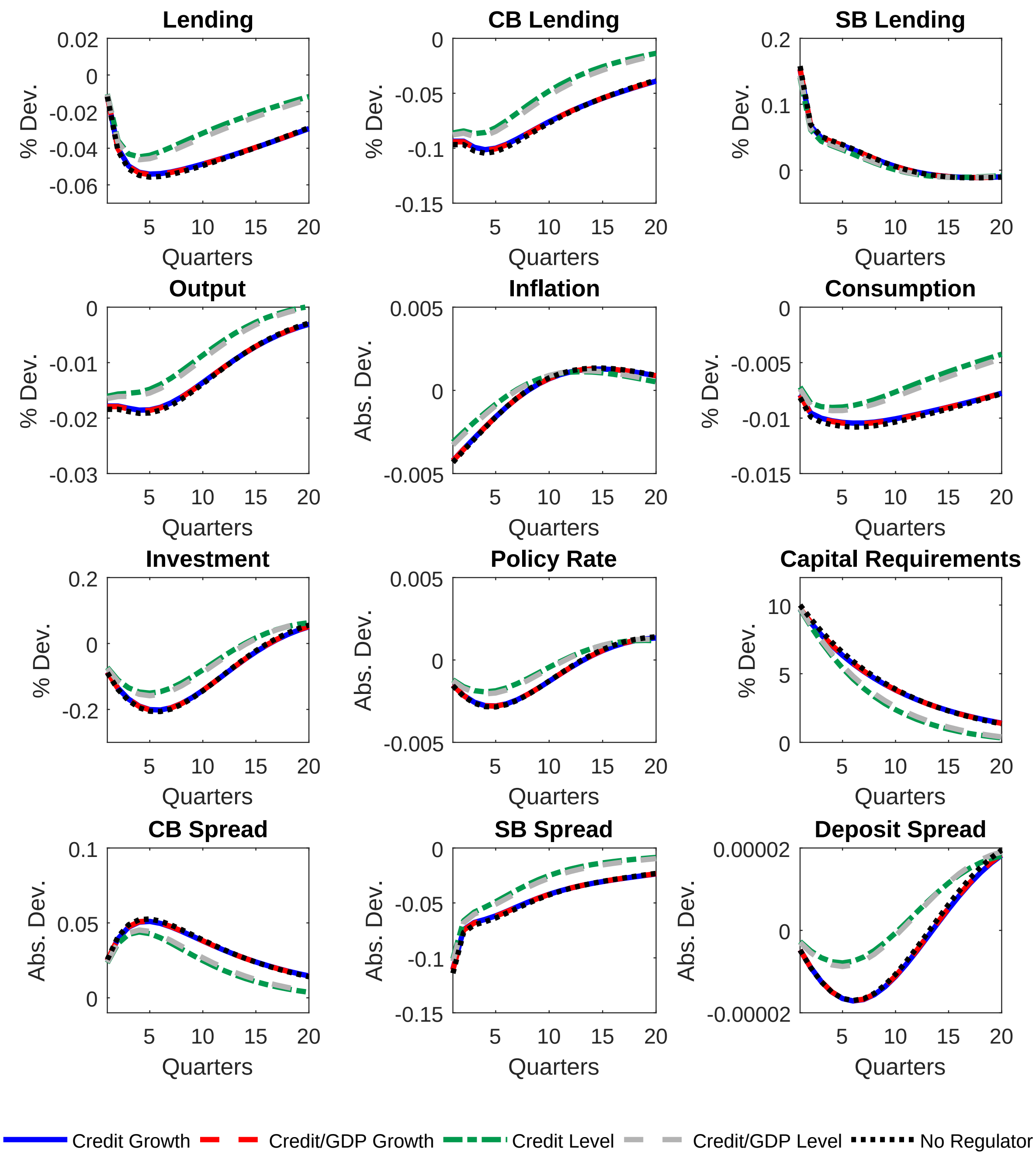
Capital Requirement Shock

In the previous section we verify that our model can generate dynamics of commercial and shadow bank credit in response to tighter monetary policy which are qualitatively in line with empirical evidence. Similar evidence on the effects of regulatory changes on credit intermediation is still relatively scarce, primarily due to issues of identifying unanticipated shocks to capital regulation on the macro level.[36] Irani et al. (2018) use detailed US corporate loan data to evaluate the effect of capital requirement changes on the development of non-bank financial intermediation. Relying on data derived from a supervisory register on syndicated loans, they find that shadow bank credit increases in response to commercial bank capital constraints. Similarly, Buchak et al. (2018) examine data on Fintech lenders in residential mortgage markets. They find that commercial banking contracted due to a higher regulatory burden – such as higher bank capital requirements as well as mortgage market-related regulatory changes – and was partly replaced by unregulated shadow bank intermediation. To evaluate the effect of credit leakage towards shadow banks in response to tighter regulation, we simulate an unanticipated increase in commercial bank capital

[35] As we do not derive welfare implications of shadow banking here, no discussion about the optimality or desirability of different policy responses can be drawn from the presented results. In chapter 5, I introduce such a welfare analysis in a modified version of the model applied in this chapter.

[36] Compared to well-established procedures to identify monetary policy shocks, the empirical identification of macroprudential policy shocks is less straightforward. First, policy decisions are taken in a process that only started to mature since the financial crisis, while monetary policy has a long history of regular meetings of the monetary policy committees that announce their decisions in a public manner, at least in many developing countries over several decades. Second, as many of the macroprudential tools discussed now were only implemented over the last ten years, time series for respective measures are still short.

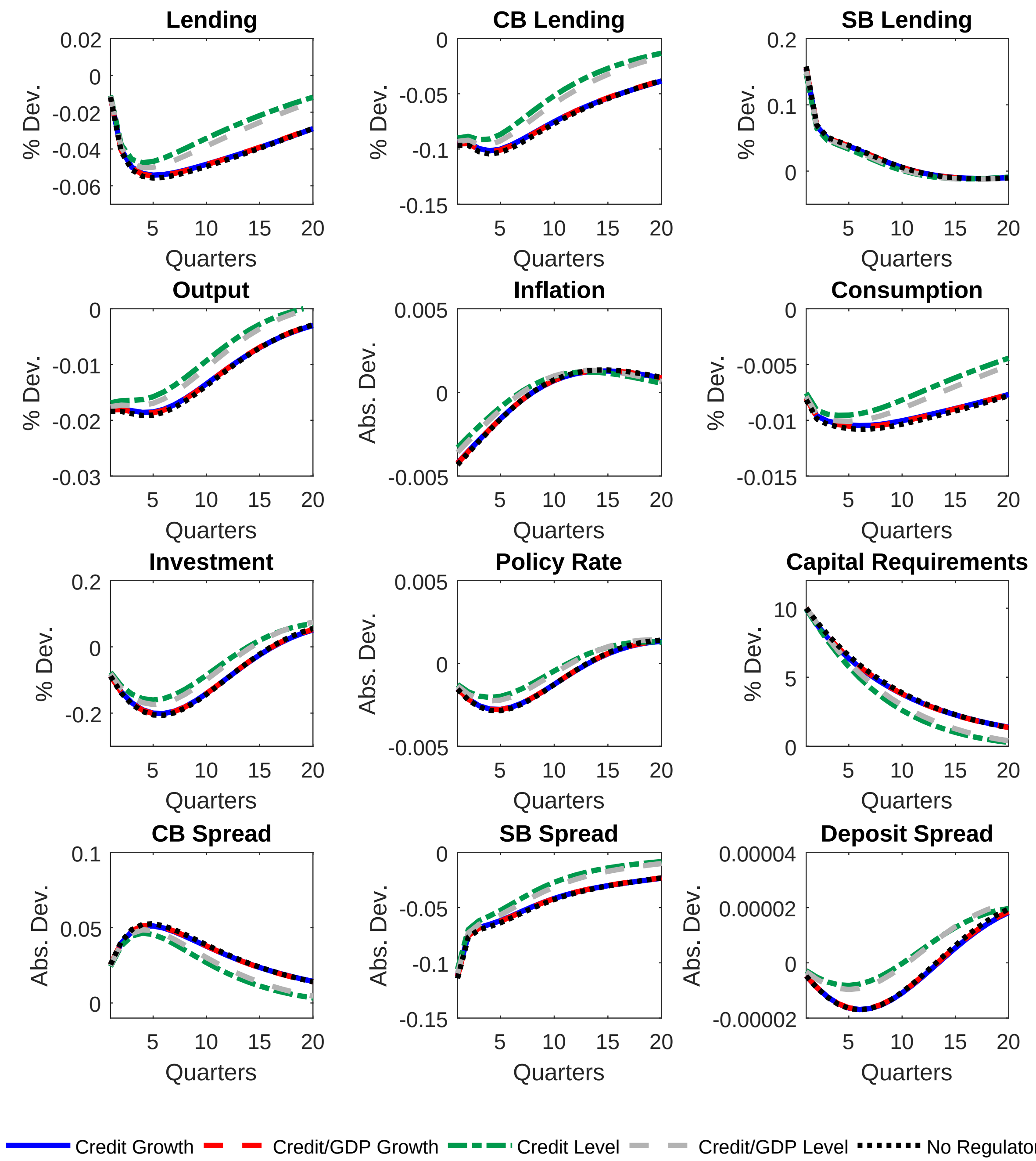
Figure 4.4: Impulse Responses: Capital Requirement Shock – Moderate Regulator



Note: Impulse responses to a one-standard-deviation capital requirement shock. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

requirements by one percentage point (resembling a positive ten-percent deviation from steady state) and provide impulse responses in figures 4.4 and 4.5.

Figure 4.5: Impulse Responses: Capital Requirement Shock – Prudent Regulator



Note: Impulse responses to a one-standard-deviation capital requirement shock. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

Whereas overall lending is reduced by increased bank capital requirements, lower credit intermediation by commercial banks is partly offset by increased shadow bank activity in all scenarios. Due to the leakage mechanism laid out in detail in appendix A.1, higher capital requirements result in a deviation of actual capital-to-asset ratios held by commercial banks from the regulatory requirement and increase the intermediation cost for commercial banks (equation 4.13). In response, both the wholesale and retail loan rates r_t^C and r_t^{bC} increase. As in the case of a monetary policy tightening, due to the collateral constraint 4.5, the quantity of loans $b_t^{E,C}(i)$ declines. Monopolistically competitive banks raise loan rates and generate profits via retained earnings, and borrowing from shadow banks becomes relatively more attractive. The initially unaffected demand for credit by entrepreneurs eases the shadow bank leverage constraint (equation 4.13). In response, the shadow bank lending rate spread declines and shadow bank intermediation and leverage increases.[37] Thus, in response to a macroprudential tightening, borrowers increase the share of relatively costly shadow bank loans which raises the overall cost of borrowing. Finally, tighter macroprudential regulation reduces overall lending activity and ultimately, due to lower credit supply, dampens economic activity. Lower aggregate demand reduces inflation, and monetary policy consequently responds by lowering interest rates.

The different degrees to which macroprudential policymakers take shadow banks into consideration has implications for the development of both credit and macroeconomic variables in the model. Following an unanticipated rise in capital requirements, regulators following level-based rules pursue a path of relative rapid policy normalization compared to the case of growth-based rules, both under moderate and prudent regulation. In return, even though the drop in commercial bank lending is equally pronounced on impact, credit returns to its steady-state level more quickly under level rules. Therefore, the reduction in overall credit is relatively smaller in the case of the level-based regulators, and the described losses in aggregate demand are weaker. Inflation is reduced to a lesser extent and monetary policy reacts less aggressively in the case of level-based rules.

Policy Coordination

In the two preceding policy exercises, an unexpected tightening by one policymaker triggered counteractive measures implemented by the other to mitigate adverse effects on price stability and output. Furthermore, tighter regulation and monetary policy caused leakage towards the shadow banking sector. Both observations indicate a potential role for coordination among policymakers to mitigate dampening macroeconomic implications of tighter regulation and, in particular, to limit the unintended leakage of credit towards the shadow banking sector.

In the following exercise, we evaluate to what extent a coordinated reaction using monetary policy could limit the increase in shadow bank lending in response to tighter bank capital regulation in our model setup. Higher capital requirements indeed reduce lending activity by commercial banks, as shown in the analysis of the previous section. However,

[37] Aikman et al. (2019) provide a similar rationale for credit leakage in response to tighter regulation.

the contemporaneous increase in shadow bank lending depicts a limitation of macroprudential policy efficiency. First, the intended reduction in lending activity is partly counteracted by an increase in shadow bank intermediation, resulting in a smaller reduction in overall lending compared to a situation without shadow bank intermediation. Second, an increase in shadow bank lending potentially increases financial instability as a relatively larger share of intermediation is now conducted by unregulated financial institutions.

To discuss benefits from policy coordination, we evaluate whether monetary policy can be employed to avoid credit leakage towards shadow banks. Whereas capital requirements only affect commercial banks, interest rates depict a universal tool that reaches through "all the cracks in the economy" (Stein, 2013). To this end, we apply the monetary policy reaction that is necessary to keep shadow bank intermediation at its steady-state level in response to the capital requirement shock discussed in the previous section.

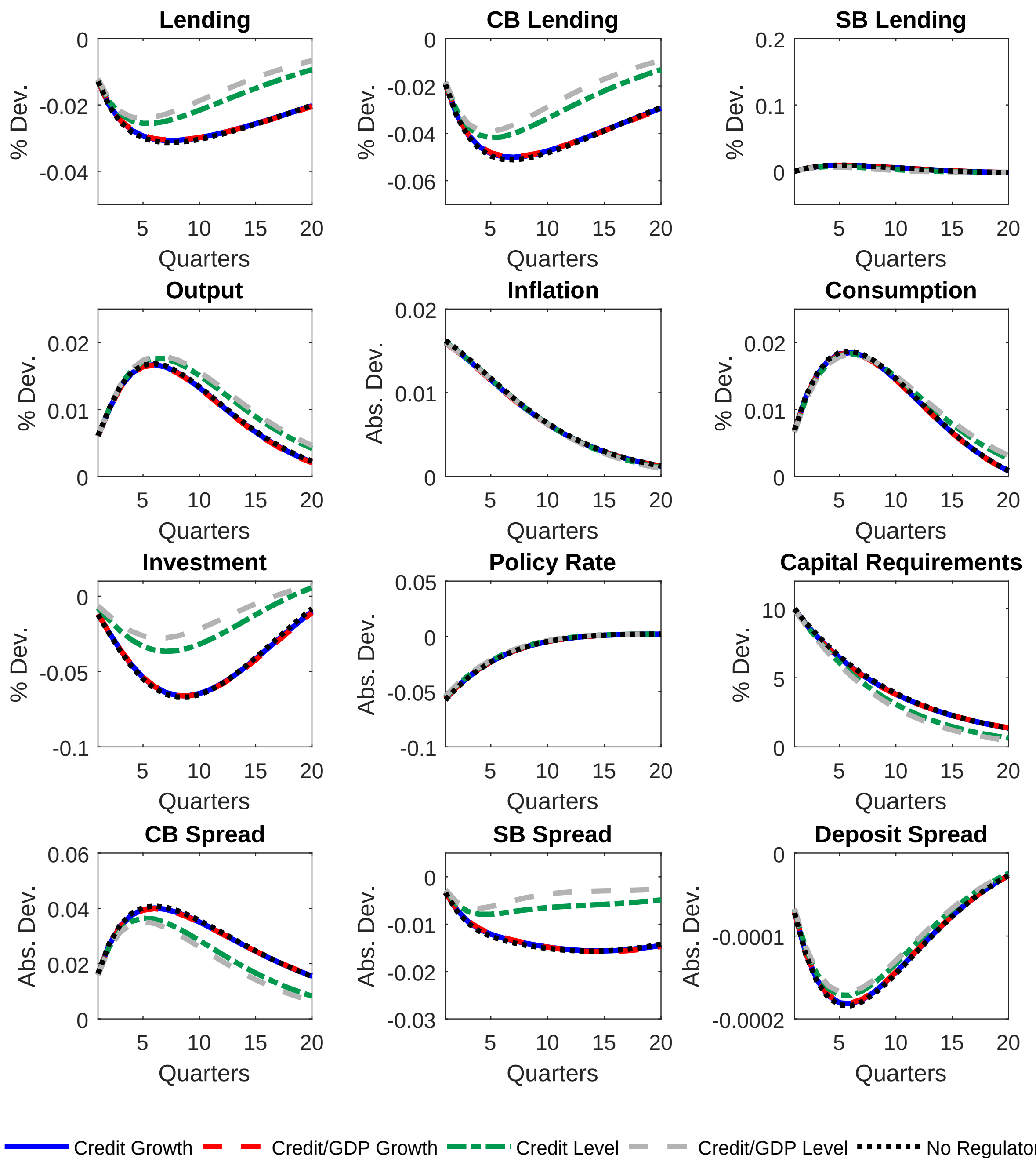
Figures 4.6 and 4.7 depict impulse responses to an unanticipated increase in commercial bank capital requirements by one percentage point in combination with a contemporaneous response by monetary policy that mitigates the reaction of shadow bank intermediation. In the simulations, the reaction in shadow bank lending is negligible as the central bank lowers interest rates by approximately 5 to 6 basis points in response to tighter capital requirements. As indicated in section 4.4.2, commercial bank credit increases in reaction to monetary policy easing, and therefore the decrease in commercial bank lending is less pronounced in figures 4.6 and 4.7 compared to the respective reductions in figures 4.4 and 4.5. Therefore, even though monetary policy easing partly counteracts the intended reduction in overall lending stemming from an increase in capital requirements, it can help to mitigate potentially undesired leakage towards shadow banks as a side effect of tighter commercial bank regulation.

4.4.3 Counterfactual Simulation

Finally, we evaluate how euro area regulators would have set capital requirements under Basel III, if the framework would have been in place already in 1999 and throughout the existence of the common currency. For all regulatory regimes, we use the estimated baseline model (section 4.3) to filter the data and simulate the evolution of endogenous model variables over the period 1999 – 2014 in a counterfactual analysis. In the counterfactual simulation we allow for endogenous feedback between capital requirements and macroeconomic and financial variables. We focus on hypothetical capital requirements that the regulator would have set in response to macroeconomic and financial shocks under the growth-based rules of equations 4.20–4.21 and 4.24–4.25, reported in figure 4.8.[38]

[38] We focus on the growth-based rules to avoid taking a stance on the steady-state level of credit, which would be required to construct the level-based rules, equations 4.22–4.23 and 4.26–4.27.

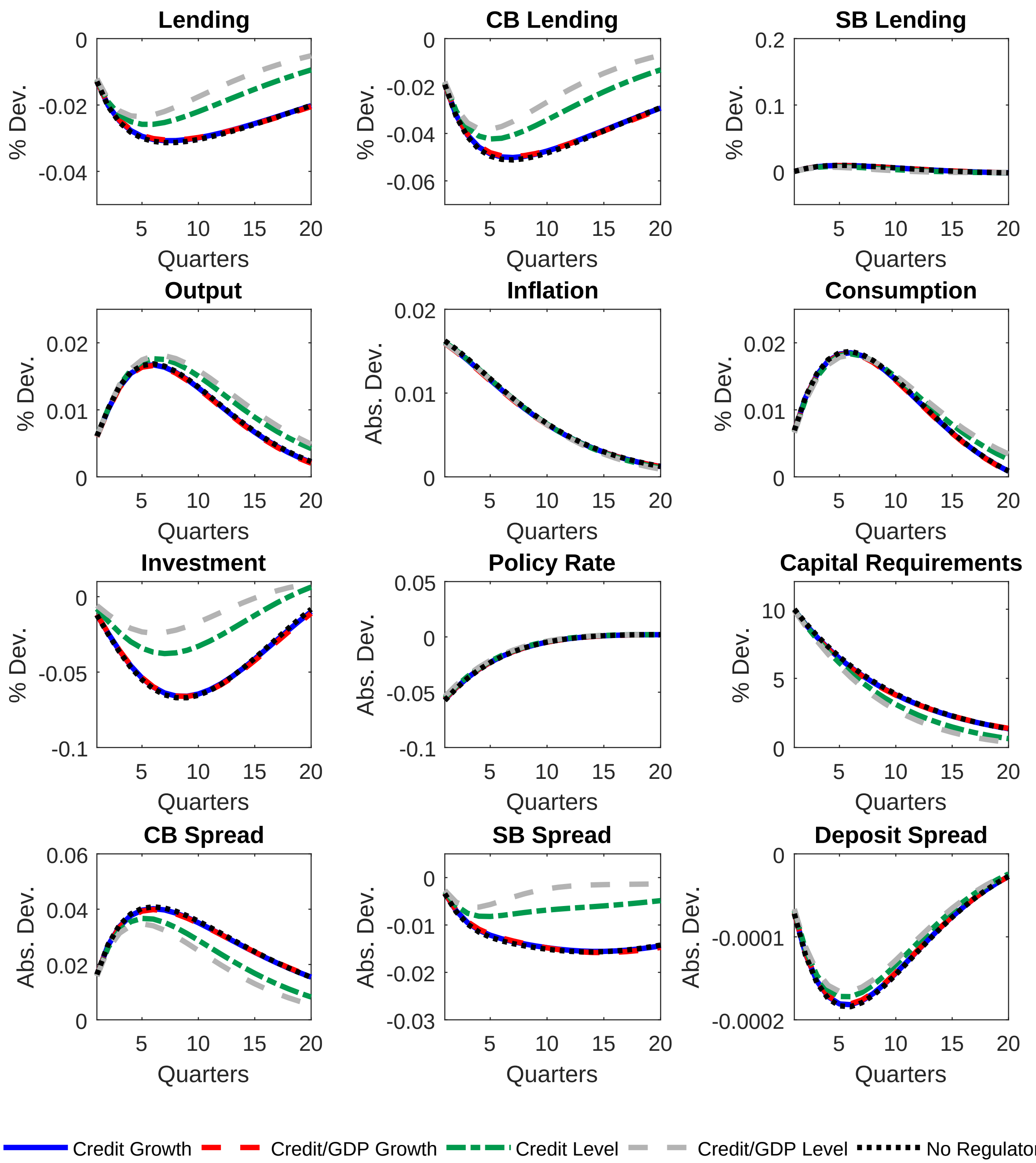
Figure 4.6: Impulse Responses: Policy Coordination – Moderate Regulator



Note: Impulse responses to a combination of capital requirement and monetary policy shocks. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

Independent of the rule type, both the moderate and the prudent regulator would have applied some form of countercyclical regulation by reducing capital requirements in times of financial distress and by raising requirement in times of excessive lending. All rules would have prescribed a sharp tightening of credit standards from the mid-2000s onward,

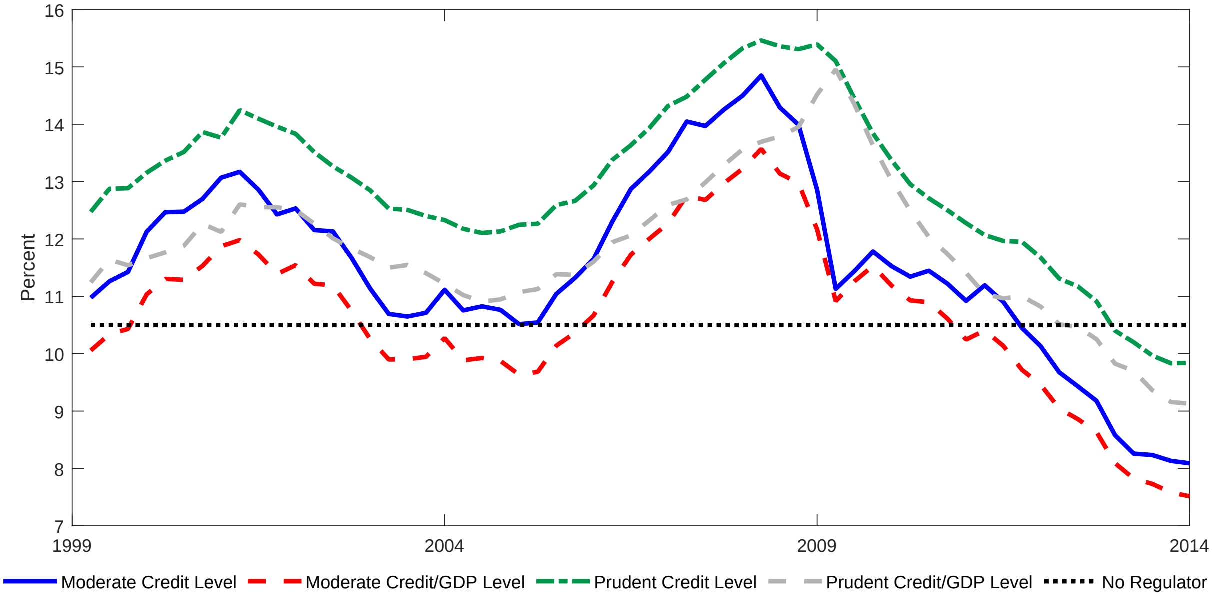
Figure 4.7: Impulse Responses: Policy Coordination – Prudent Regulator



Note: Impulse responses to a combination of capital requirement and monetary policy shocks. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

in response to massive credit growth in the European financial sector (figure 1.1). Over the course of the global financial crisis starting in 2008 and the European debt crisis, both regulators would have prescribed a reduction in capital requirements due to subdued lending activity in the euro area.

Figure 4.8: Counterfactual Analysis: Different Regulatory Regimes



Note: Simulated path of capital requirements based on shock series identified in estimation of section 4.3 and for different regulators of section 4.4.1.

Thereby, the moderate regulators only concerned with commercial bank credit would have set lower capital requirements relative to their prudent counterparts throughout the sample period. Also, they would have raised capital requirements more aggressively prior to the 2008 financial crisis, as commercial bank credit grew rapidly in these years (figure 1.1). Prudent regulators on the other hand would have eased requirements later and less strongly in response to the financial crisis: In the years 2008-2009, shadow bank credit continued to grow further while the increase in commercial bank lending stalled. If the leakage channel would have been taken into account by the regulator, the migration of credit to the shadow banking system at a time when financial stability considerations take center stage may have led to yet different dynamics.[39]

These findings indicate that the existence of shadow banking and the resulting credit leakage requires a detailed understanding of the exact transmission mechanism of financial regulation. Considering non-bank financial intermediation in regulation for commercial banks as depicted by the prudent regulator can, on the one hand, result in lower capital requirements and a resulting lower leakage of credit to unregulated intermediaries. On

[39]Implications of the leakage channel for optimal capital regulation are further explored in chapter 5. There, I show that under optimal policy, credit leakage provides a motive for mitigating the regulatory response to commercial bank credit whenever commercial and shadow bank credit move in the *same* direction. Thus, in addition to the consideration of movements in *overall* credit, as in the ad-hoc rules considered here, the *composition* of credit would have potentially resulted in an even weaker increase of capital requirements prior to the financial crisis under optimal policy.

the other hand, giving a stronger weight to the developments in *overall credit* relative to the leakage motive, can, as in our simulation, lead to higher requirements for commercial banks. Furthermore, as shown in section 4.4.2, monetary policy can play an active role in mitigating shadow bank intermediation. Thus, it can play a crucial part whenever leakage concerns limit the scope for tighter commercial banking regulation.

Table 4.3: Differences in Variation Under Different Policy Regimes

	Moderate Regulator		**Prudent Regulator**	
	Credit	Credit/GDP	Credit	Credit/GDP
GDP	-5.85	-5.16	-5.74	-4.72
Consumption	-3.20	-2.46	-2.81	-1.70
Investment	-25.14	-23.77	-25.77	-23.70
Inflation	-1.98	-2.00	-2.20	-2.24
Policy Rate	-2.12	-2.19	-2.35	-2.47
Total Lending	-4.12	-4.23	-4.56	-4.74
CB Lending	-5.43	-5.35	-5.67	-5.56
SB Lending	-5.10	-4.39	-4.37	-3.29

Note: Percentage difference in the variance of macroeconomic and financial variables, compared to the variation under the baseline scenario without cyclical regulation. For variable X, the percentage difference ΔX is defined as $\Delta X = [Var(X^{Reg}) - Var(X^{NoReg})]/Var(X^{NoReg})$.

In table 4.3, we report the percentage difference in the variance of simulated variables when considering macroprudential rules compared to the baseline scenario without cyclical capital requirements. We find that the growth-based rules in figure 4.8 would have been effective at reducing macroeconomic volatility. Moderate regulators are particularly successful in reducing volatility in real macroeconomic variables, as the variance reduction in GDP and consumption is largest under this set of regulators. Investment volatility also declines slightly more under moderate regulation if growth in the credit-to-GDP gap is used as the target variable. In turn, prudent regulators are better equipped at stabilizing nominal variables and overall lending.

4.5 Conclusion

In this chapter, we develop a DSGE model featuring two different types of financial intermediaries: regulated commercial banks and unregulated shadow banks. Methodologically, we combine two seminal strands of the literature for modeling financial frictions that were independently developed in recent years. In doing so, we exploit differences with respect to market power and regulatory coverage in the two frameworks and argue that they can be applied to structurally different financial institutions.

We highlight the key mechanism of bank capital requirements and evaluate how tighter regulation of commercial bank credit intermediation can result in higher intermediation activity by unregulated shadow banks. We estimate the structural parameters of the model via Bayesian methods using euro area data on both commercial and shadow banks.

We use our estimated model to evaluate quantitative responses of macroeconomic variables to unexpected changes in macroprudential and monetary policy. We find that macroprudential tightening leads to a reduction in commercial bank credit, but increases intermediation by shadow banks. If a macroprudential rule is employed, this leakage mechanism can be reduced, but not eliminated.

Whereas capital requirements can only be employed with respect to commercial banks, interest rates depict a universal tool to reach though "all the cracks in the economy" (Stein, 2013). We evaluate whether monetary policy can be employed to counteract the leakage mechanism in a coordinated macroprudential and monetary policy interaction scenario. Even though monetary easing partly counteracts the intended reduction in overall lending stemming from an increase in capital requirements, it can help to mitigate potentially undesired leakage towards shadow banks as a side effect of tighter bank regulation.

We furthermore evaluate in a counterfactual analysis how regulation would have been set had it followed Basel III rules, and how this would have affected macro indicators through the global financial crisis and the sovereign debt crisis. We find macroprudential tightening during episodes of credit increases, and easing during credit crunches. Furthermore, regulators only concerned with commercial bank credit would have raised capital requirements more strongly in the years preceding the global financial crisis, when growth in commercial bank lending was particularly pronounced. However, more prudent regulators taking both commercial and shadow bank credit into consideration would have generally applied higher levels of capital requirements. Also, these prudent regulators would have eased requirements only later and less strongly after the outbreak of the financial crisis, as shadow bank credit continued to grow thereafter.

We therefore highlight the need for understanding credit leakage and the emerging trade-off for regulators taking lending by both regulated and unregulated intermediaries into account when lending by both intermediaries increases. On the one hand, an increase in overall credit might indicate the need for tighter regulation. On the other hand, tighter regulation on the regulated entity only fuels credit leakage to the unregulated entity, with potential implications for financial stability. This chapter develops a framework for financial regulators to think of such trade-offs, and take them into account when making macroprudential decisions, potentially by including a role for policy coordination with the monetary authority, which requires further investigation. To shed more light on the normative implications for macroprudential policy, I investigate the welfare implications of credit leakage in the following chapter.

5 Welfare-Based Optimal Macroprudential Policy with Shadow Banks

The importance of non-bank financial intermediation has continuously increased around the globe even after the financial crisis. In this chapter, I show that the existence of shadow banks has implications for the optimal regulation of the traditional banking sector. I develop a New Keynesian DSGE model for the euro area featuring a heterogeneous financial sector, taking the existence of potential credit leakage towards unregulated shadow banks into account. Introducing shadow banks raises the importance of credit stabilization relative to other policy objectives in the welfare-based loss function of the regulator. The resulting optimal policy rule indicates that regulators adjust dynamic capital requirements more agressively in response to macroeconomic shocks due to credit leakage. Furthermore, introducing shadow banking not only alters the cyclicality of optimal regulation, but also has implications for the optimal steady-state level of capital requirements and loan-to-value ratios. Sector-specific characteristics such as bank market power and risk affect welfare gains from traditional and shadow bank credit.

5.1 Introduction

As discussed in the previous chapter, credit leakage towards unregulated shadow banks can affect the design and effectiveness of macroprudential regulation for commercial banks. In this chapter, I deviate from ad-hoc policy rules and turn to optimal macroprudential policies while allowing credit to be intermediated by both commercial and shadow banks. I base the analysis on a New Keynesian model featuring a heterogeneous financial sector similar to the one derived in chapter 4. Shadow banks and commercial banks differ in the degree of competitiveness and risk and are affected to a different degree by regulation. For the commercial banking sector, a financial framework similar to the one derived in Gerali et al. (2010) is introduced which allows explicitly for commercial bank capital regulation. Furthermore, it features structural elements that describe the banking sector in the euro area well. For shadow banks, elements of the banking framework developed in Gertler and Karadi (2011) are introduced. Instead of being affected by banking regulation, non-bank credit is limited by a moral hazard friction between investors and shadow banks that results in an endogenous leverage constraint.

To discuss optimal regulation, I derive welfare loss functions and optimal policies under commitment following the LQ approach introduced in the literature on monetary policy. The approach relies in large part on the derivation of optimal policy under the timeless perspective developed in Giannoni and Woodford (2003a,b), Benigno and Woodford (2005, 2012) and Woodford (2011). I derive optimal policy under commitment to study the design of an optimal policy rule to which a macroprudential policy maker would commit at all future dates. Ultimately, the aim of deriving such an optimal rule under commitment is to base policy decisions on a framework that allows for a systematic adjustment of capital requirements in response to financial market developments.

I find that first, shadow bank credit matters for optimal macroprudential regulation, as the derived welfare loss function for the model with shadow banks features shadow bank credit. The relative weights on both commercial bank and shadow bank credit are large compared to the commercial bank credit weight in the loss function dervided from the same model without shadow banks. Furthermore, it turns out to be optimal for the regulator to take the volatility in nominal interest rates, set by the central bank without coordination, into account. This finding provides indication that coordinating monetary and macroprudential policies might be welfare-improving. Finally, and in line with the "revealed-preferences" literature on macroprudential regulation, credit and a measure for the output gap enter the welfare loss functions.

Furthermore, not only the variation of target variables, but also deviations of credit *levels* from efficient values have welfare implications. Inefficiencies in commercial and shadow bank credit markets cause permanent distortions in steady state and provide scope for time-invariant policies that close the gaps between actual and efficient steady-state credit levels. I find that resolving distortions in both credit markets requires two separate tools, each one employed to remove inefficiencies in one credit market. I propose that permanent commercial bank capital requirements can be set accordingly to remove inefficiencies stemming from monopolistic competition in the banking sector. As shadow banks cannot be regulated directly, I propose credit demand tools such as borrower loan-to-value (LTV) ratios to account for permanent distortions in shadow bank credit markets. Under the proposed framework, such borrower-side regulations are set to levels that mitigate shadow bank credit distortions. In return, time-invariant capital requirements are set conditional on LTV ratios to levels that resolve commercial bank credit inefficiencies.

The central implication from these findings is that commercial bank macroprudential regulations should be designed in coordination with other policies in the presence of unregulated shadow banks. Thereby, borrower-side policies such as LTV ratios can be employed to target the share of credit intermediated by institutions that do not fall under the jurisdiction of credit-supply policies. Furthermore, monetary policy can play a role in the optimal policy mix. Short-term interest rates depict a universal tool to reach through "all the cracks in the economy" (Stein, 2013), and therefore affect both commercial and shadow bank intermediation.

In addition to the analytic derivations of welfare loss functions and policy rules, I conduct simulation exercises to discuss the optimal design of policies quantitatively. In the model with shadow banking, the optimal permanent level of capital requirements turns out to be lower than in a comparable model without non-bank finance. Due to undesirable credit leakage towards risky shadow banks, regulators optimally set requirements to 13.5 percent in steady state. In a model without shadow banking, the absence of the credit leakage trade-off results in an optimal level of bank capital requirements of 16 percent.

In addition to time-invariant level policies, I evaluate dynamic policies by deriving an optimal capital requirement rule and discuss optimal regulatory responses to exogenous disturbances. I show that macroprudential regulators adjust capital requirements countercyclically in response to deviations of output and commercial bank credit from their efficient levels. They also try to mitigate credit leakage towards non-bank intermediaries. Consequently, if both credit aggregates move in the same direction after macroeconomic shocks, they adjust requirements less strongly than they would in the absence of shadow banking. In contrast, whenever macroeconomic shocks cause leakage, i.e. credit aggregates to move in opposite directions, regulators will adjust capital requirements more aggressively as in a situation without shadow banking.

I briefly discuss the DSGE model and the calibration in sections 5.2 and 5.3. In sections 5.4 to 5.6, I provide a comprehensive welfare analysis. I first derive welfare-based loss functions for scenarios with and without shadow banks and discuss both time-invariant and cyclical macroprudential policies in detail. Section 5.7 concludes.

5.2 A New Keynesian DSGE Model

In the following, I rely on a simplified version of the heterogeneous financial sector model developed in chapter 4.[1] Patient households provide funds to impatient entrepreneurs[2] which are intermediated via financial institutions. Final goods producers buy output produced by entrepreneurs on competitive markets and resell the retail good with a markup to households. The model features price stickiness which is modelled as in Calvo (1983) and implies a New-Keynesian Phillips curve. The financial sector of the model features two representative agents, commercial and shadow banks. These financial sector agents are based on different microfoundations, and those differences have welfare implications.

[1]The full set of non-linear equations for this chapter's model version is provided in appendix B.1.

[2]As in chapter 4, different values in the discount factors determine the borrower-lender relationship between entrepreneurs and households.

First, financial sector institutions are differently affected by regulation. Commercial banks, on the one side, have to fulfill capital requirements, and borrowing from these institutions requires compliance with regulatory LTV ratios. Therefore, both credit supply and demand policies directly affect credit intermediation by these institutions. The shadow banking sector, on the other side, is assumed to consist of a multitude of specialized institutions which intermediate funds through a prolonged intermediation chain. Thus, on aggregate, they provide the same intermediation services as traditional banks, but are not covered by macroprudential regulation. Absent regulatory oversight, shadow bankers can default on their obligations and divert funds without reimbursing depositors. They will do so whenever the present value of future returns from intermediation is lower than the share of funds they can retain after default. This moral hazard problem between shadow banks and investors implies an endogenous constraint on shadow bank leverage, as investors are only willing to provide funding as long as shadow banks are expected to behave honestly.

The limit on shadow bank funding implies that the risk-adjusted return shadow banks earn over the deposit rate paid to investors can be positive.[3] However, due to shadow bank risk, depositors demand a higher return on shadow bank investments.[4] Therefore, the spread between shadow bank and commercial bank loan rates is positive. Higher returns on shadow banks cause welfare costs as resulting shadow bank profits are not transferred to households. The permanent spread can therefore be interpreted as an additional per-unit default cost paid every period.

Finally, the market structure differs in both sectors. In line with empirical evidence on the euro area banking sector, commercial banks are assumed to exert market power and act under monopolistic competition. Shadow banks, on the contrary, act under perfect competition in the model. In reality, the non-bank intermediation sector includes specialized institutions such as money market mutual funds, hedge funds, bond funds, investment funds or special purpose vehicles. As discussed in the previous chapter, the specialization of these institutions implies a high degree of intermediation efficiency in the shadow banking sector.

Consequently, the model framework implies that shadow banking can increase efficiency in the financial system, as long as intermediation outside the regulated banking sector does not pose a threat to financial stability.[5] Furthermore, tighter commercial bank regulation fosters leakage of credit intermediation towards the unregulated part of

[3]See Gertler and Karadi (2011).

[4]Several studies have highlighted that higher shadow banking activity can increase overall risk in financial markets and undermine financial stability, for instance if investors neglect tail-risks in unregulated credit markets, see Adrian and Ashcraft (2016), Adrian and Liang (2014) or Gennaioli et al. (2013). Furthermore, default in the shadow banking sector has been identified as a key driver of the global financial crisis of 2007/2008, see for instance Christiano et al. (2018).

[5]See for instance Acharya et al. (2013).

the financial system. Changes in capital requirements for commercial banks increase intermediation costs and result in reduced intermediation by these institutions. As credit demand by real economic agents is not initially affected by changes in banking regulation, the leverage constraint shadow bankers face becomes less binding and intermediation via shadow banks more attractive.

5.2.1 Households

The representative patient household i maximizes the expected utility

$$\max_{C_t^P(i), L_t^P(i), D_t^{P,C}(i), D_t^{P,S}(i)} E_0 \sum_{t=0}^{\infty} \beta_P^t \Big[\tilde{u}^P(C_t^P) - \int_0^1 \tilde{\nu}^P(L_t(j))dj \Big] \tag{5.1}$$

where

$$\tilde{u}^P(C_t^P) \equiv \frac{C_t^{P\,1-\sigma}}{1-\sigma} = \ln(C_t^P) \text{ if } \sigma \rightarrow 1 \tag{5.2}$$

$$\tilde{\nu}^P(L_t^P) \equiv \frac{L_t^{P\,1+\phi^P}}{1+\phi^P}. \tag{5.3}$$

Each household (i) consumes the composite consumption good C_t^P which is given by a Dixit-Stiglitz aggregate consumption good

$$C_t^P \equiv \Bigg[\int_0^1 c_t^P(i)^{\frac{\theta^P-1}{\theta^P}} di \Bigg]^{\frac{\theta^P}{\theta^P-1}} \tag{5.4}$$

with $\theta^P > 1$.[6] Each type of the differentiated goods $c_t^P(i)$ is supplied by one monopolistic competitive entrepreneur. I assume $\sigma \rightarrow 1$ such that utility from consumption (equation 5.2) can be expressed as log-utility. Entrepreneurs in industry j use a differentiated type of labor specific to the respective industry, whereas prices for each class of differentiated goods produced in sector j are identically set across firms in that sector. I assume that each household supplies all types of labor and consumes all types of goods. The representative household maximizes utility subject to the budget constraint

$$C_t^P(i) + D_t^{P,C}(i) + D_t^{P,S}(i) \leq w_t L_t^P(i) + (1 + r_{t-1}^{dC}) D_{t-1}^{P,C}(i) + (1 + r_{t-1}^{dS}) D_{t-1}^{P,S}(i) + T_t^P(i) \tag{5.5}$$

[6] In the simulation exercises, I calibrate $\theta^P = 1.1$.

where $C_t^P(i)$ depicts current total consumption. Total working hours (allotted to the different sectors j) are given by L_t^P and labor disutility is parameterized by ϕ^P. The flow of expenses includes current consumption and real deposits to be made to both commercial and shadow banks, $D_t^{P,C}(i)$ and $D_t^{P,S}(i)$. Resources consist of wage earnings $w_t^P L_t^P(i)$ (where w_t is the real wage rate for the labor input of each household), gross interest income on last period deposits $(1+r_{t-1}^{dC})D_{t-1}^{P,C}(i)$ and $(1+r_{t-1}^{dS})D_{t-1}^{P,S}(i)$, and lump-sum transfers T_t^P that include dividends from firms and commercial banks (of which patient households are the ultimate owners).

5.2.2 Entrepreneurs

Entrepreneurs engaged in a certain sector j use the respective labor type provided by households as well as capital to produce intermediate goods that retailers purchase in a competitive market. Each entrepreneur i derives utility from consumption $C_t^E(i)$, and maximizes expected utility

$$\max_{C_t^E(i),\, L_t^P(i),\, B_t^{E,C}(i),\, B_t^{E,S}(i)} E_0 \sum_{t=0}^{\infty} \beta_E^t \frac{{C_t^E}^{1-\sigma}}{1-\sigma} \tag{5.6}$$

subject to the budget constraint

$$C_t^E(i) + w_t l_t^P(i) + (1+r_{t-1}^{bC})B_{t-1}^{E,C}(i) + (1+r_{t-1}^{bS})B_{t-1}^{E,S}(i) \leq \frac{y_t^E(i)}{x_t} + B_t^{E,C}(i) + B_t^{E,S}(i) \tag{5.7}$$

with x_t determining the price markup in the retail sector. Entrepreneurs' expenses, consisting of period-t consumption $C_t^E(i)$, wage payments $w_t l_t^P(i)$, and gross repayments of loans taken on in the previous period from commercial and shadow banks ($(1+r_{t-1}^{bC})B_{t-1}^{E,C}(i)$ and $(1+r_{t-1}^{bS})B_{t-1}^{E,S}(i)$) are financed by production output $\frac{y_t^E(i)}{x_t}$ and period-t borrowing.

Entrepreneurs face a constraint on the amount of loans $B_t^{E,C}(i)$ they can borrow from commercial banks depending on the fixed stock of capital K they hold as collateral. Whereas a regulatory loan-to-value (LTV) ratio m_t^E applies for funds borrowed from commercial banks, shadow bank funding is not prone to regulation. Due to a positive spread between interest rates charged for shadow bank and commercial bank loans, entrepreneurs have an incentive to borrow from commercial banks first and turn to shadow bank lending only whenever the possible amount of commercial bank funds, determined by $m_t^E K$, is reached. Further borrowing can be obtained from shadow banks by using capital holdings not reserved for commercial bank funds, $(1-m_t^E)K$.[7] As stock of physical capital is assumed to be fixed, the two respective borrowing constraints are given by

$$(1+r_t^{bC})B_t^{E,C} \leq m_t^E K \tag{5.8}$$

$$(1+r_t^{bS})B_t^{E,S} \leq (1-m_t^E)K \tag{5.9}$$

where the LTV ratio for commercial banks m_t^E is set by a separate regulator in an exogenous way. In contrast, the LTV ratio applying to shadow bank lending, $m_t^{E,S} = 1-m_t^E$, depicts an endogenous variable in the model. Shadow bank credit thus may rise if either LTV ratios for commercial bank credit are tightened, or if the borrowing constraint 5.8 does not bind. Furthermore, I show in appendix B.3 how commercial bank market power and resulting commercial bank credit rationing can shift credit towards shadow banks. Consequently, steady-state credit provided by both intermediaries permanently deviates from levels obtained in the efficient steady state without market power.

As in chapter 4 and in Iacoviello (2005), entrepreneurs face binding borrowing constraints in equilibrium, such that equations 5.8 and 5.9 hold with equality. One can furthermore derive an expression for firm net worth along the lines of Gambacorta and Signoretti (2014)

$$NW_t^E = \alpha\frac{y_t^E}{x_t} + K - (1+r_{t-1}^{bC})B_{t-1}^{E,C} - (1+r_{t-1}^{bS})B_{t-1}^{E,S} \tag{5.10}$$

where firm net worth in period t is given by net revenues minus wage and interest expenses. Finally, as in Gambacorta and Signoretti (2014), entrepreneur consumption C_t^E is dependent on firm net worth:

$$C_t^E = (1-\beta_E)NW_t^E. \tag{5.11}$$

5.2.3 Financial Intermediaries

The financial sector consists of two types of banks, regulated commercial banks and unregulated shadow banks. Furthermore, commercial banks act under monopolistic competition in the loan market, whereas shadow banks are perfectly competitive entities, but constrained by a moral hazard friction arising with the depositing household.

Commercial Banks

Following Gambacorta and Signoretti (2014), the commercial bank consists of two agents: A wholesale unit managing the bank's capital position and taking deposits from house-

[7] See appendix A.1 of chapter 4 for details.

holds, and a retail loan entity that lends funds managed by the wholesale unit to entrepreneurs, charging an interest rate markup.[8]

The *wholesale branches* of commercial banks operate under perfect competition and are responsible for the capital position of the respective commercial bank. On the asset side, they hold funds they provide to the retail loan branch, $B_t^{E,C}$, earning the wholesale loan rate r_t^C. On the liability side, they combine commercial bank net worth, or capital, K_t^C, with household deposits, $D_t^{P,C}$ which earn the policy rate r_t. Furthermore, the capital position of the wholesale branch is prone to a regulatory capital requirement, ν_t. Moving away from the regulatory requirement imposes a quadratic cost to the bank, which is proportional to the outstanding amount of bank capital and parameterized by κ_k^C.

The wholesale branch maximization problem can be expressed as

$$\max_{B_t^{E,C},\, D_t^{P,C}} \quad r_t^C B_t^{E,C} - r_t D_t^{P,C} - \frac{\kappa_k^C}{2}\left(\frac{K_t^C}{B_t^{E,C}} - \nu_t\right)^2 K_t^C \tag{5.12}$$

subject to the the balance sheet condition

$$B_t^{E,C} = K_t^C + D_t^{P,C}. \tag{5.13}$$

The first-order conditions yield the following expression:

$$r_t^C = r_t - \kappa_k^C \left(\frac{K_t^C}{B_t^{E,C}} - \nu_t\right)\left(\frac{K_t^C}{B_t^{E,C}}\right)^2. \tag{5.14}$$

Aggregate bank capital K_t^C is accumulated from retained earnings only:

$$K_t^C = K_{t-1}^C(1-\delta^C) + J_t^C \tag{5.15}$$

where J_t^C depicts aggregate commercial bank profits, see equation B.1.26 in appendix B.1. Capital management costs are captured by δ^C.

Finally, *retail loan branches* act under monopolistic competition. They buy wholesale loans, differentiate them at no cost, and resell them to borrowing entrepreneurs. In doing so, the retail loan branch charges a markup μ_t over the wholesale loan rate, and the retail loan rate is thus given by

$$r_t^{bC} = r_t - \kappa_k^C \left(\frac{K_t^C}{B_t^{E,C}} - \nu_t\right)\left(\frac{K_t^C}{B_t^{E,C}}\right)^2 + \mu_t. \tag{5.16}$$

[8] In contrast to chapter 4, I do not consider market power in deposit markets in the model, as monopolistic competition in loan markets is sufficient to derive the key findings. However, the model could straightforwardly be extended by introducing a monopolistically competitive deposit entity and deposit rate markdowns as in chapter 4.

Shadow Banks

In contrast to the commercial banking sector, shadow banks are not regulated and do not operate under monopolistic competition. Furthermore, shadow banks' ability to acquire external funds is constrained by a moral hazard problem as in chapter 4 that limits the creditors' willingness to provide external funds.

Shadow bankers are assumed to have a finite lifetime: they disappear from the market after some years, whereas the point of exit is unknown a priori. Each shadow banker faces an i.i.d. survival probability σ^S with which he will be operating in the next period, so his exit probability in period t is $1-\sigma^S$. Every period new shadow bankers enter with an initial endowment of w^S they receive in the first period of existence, but not thereafter. The number of shadow bankers in the system is constant.

For shadow banker j, as long as the real return on lending, $(r_t^{bS} - r_t^{dS})$ is positive, it is profitable to accumulate capital until he exits the shadow banking sector. Thus, the shadow bank's objective to maximize expected terminal wealth, $v_t(j)$, is given by

$$v_t(j) = \max E_t \sum_{i=0}^{\infty} (1-\sigma^S){\sigma^S}^i \beta_S^{i+1} K_{t+1+i}^S(j). \tag{5.17}$$

As I assume some shadow bankers to exit each period and new bankers to enter the market, aggregate capital K_t^S is determined by capital of continuing shadow bankers, $K_t^{S,c}$, and capital of new bankers that enter, $K_t^{S,n}$

$$K_t^S = K_t^{S,c} + K_t^{S,n}. \tag{5.18}$$

Following chapter 4 yields the following law of motion for shadow bank capital:

$$K_t^S = \sigma^S[(r_{t-1}^{bS} - r_{t-1}^{dS})\phi_{t-1}^S + (1 + r_{t-1}^{dS})]K_{t-1}^S + \omega^S B_{t-1}^{E,S} \tag{5.19}$$

and the aggregate shadow bank balance sheet condition is given by

$$B_t^{E,S} = D_t^{P,S} + K_t^S. \tag{5.20}$$

Finally, I assume a non-negative spread between the interest rates earned on shadow bank deposits, r_t^{dS}, and on the deposits households can place with commercial banks, r_t^{dC}, which is determined by the parameter τ^S, with $0 \leq \tau^S \leq 1$:[9]

$$1 + r_t^{dS} = \frac{1 + r_t^{dC}}{1 - \tau^S \varepsilon_t^{\tau}}. \tag{5.21}$$

[9] In appendix A.1 to chapter 4, a microfoundation for the existence of a positive spread is provided.

5.2.4 Monetary Policy and Market Clearing

The central bank is assumed to follow a Taylor-type policy rule given by

$$1 + R_t = (1 + R)^{1-\phi^r}(1 + R_{t-1})^{\phi^r}\left[\pi_t^{\phi^\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi^y}\right]^{1-\phi^r}(1 + \epsilon_t^R) \tag{5.22}$$

where ϕ^r is equal to zero in the analytic derivations of in appendix B.4. The model features sticky prices à la Calvo (1983), which are introduced following Benigno and Woodford (2005). The aggregate resource constraint is given by

$$Y_t = C_t + K + \frac{K_{t-1}^C \delta^C}{\pi_t}. \tag{5.23}$$

Market clearing implies

$$Y_t = \gamma_y y_t^E \tag{5.24}$$

$$C_t = C_t^P \gamma_p + C_t^E \gamma_e \tag{5.25}$$

$$B_t = B_t^{E,C} + B_t^{E,S}. \tag{5.26}$$

Shadow bank and commercial bank credit-to-GDP ratios are defined as:

$$Z_t = \frac{B_t^{E,C}}{Y_t} \tag{5.27}$$

$$Z_t^{SB} = \frac{B_t^{E,S}}{Y_t}. \tag{5.28}$$

Spreads on commercial and shadow banks' loan and deposit rates are given by

$$\Delta_t^{loan} = r_t^{bS} - r_t^{bC} \tag{5.29}$$

$$\Delta_t^{deposit} = r_t^{dS} - R_t, \tag{5.30}$$

and the spreads earned on intermediation by commercial and shadow banks by

$$\Delta_t^C = r_t^{bC} - R_t \tag{5.31}$$

$$\Delta_t^S = r_t^{bS} - r_t^{dS}. \tag{5.32}$$

5.3 Calibration

The calibrated model parameters are largely based on the estimated parameter values in chapter 4 and shown in table 5.1.[10] In the baseline calibration, the steady-state commercial bank capital requirement is set to 10.5 percent, in line with the proposed level in the Basel III framework. The discount factors for households and firms are calibrated in line with Gerali et al. (2010) and allow for distinguishing between patient households as savers and impatient entrepreneurs as borrowers. The commercial bank steady-state LTV-ratio is set to 0.3, in line with empirical estimates derived in Gerali et al. (2010). Firms can therefore acquire 30 percent of lending relative to collateral they pledge, and can furthermore use the remaining 70 percent of their collateral to borrow from shadow banks.

Table 5.1: Calibration

Parameter	**Description**	**Value**
ν	Steady-State Capital Requirement	0.105
β_P	Discount Factor Households	0.9943
β_E, β_S	Discount Factor Entrepreneurs and Shadow Banks	0.975
m^E	Steady-State LTV Ratio vs. Commercial Banks	0.3
γ^S	Steady-State Share of Shadow Bank Lending	0.33
τ^S	Deposit Rate Spread Parameter	0.05
θ^S	SB Share of Divertible Funds	0.2
σ^S	SB Survival Probability	0.9
α	Capital Share in Production Function	0.2
δ^C	Bank Capital Management Cost	0.1049
θ^p	Calvo Parameter	0.87
ϕ^π	Taylor-Rule Coefficient π	1.87
ϕ^y	Taylor-Rule Coefficient y	0.24
ϕ^r	Interest Rate Smoothing Parameter	0.88
$\gamma_y, \gamma_p, \gamma_e$	Population Weights	1

Note: Calibration following chapter 4, see also table 4.1. In part based on Gerali et al. (2010) and Gertler and Karadi (2011).

In the following, the parameters governing commercial bank market power and shadow bank risk will have significant welfare implications. The steady-state commercial bank loan rate markup μ is set to 200 basis points, such that it closely matches with the average annualized commercial bank loan rate spread with respect to the EONIA rate in the empirical sample of chapter 4. Furthermore, as discussed there, finding an empirical estimate for the spread parameter τ^S is difficult. Under the baseline calibration, the

[10] For the remaining parameters not listed in table 5.1, see also tables 4.1 and 4.2. Furthermore, while I rely on the estimated parameters of the quantitative model developed in chapter 4, I compare dynamic simulations under this parameterization with an estimated version of the modified model described in section 5.2 in appendix section B.2.

parameter is set such that the implied default probability of shadow banks is approximately five percent per quarter and the resulting annualized spread between shadow bank and commercial bank deposit rates is approximately two percentage points in steady state. When discussing welfare implications of steady-state shadow bank risk in section 5.5 and appendix B.3, I evaluate the sensitivity of results with respect to different values of τ^S, thereby acknowledging that the empirical variation in actual returns and resulting spreads can be large on the micro level. Remaining parameters are calibrated such that basic empirical relationships observed in the euro area data on commercial and shadow banking are matched.[11] The size of the average shadow bank loan portfolio is one-third the size of shadow bank assets, and the overall share of shadow banks in total lending activity is also set to 33 percent. The remaining parameters are also set as discussed in chapter 4.

5.4 Welfare Analysis: Loss Functions

In the following, I summarize the derivations of welfare loss functions for the cases with and without shadow banking.[12] Furthermore, I discuss welfare-optimal macroprudential regulation both from a static and a dynamic perspective. In the iterative substitution of the terms in the utility functions sketched below, I make use of the Taylor rule as an additional model equation linking the nominal interest rate to output and inflation. Thus, I assume that macroprudential policy takes the central bank's actions as given, and sets policy by assuming these actions to be conducted in a Taylor-type fashion. Therefore, no coordination among policy makers is assumed at this point.[13]

5.4.1 No Shadow Banking

In each case, the welfare function is derived following Benigno and Woodford (2005, 2012) from a second-order approximation of aggregate utility. Following Lambertini et al. (2013) and Rubio (2011), the social welfare measure is given by a weighted sum of patient households' and impatient firms' welfare functions:[14]

$$W_{t_0} = (1-\beta_P)W^P_{t_0} + (1-\beta_E)W^E_{t_0}. \tag{5.33}$$

[11] See chapter 4 as well as Bakk-Simon et al. (2012) or Malatesta et al. (2016).

[12] Derivations are described in detail in appendix B.4.

[13] Several papers recently deviated from this strict assumption by discussing the case of policy coordination, either by assuming perfect coordination or in the form of strategic-interaction games, see for instance Bodenstein et al. (2019), Binder et al. (2018), Gelain and Ilbas (2017), or Beau et al. (2012). The analysis here could be extended in the same direction, by deriving optimal monetary and macroprudential policies jointly. However, as I will show in the following, my analysis will provide scope for policy coordination even without the assumption of jointly-optimal policy coordination of some form in the first place.

[14] Under such a definition, households and firms derive the same level of utility from a constant consumption stream. See chapter 6 for an alternative design of welfare weights.

For patient household and entrepreneurs, the respective welfare function is given by the conditional expectation of lifetime utility at date t_0,

$$W^P_{t_0} \approx E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0} [U(C^P_t, L^P_t)] \tag{5.34}$$

and

$$W^E_{t_0} \approx E_{t_0} \sum_{t=t_0}^{\infty} \beta_E^{t-t_0} [U(C^E_t)]. \tag{5.35}$$

Starting from a second-order approximation of the patient household's utlity function in equation 5.1, one can derive an approximated period welfare measure $\widehat{W}^P_t$ of the form

$$\begin{aligned} \widehat{W}^P_t = & \tfrac{1}{2}\psi^{Y^2}_{(8)}\widehat{Y}^2_t + \tfrac{1}{2}\psi^{r^2}_{(4)}\widehat{r}^2_t + \tfrac{1}{2}\psi^{\nu^2}_{(3)}\widehat{\nu}^2_t + \tfrac{1}{2}\psi^{z^2}_{(4)}\widehat{Z}^2_t + \\ & + \psi^{Y}_{(7)}\widehat{Y}_t + \psi^{\pi}_{(4)}\widehat{\pi}_t + \psi^{\nu}\widehat{\nu}_t + \psi^{z}_{(2)}\widehat{Z}_t + \\ & + covars + t.i.p. + O^3 \end{aligned} \tag{5.36}$$

where $\widehat{W}^P_t \equiv \frac{U^P_t - U^P}{U^P_{C^P} C^P}$. Hats denote percentage deviations from steady state and the parameters are given in appendix B.4.1. The terms $covars$ summarizes the sum of covariances in equation 5.36. As in Benigno and Woodford (2005, 2012), $t.i.p.$ covers terms independent of policy decisions and O^3 terms of higher order.

Similarly, a period welfare term for entrepreneurs

$$\widehat{W}^E_t = \widehat{C}^E_t + (1-\sigma)\frac{1}{2}(\widehat{C}^E_t)^2 \tag{5.37}$$

can be derived from the second-order approximation of the firm utility function (equation 5.6). Finally, the terms for $\widehat{W}^P_t$ and $\widehat{W}^E_t$ can be used in the approximation of the period joint welfare function

$$W_t = (1-\beta_P)W^P_t + (1-\beta_E)W^E_t. \tag{5.38}$$

Using second-order approximations of structural relations in the model, the resulting loss function can be expressed as

$$\widehat{L}_t = \tfrac{1}{2}\lambda^{y^2}\widetilde{Y}^2_t + \tfrac{1}{2}\lambda^{r^2}\widetilde{r}^2_t + \tfrac{1}{2}\lambda^{z,cb^2}\widetilde{Z}^2_t + \tfrac{1}{2}\lambda^{\nu^2}\widehat{\nu}^2_t + \lambda^{z,cb}\widehat{Z}_t. \tag{5.39}$$

The period welfare loss depends on the variation of the efficient output gap $\widetilde{Y}_t = \widehat{Y}_t - \widehat{Y}_t^*$,[15] the variation in the efficient policy rate gap $\widetilde{r}_t = \widehat{r}_t - \widehat{r}_t^*$, the efficient commercial bank credit-to-GDP ratio gap $\widetilde{Z}_t = \widehat{Z}_t - \widehat{Z}_t^*$, and the capital requirement $\widehat{\nu}_t$. In addition, deviations from the steady-state level of the credit-to-GDP ratio Z_t affect period welfare. The parameters λ^{y^2}, λ^{r^2}, λ^{ν^2}, λ^{z,cb^2}, and $\lambda^{z,cb}$ are determined by steady-state relationships and the structural parameters.

The derived welfare loss function generally resembles the functions employed under the "revealed preferences approach" (Binder et al., 2018; Angelini et al., 2014), as welfare depends on variations in the output gap, credit-to-GDP, and the macroprudential policy tool ν_t. However, even without an explicit a-priori mandate for policy coordination, the monetary policy tool enters the welfare objective of the regulator.[16] Furthermore, the derived loss function features a level term and therefore does not only contain purely quadratic terms. In section 5.5.1, I describe the role of level terms in period loss functions as an indication of distortionary effects arising from inefficiencies in the economy related to credit.

5.4.2 Shadow Banking

Whereas the broad structure of the derivation is the same for the model with shadow banks, I briefly highlight how these institutions enter the welfare analysis.[17] The derivation of the second-order approximation of the patient household's welfare criterion $\widehat{WP}_t$ does not change once shadow banks are allowed for in the model. Shadow banking enters the overall welfare criterion via entrepreneurs, as entrepreneur net worth now depends on borrowing from both intermediaries (equation B.1.19). By including shadow bank credit via firm net worth, one can derive the loss function for the model with shadow banks:

$$\widehat{L}'_t = \frac{1}{2}\lambda^{y^2\prime}\widetilde{Y}_t^2 + \frac{1}{2}\lambda^{r^2\prime}\widetilde{r}_t^2 + \frac{1}{2}\lambda^{z,cb^2\prime}\widetilde{Z}_t^2 + \frac{1}{2}\lambda^{z,sb^2\prime}(\widetilde{Z}_t^{SB})^2 + \frac{1}{2}\lambda^{\nu^2}\widehat{\nu}_t^2 + \\ + \lambda^{z,cb\prime}\widehat{Z}_t + \lambda^{z,sb\prime}\widehat{Z}_t^{SB} \quad (5.40)$$

where $\widetilde{Z}_t^{SB} = \widehat{Z}_t^{SB} - \widehat{Z}_t^{SB*}$ depicts the efficient shadow bank credit-to-GDP gap, based on the shadow bank credit-to-GDP ratio Z_t^{SB}. Due to the inclusion of shadow banking, the composite parameters in equation 5.40 take different values compared to the parameters in

[15] Deviations from steady state in the efficient economy absent any frictions are indicated with asterisks. In such an economy, variations are only determined by exogenous shocks.

[16] By substituting the approximated Taylor rule, the inflation rate instead of the nominal interest rate would appear in the loss function, indicating that the policy objectives of both the central bank and the macroprudential regulator are similar.

[17] See appendix B.4.2 for the derivation of the loss function with shadow banks.

equation 5.39. Furthermore, the level terms with respect to credit-to-GDP ratios indicate that both commercial bank and shadow bank credit relative to GDP deviate permanently from the optimal level whenever $\lambda^{z,cb'}$ and $\lambda^{z,sb'}$ are different from zero; even when no variations in the objective variables are observed. In section 5.5.1, I discuss potential reasons for distortionary credit levels and evaluate how these distortions can be corrected.

5.4.3 Static Evaluation

Analytic derivations of the coefficients in equations 5.39 and 5.40 allow for a computation of parameter values under the baseline calibration. Table 5.2 depicts the respective parameter values on the quadratic terms in the form of "sacrifice ratios": The parameters on the quadratic terms related to the capital requirement, the output gap, the shadow bank credit-to-GDP ratio, and the interest rate are expressed relative to the coefficient on the commercial bank credit-to-GDP ratio. Thus, the relative importance of other policy objectives vis-à-vis commercial bank credit stabilization in the welfare criterion can be evaluated. The level term parameters $\lambda^{z,cb}$, $\lambda^{z,cb'}$ and $\lambda^{z,sb'}$ are reported in absolute terms.

Table 5.2: Loss Function Parameters

		No Shadow Banks	**Shadow Banks**
$\lambda^{y^2}/\lambda^{z,cb^2}$	Output	2.72	0.76
$\lambda^{z,sb^2}/\lambda^{z,cb^2}$	SB Credit/GDP	-	0.92
$\lambda^{r^2}/\lambda^{z,cb^2}$	Interest Rate	34.25	12.90
$\lambda^{\nu^2}/\lambda^{z,cb^2}$	Capital Requirement	0.009	0.002
$\lambda^{z,cb}$	CB Credit/GDP level	-0.16	-1.33
$\lambda^{z,sb}$	SB Credit/GDP level	-	1.52

Note: Values of coefficients in equations 5.39 and 5.40 under baseline parameterization. See appendix B.4 for derivations.

Strikingly, the importance of credit stabilization relative to interest rate and output gap stabilization increases substantially once shadow banks are included in the model. Whereas the weight on output gap stabilization is almost three times larger than the weight on commercial bank credit stabilization in the model without shadow banks, the latter exceeds the output gap weight in the loss function of the model including shadow banking. Also, the weight on commercial bank credit stabilization increases substantially relative to the weight on the interest rate objective in the model with shadow banking. Furthermore, even though the regulator cannot directly stabilize shadow bank credit, he puts a relatively high weight on its variation when setting policy: Stabilization of credit in the shadow banking sector enters with almost the same weight as commercial bank credit variations. Thus, total credit stabilization plays a much larger role in the model with shadow banking compared to the case of perfectly implementable financial regulation without shadow banks.

Finally, the parameters on commercial bank credit level terms, $\lambda^{z,cb}$ and $\lambda^{z,cb'}$ are negative in both model versions, whereas the parameter for the shadow bank credit level term $\lambda^{z,sb'}$ is positive under reasonable parameter values. As discussed in more detail in section 5.5.1 and appendix B.3, due to market power and shadow bank inefficiencies, steady-state levels of commercial (shadow) bank credit are below (above) efficient levels that would prevail in a frictionless economy. Due to these deviations, a marginal increase (decrease) in commercial (shadow) bank credit has a positive welfare effect (as losses are reduced). I discuss the existence of level terms in the loss functions and implications for policy in the following section.

5.5 Welfare Analysis: Optimal Level Policy

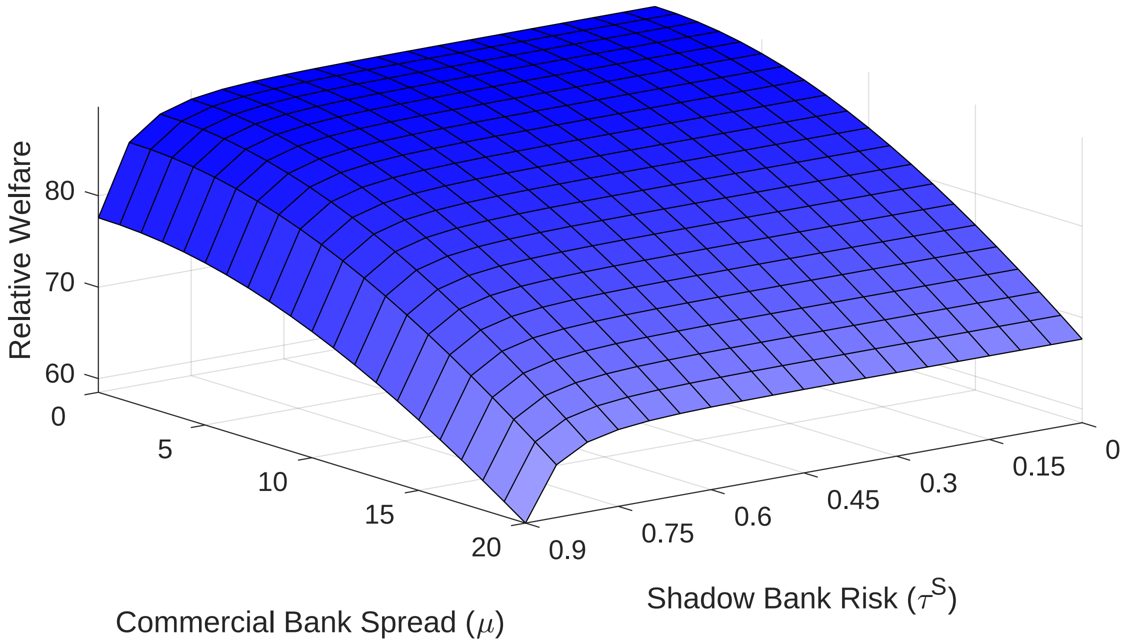
The loss functions derived above indicate that social welfare not only depends on the ability of policy makers to stabilize *cyclical* fluctuations in the target variables, but also that the permanent *levels* of commercial and shadow bank credit have welfare implications. Thus, the findings suggest that both time-invariant and cyclical macroprudential policies can be welfare-enhancing. In the following, I discuss how financial frictions induce permanent steady-state distortions that provide scope for time-invariant macroprudential policies. Furthermore, I evaluate how different permanent regulatory tools can be employed to resolve the resulting policy trade-off.

5.5.1 Distortionary Effects of Bank Market Power and Shadow Bank Inefficiencies

As I discuss in detail in the steady-state analysis of appendix B.3, financial frictions in both the commercial and shadow banking sector result in permanent deviations of shadow and commercial bank credit from their efficient levels. Due to market power, commercial banks charge a steady-state markup μ on credit they provide to borrowing entrepreneurs. At the same time, the amount of credit intermediated by these institutions is below the efficient level. To accommodate their demand for funding, entrepreneurs turn to perfectly competitive but risky shadow banks: They use a larger share of their collateral capital stock K to pledge against borrowing from these institutions. Thus, both monopolistic competition in the commercial banking sector and the default risk of shadow banks – where the frictions are governed by μ and τ^S, respectively – imply welfare losses. Figure 5.1 reports welfare implications of increases in both friction parameters. Relative welfare levels are expressed in terms of consumption equivalents given by

$$1 - \xi \equiv (1 - \xi^P)^{1-\beta_E}(1 - \xi^E)^{1-\beta_P} = \exp[(W_{t_0} - W^*_{t_0})(1 - \beta_P)]^{1-\beta_E} \qquad (5.41)$$

Figure 5.1: Welfare Implications of Steady-State Distortions



Note: Relative welfare levels under Ramsey-optimal policies based on objective 5.41 for different values of the commercial bank loan markup μ (percentage points) and shadow bank risk τ^S.Welfare levels are in relation to levels obtained in the decentralized economy presented in section B.3.2.

derived from the welfare criterion 5.33 in appendix B.5. Cost parameters ξ^P and ξ^E determine the loss in consumption by households and entrepreneurs in the economy with financial, real and nominal frictions, compared to the decentralized economy presented in appendix section B.3.2. In the decentralized economy, both shadow and commercial banks exist. They intermediate funds equally efficient since no financial frictions such as market power and risk (and no real frictions or nominal rigidities from sticky prices) are present in this scenario. Welfare in the friction economy (W_{t_0}) relative to welfare in the decentralized frictionless economy ($W^*_{t_0}$) is compared in terms of composite consumption equivalents, i.e. by the maximum fraction ξ of consumption that both households and entrepreneurs would be willing to forgo in the economy featuring financial, nominal and real frictions to join the decentralized economy of appendix B.3.2. The composite cost ξ is defined such that an increase in the welfare share of one agent in equation 5.33 results in a lower contribution of the other agent's consumption losses to overall losses, given that $0 < \beta_P, \beta_E < 1$.

An increase in the friction parameters results in a reduction of overall welfare in the model featuring shadow banks, whereas the amplification of the welfare losses increases for high levels of distortions in both cases. Particularly for high levels of default risk, welfare drops sharply. Furthermore, as shown in appendix B.3.5, both frictions imply that the market-clearing level of time-invariant capital requirements is different in the shadow bank and commercial bank credit market. While the efficient level of capital requirements in the decentralized economy absent financial frictions

$$\nu^* = \frac{K^C}{\beta_P m^E K} \tag{5.42}$$

results in clearing of both markets, the levels of steady-state capital requirements implied by clearing in each credit market – ν^C and ν^S, respectively – are given by

$$\begin{aligned} \nu^C &= \frac{K^C(1+\beta_P\mu)}{\beta_P m^E K} \\ \nu^S &= K^C\left[\beta_P K - (1-\tau^S)\beta_P\left(1 - \frac{1}{1+\beta_P\mu}m^E\right)K\right]^{-1} \end{aligned} \tag{5.43}$$

in the steady state featuring distortions from financial frictions. As discussed in proposition 13 in the appendix and shown in the upper part of figure 5.2, these requirements

1. differ from the efficient level ν^* in the decentralized frictionless economy
2. increase (decrease) in commercial bank market power (shadow bank risk).

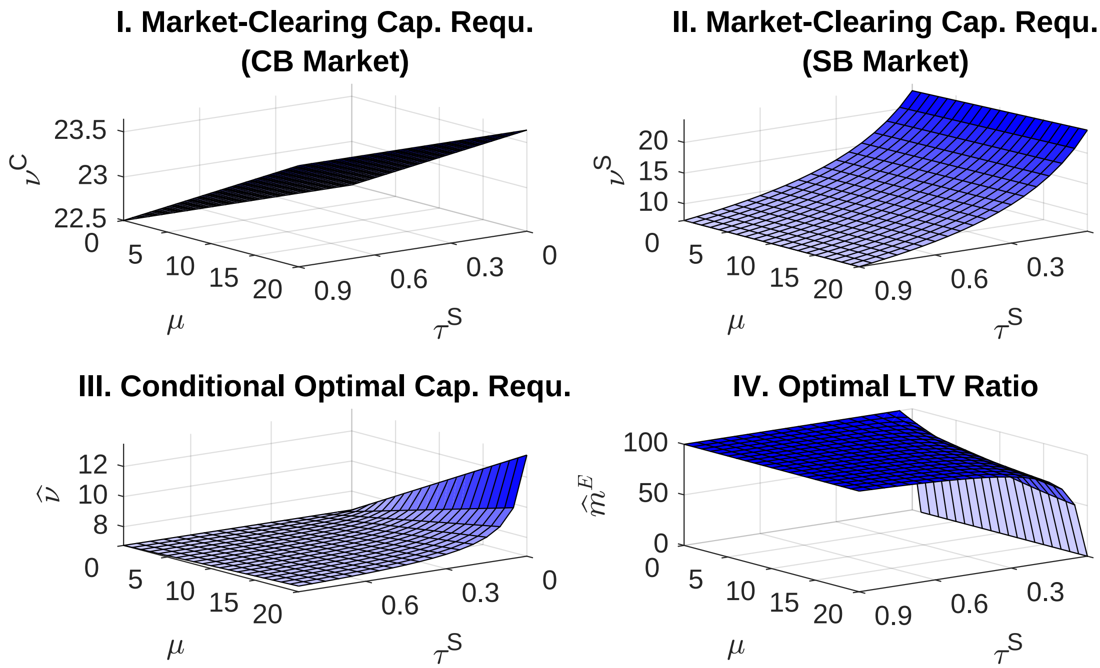
The discrepancy in market-clearing levels of permanent capital requirements due to steady-state distortions has implications for optimal time-invariant macroprudential regulation. As a consequence, it is not feasible to account for *both* origins of steady-state distortions with only one macroprudential tool. However, in line with the Tinbergen (1952) principle, policy makers can pursue a strategy of targeting credit deviations in each lending market separately, by applying one tool to one distortion.

In section B.3.5 of the appendix, I propose that a mix of both supply- and demand-side oriented time-invariant macroprudential policy tools can lead to allocations where steady-state levels of both commercial and shadow bank credit are at their efficient levels. Capital requirements, targeting credit supply of commercial banks directly, appear suited to account for distortions stemming from commercial bank market power. Additionally, whenever shadow bank credit supply cannot be regulated directly, borrower-side tools such as LTV ratios present a means for taking account of distortions in this market.

In the strategy outlined, the regulator sets permanent LTV ratios such that the efficiency gap in the shadow bank credit market – the difference in shadow bank credit in the distorted and the decentralized economy's steady state – given by

$$\widehat{B}^{E,S} = B^{E,S} - B^{E,S*} = \left[\left(1 - \frac{1-\tau^S}{1+\beta_P\mu}\right)m^E - \tau^S\right]K\beta_P \tag{5.44}$$

Figure 5.2: Time-Invariant Levels of Macroprudential Policies



Note: Levels of steady-state capital requirements (ν^C, ν^S, $\hat{\nu}$) and LTV ratios ($\widehat{m}^E$) for different values of the commercial bank loan markup μ (percentage points) and shadow bank risk τ^S.

is zero. The implied optimal level of steady-state LTV ratios is then given by

$$\widehat{m}^E = \tau^S \frac{1 + \beta_P \mu}{\tau^S + \beta_P \mu}. \tag{5.45}$$

Conditional on the gap-closing level $\widehat{m}^E$, steady-state capital requirements are chosen such that the commercial bank efficiency gap given by

$$\widehat{B}^{E,C} = B^{E,C} - B^{E,C*} = \left(\frac{\beta_P}{1 + \beta_P \mu} - \beta_P \right) m^E K \tag{5.46}$$

is closed. The resulting optimal capital requirement is equal to

$$\hat{\nu} = \frac{K^C(\tau^S + \beta_P \mu)}{\beta_P \tau^S K}. \tag{5.47}$$

The lower part of figure 5.2 shows the implied optimal levels of capital requirements and LTV ratios that close credit gaps stemming from steady-state distortions in the economy with financial frictions.[18] Whenever shadow bank risk is almost absent in the economy

[18]In effect, $\hat{\nu}$ is only defined whenever the shadow bank risk parameter τ^S is positive. Whenever τ^S is zero, $\nu^C = \nu^S$ and the efficient level coincides with these expressions (if $\mu > 0$), or with ν^* (if $\mu = 0$).

($\tau^S \rightarrow 0$), it is optimal for the regulator to set permanent LTV ratios close to zero, independent of the degree of commercial bank market power (quadrant IV.). In this case, it is beneficial to limit credit intermediation of monopolistic-competitive commercial banks and enforce a shift of credit intermediation towards (almost) risk-free shadow banks which act under perfect competition. Similarly, an increase in commercial bank market power leads to the relative superiority of shadow bank credit.

In contrast, higher levels of shadow bank risk and lower levels of bank market power induce an increase in the optimal steady-state LTV ratio. In these cases, a welfare-optimal lending mix features a larger share of commercial bank credit. Therefore, lowering borrowing standards with respect to commercial bank lending becomes beneficial, and in the boundary case of no commercial bank market power, it is optimal to set LTV ratios to 100 percent, such that all intermediation is conducted by commercial banks. Similarly, the optimal level of steady-state capital requirements increases whenever bank market power increases and shadow bank risk is low. Again, tighter regulation for commercial bank is welfare-enhancing whenever shadow bank credit becomes relative more attractive.

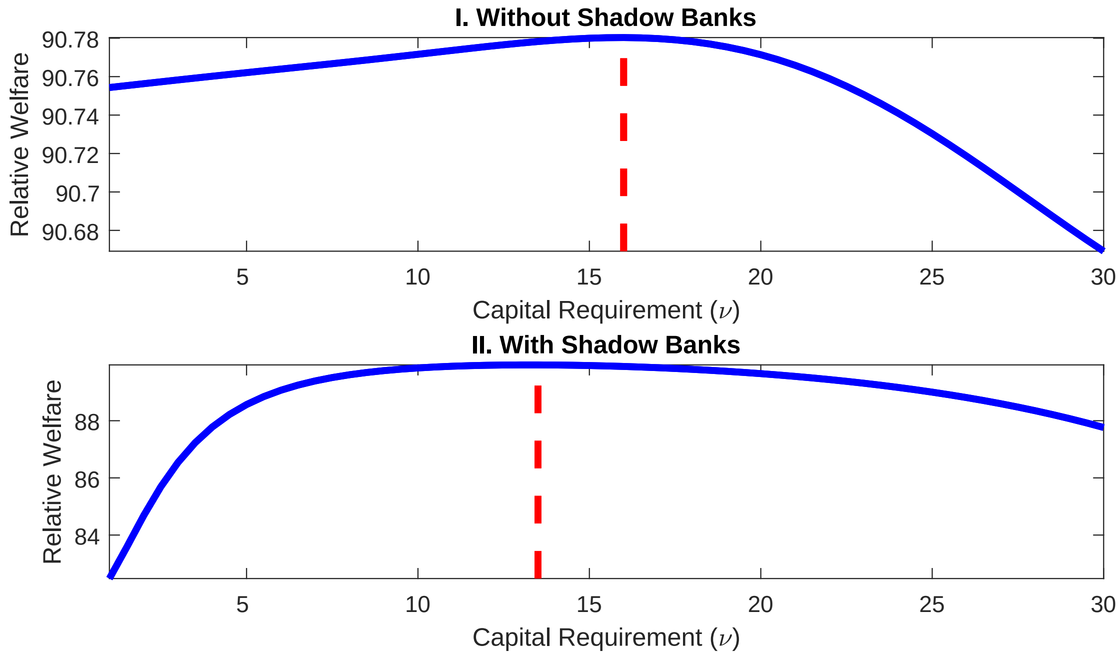
5.5.2 Welfare-Optimal Level of Permanent Capital Requirements

In the previous section, I showed analytically that the existence of commercial bank market power and shadow bank default risk implies a trade-off for policy makers deciding on the adequate level of commercial bank capital requirements. Quadrant III in figure 5.2 indicates that it is optimal for regulators to set capital charges to a high level in the presence of commercial bank market power to shift intermediation to the perfectly competitive shadow banking sector. However, the presence of shadow bank risk induces welfare losses[19] that limit the optimal amount of credit intermediation by these institutions. Due to the implied trade-off, the optimal level of steady-state capital requirements is unclear a priori. Figure 5.3 shows relative welfare according to equation 5.41 under the baseline calibration of μ and τ^S for different levels of ν. The optimal level of capital requirements is given by approximately 13.5 percent for the model with shadow banks, which coincides with the computed value of $\widehat{\nu}$ under the baseline calibration.

Furthermore, the shape of the welfare profile in figure 5.3 depends on the presence of shadow banks. In the absence of shadow banks (panel I.), welfare is relatively high for capital requirements below the optimum level of approximately 16 percent, but drops significantly for higher levels. Commercial banks are the only intermediaries and therefore the financial sector as a whole is affected by regulation. Whenever capital requirements are

[19]In the model, the actual losses stem from the fact that shadow bank profits – which increase in response to higher intermediation as the leverage constraint of shadow banks is loosened – are not transferred to households.

Figure 5.3: Welfare for Different Levels of Steady-State Capital Requirements



Note: Relative welfare under Ramsey-optimal policies based on objective 5.41 for different values of the steady-state capital requirement ν (percentage points). Welfare levels are relative to levels obtained in the decentralized economy presented in section B.3.2, when shadow banks are absent (I.) or present (II.).

above the optimal level, subdued intermediation adversely affects real economic activity, and ultimately household and firm consumption. In contrast, the drop in welfare associated with steady-state capital requirements above the optimal level is moderate in the model with shadow banks (panel II.), compared to welfare losses for lower-than-optimal requirement levels. In response to excessive regulation, the decline in commercial bank lending is partly compensated by shadow bank intermediation, and adverse effects for the real economy due to higher-than-optimal requirements are mitigated.

5.6 Welfare Analysis: Optimal Dynamic Policy

In the previous section, I discussed the importance of time-invariant macroprudential policies and the adequate permanent *level* of capital requirements. Under Basel III, regulators have the opportunity to adjust bank capital charges in a dynamic fashion within bands around such permanent levels,[20] depending on movements in business and credit cycles. In principle, policy makers agreed that these cyclical buffers should be adjusted in a *countercyclical* fashion, i.e. raised (lowered) whenever lending and potentially real economic

[20]The regulatory bands for countercyclical capital requirements allow for symmetric deviations of up to 2.5 percentage points from permanent levels under Basel III.

activity are "excessively" high (low). However, the discussion on the definition of excessive lending and the optimal design of dynamic policy rules for setting countercyclical capital requirements is still ongoing.[21]

In the following, I discuss the *cyclical* component of optimal regulation by deriving the optimal policy from a timeless perspective as in Benigno and Woodford (2005, 2012). First, I derive the welfare-optimal rule analytically in section 5.6.1 and discuss its properties. As the rule relates the adjustment of capital requirements to both contemporaneous and lagged values of a variety of target variables, less complex rules might be desirable from a practical perspective. Therefore, I evaluate the performance of more simple rules that only feature a subset of variables in comparison to the welfare-optimal rule in section 5.6.1. Finally, I discuss optimal dynamic responses to exogenous disturbances in a simulation exercise in section 5.6.2.

5.6.1 Optimal Policy Rules with Shadow Banking

The Welfare-Optimal Policy Rule

Based on the derivations in section 5.4, I derive an optimal macroprudential policy rule. To do so, I minimize the quadratic loss function subject to the linearized model constraints and initial conditions related to the timeless-perspective approach. However, the linear-quadratic approach requires the welfare (loss) function to contain purely quadratic terms only, such that linear approximations to equilibrium conditions are sufficient to evaluate the second-order welfare criterion.[22] To pursue with a purely quadratic loss function, I calibrate steady-state capital requirements and LTV ratios to 13.5 and 91.4 percent, respectively: These values correspond to the levels implied by equations 5.45 and 5.47 under the baseline calibration of section 5.3. As shown in appendix B.3, the permanent gaps between steady-state commercial and shadow bank credit and the respective efficient levels are closed when time-invariant macroprudential policies are set to these values. Put differently, the distortionary level terms $\widetilde{Z}_t$ and $\widetilde{Z}_t^{SB}$ in loss function (5.40) disappear. The resulting purely quadratic welfare objective allows for the derivation of an optimal policy rule following the LQ-approach[23] and is given by

$$\widehat{L}_t' = \frac{1}{2}\lambda^{y^2\prime}\widetilde{Y}_t^2 + \frac{1}{2}\lambda^{r^2\prime}\widetilde{r}_t^2 + \frac{1}{2}\lambda^{z,cb^2\prime}\widetilde{Z}_t^2 + \frac{1}{2}\lambda^{z,sb^2\prime}(\widetilde{Z}_t^{SB})^2 + \frac{1}{2}\lambda^{\nu^2\prime}\widehat{\nu}_t^2. \tag{5.48}$$

Furthermore, as outlined in appendix B.6, the rule is derived such that Lagrange multipliers on lagged terms in the first-order conditions of the Ramsey planner (equations

[21] See for instance Binder et al. (2018), Angelini et al. (2014), Cúrdia and Woodford (2010b), or De Paoli and Paustian (2017).

[22] See Benigno and Woodford (2012).

[23] See Benigno and Woodford (2005, 2012) and Giannoni and Woodford (2003a,b).

B.5.2 to B.5.43 in appendix B.6) are treated as parameters. Thus, initial conditions are honoured and not automatically set equal to zero in the minimization problem of the Ramsey planner. The time-dependence problem arising in the implementation of policy in period t_0 is consequently taken into account. Therefore, optimal policy is derived from a timeless perspective,[24] and the policy rule describes the optimal response of the policy maker to random disturbances in all periods $t \geq 0$.[25]

Minimizing loss function 5.48 subject to the linearized structural equations given in appendix B.1 and following the iterative approach outlined in appendix B.6 yields the macroprudential policy rule

$$\begin{aligned}\widehat{\nu}_t = {} & \rho^{\nu} + \rho_1^{\nu}\widehat{\nu}_{t-1} + \rho_2^{\nu}\widehat{\nu}_{t-2} + \rho_3^{\nu}\widehat{\nu}_{t-3} + \\ & + \phi_1^{r}\widetilde{r}_t + \phi_2^{r}\widetilde{r}_{t-1} + \phi_3^{r}\widetilde{r}_{t-2} + \phi_4^{r}\widetilde{r}_{t-3} + \\ & + \phi_1^{y}\widetilde{Y}_t + \phi_2^{y}\widetilde{Y}_{t-1} + \phi_3^{y}\widetilde{Y}_{t-2} + \phi_4^{y}\widetilde{Y}_{t-3} + \\ & + \phi_1^{z,cb}\widetilde{Z}_t + \phi_2^{z,cb}\widetilde{Z}_{t-1} + \phi_3^{z,cb}\widetilde{Z}_{t-2} + \phi_4^{z,cb}\widetilde{Z}_{t-3} + \\ & + \phi_1^{z,sb}\widetilde{Z}_t^{SB} + \phi_2^{z,sb}\widetilde{Z}_{t-1}^{SB} + \phi_3^{z,sb}\widetilde{Z}_{t-2}^{SB} + \phi_4^{z,sb}\widetilde{Z}_{t-3}^{SB},\end{aligned} \tag{5.49}$$

where the policy parameters ρ^{ν}, $\rho_k^{\nu}, k \in \{1, 2, 3\}$ and $\Phi_n^m, m \in \{r; y; z, cb; z, sb\}; n \in \{1, 2, 3, 4\}$ are composite parameters consisting of structural parameters and steady-state relations.[26] In the terminology of Giannoni and Woodford (2003a,b), the rule given by equation 5.49 depicts a *robustly optimal* rule, as none of the derivations outlined in appendix B.6 depends on the structural form of the disturbance processes of the model.[27] It is also a robustly optimal *direct* policy rule, as it does not involve direct response to exogenous shocks, but to observed target variables only. It is furthermore an *implicit* policy rule, as contemporaneous values of the target variables in addition to lagged (predetermined) values enter equation 5.49. For contemporaneous values, projections have to be formed implicitly in period t. Table 5.3 reports parameter values under the baseline calibration reported in table 5.1.

Several observations can be drawn from rule 5.49 and the parameter values under baseline calibration in table 5.3. First, macroprudential regulators optimally respond in

[24]By treating initial multiplier conditions as parameters being equal to zero or steady-state values, I derive optimal policy from a timeless perspective as referred to in Schmitt-Grohé and Uribe (2005) when the initial multipliers are set to steady-state.

[25]See for instance Bodenstein et al. (2019), Benigno and Woodford (2005, 2012), Giannoni and Woodford (2003a,b), or Schmitt-Grohé and Uribe (2005) for extensive discussions on the time-inconsistency problems arising from neglecting initial conditions and on the derivations of optimal policy from a timeless perspective for the cases of optimal monetary and fiscal policies.

[26]See appendix B.6 where auxiliary parameters defined in the calculations are reported.

[27]See appendix B.1.5 for a description of the assumed shock processes.

Table 5.3: Policy Rule Parameters

Parameter		$\boldsymbol{\Upsilon = 0}$	$\boldsymbol{\Upsilon = \overline{\Upsilon}}$
Inertia Parameter	ρ^{ν}	0.000	0.092
	ρ_1^{ν}	0.562	0.562
	ρ_2^{ν}	<0.000	<0.000
	ρ_3^{ν}	<0.000	<0.000
Nominal Interest Rate	Φ_1^{r}	-0.030	-0.030
	Φ_2^{r}	-0.027	-0.027
	Φ_3^{r}	-0.059	-0.059
	Φ_4^{r}	-0.031	-0.031
Output	Φ_1^{y}	1.729	1.729
	Φ_2^{y}	1.909	1.909
	Φ_3^{y}	0.156	0.156
	Φ_4^{y}	-0.082	-0.082
CB Credit-to-GDP	$\Phi_1^{z,cb}$	6.103	6.103
	$\Phi_2^{z,cb}$	<0.000	<0.000
	$\Phi_3^{z,cb}$	<0.000	<0.000
	$\Phi_4^{z,cb}$	<0.000	<0.000
SB Credit-to-GDP	$\Phi_1^{z,sb}$	-0.100	-0.100
	$\Phi_2^{z,sb}$	-0.122	-0.122
	$\Phi_3^{z,sb}$	-0.256	-0.256
	$\Phi_4^{z,sb}$	-0.135	-0.135

Note: Values of policy parameters in rule 5.49 under the baseline calibration. $\Upsilon = 0$ ($\Upsilon = \overline{\Upsilon}$) when initial conditions given by vector B.5.44 are equal to zero (equal to steady-state values).

a countercyclical fashion to deviations of output and the commercial bank credit-to-GDP ratio from their efficient levels. Therefore, the optimal rule features elements usually incorporated in ad-hoc rules in the "revealed preferences" literature. Whereas the optimal response to output deviations shows some inertia, macroprudential regulators put a high weight on contemporaneous variations in commercial bank credit-to-GDP. Cumulatively, the weights associated to these variables are the largest, followed by the cumulative weight on shadow bank credit in absolute terms. Quantitatively, the response to the nominal interest rate is relative moderate in the derived rule, even if the interest rate weight in loss function 5.40 turned out to be relatively large (table 5.2).

Second, even though regulation not directly applies to credit intermediated in the shadow banking sector, the regulator attaches negative weights to deviations in shadow bank credit-to-GDP from efficient levels under optimal policy. Whenever shadow bank lending increases over the efficient level, the macroprudential regulator, ceteris paribus, has a motive to *lower* capital requirements for commercial banks to counteract credit leakage. Thus, the additional trade-off stemming from credit leakage already highlighted in the evaluation of optimal steady-state levels in section 5.4.3 is reflected in the policy rule. Without shadow banks, this trade-off would be absent, and optimal regulation would unambiguously prescribe higher capital requirements in response to exogenous shocks that increase credit intermediation – which would then be conducted by commercial banks only. However, the optimal reaction with shadow banks depends on the nature of the shock and its relative effect on both credit aggregates, and on the relative size of the credit coefficients.

Third, macroprudential policy also responds to movements in the nominal interest rate, indicating potential scope for optimal policy coordination. Under the model specifications, optimal macroprudential policy operates to mitigate adverse effects on credit and output. Tightening monetary policy increases the cost of credit and may results in sub-optimal levels of lending or output. Consequently, capital requirements are loosened whenever the policy rate is raised by the central bank. Furthermore, as discussed in chapter 4, higher interest rates induce credit leakage to shadow banks in the model, which provides an additional rationale for the macroprudential regulator to lower capital requirements in response to tighter monetary policy. Under optimal policy coordination, these adverse effects would be considered in the monetary-macroprudential policy trade-off.

Finally, optimal capital regulation for commercial banks appears to be described by some degree of time-dependence, as both lagged values of the capital requirement itself and the target variables enter the optimal rule. In some circumstances, parameter values indicate that a stronger weight should be placed on past values instead of contemporaneous projections of target variables. For instance, the response to the output efficiency gap in the previous period should be slightly larger than the contemporaneous response. For the nominal interest rate and shadow bank credit, the largest weight is attached to observations two periods in the past. Only in the case of commercial bank credit, the optimal rule indicates a strong contemporaneous response, whereas past observations do not appear to be quantitatively relevant. Given such complexities, implementing and communicating the fully optimal rule 5.3 might be tedious or even not feasible. Instead, policy makers might be tempted to rely on simpler rules, and I discuss the relative performance of simplifications of rule 5.3 in the following section.

Optimal Simple Rules

In the following, I study whether the complex optimal policy rule 5.49 can be approximated by simple implementable rules without substantial welfare losses. Following the "revealed preferences" literature, the generic simple rule is given by:

$$\widehat{\nu}_t = \rho^{\nu}\widehat{\nu}_{t-1} + \Phi'\mathbf{X_t} \tag{5.50}$$

$$\Phi = \begin{bmatrix} \phi_S^{y} \\ \phi_S^{z,cb} \\ \phi_S^{z,sb} \end{bmatrix} \mathbf{X_t} = \begin{bmatrix} \widetilde{Y}_t \\ \widetilde{Z}_t \\ \widetilde{Z}_t^{SB} \end{bmatrix}. \tag{5.51}$$

The macroprudential authority sets the capital requirement $\widehat{\nu}_t$ by considering an autoregressive component as well as deviations of output and credit-to-GDP gaps from efficient steady-state levels. In doing so, the authority minimizes the loss function 5.48 by choosing the parameters in Φ, such that the optimization problem is given by

$$\min_{\Phi} \widehat{L}_t' = \tfrac{1}{2}\lambda^{y^{2'}}\widetilde{Y}_t^2 + \tfrac{1}{2}\lambda^{r^{2'}}\widetilde{r}_t^2 + \tfrac{1}{2}\lambda^{z,cb^{2'}}\widetilde{Z}_t^2 + \tfrac{1}{2}\lambda^{z,sb^{2'}}(\widetilde{Z}_t^{SB})^2 + \tfrac{1}{2}\lambda^{\nu^{2'}}\widehat{\nu}_t^2 \tag{5.52}$$

$$\text{s.t. } \widehat{\nu}_t = \rho^{\nu}\widehat{\nu}_{t-1} + \Phi'\mathbf{X_t} \tag{5.53}$$

$$0 = E_t\{f(\mathbf{x_t}, \mathbf{x_{t+1}}, \mathbf{x_{t-1}}, \theta^{\mathbf{m}})\} \tag{5.54}$$

where the last line represents constraints arising from the model structure the regulator faces. The function $f(\bullet)$ refers to the model equations, $\mathbf{x_t}$ to the vector of endogenous variables, and $\theta^{\mathbf{m}}$ to the vector of model parameters. Table 5.4 summarizes the optimized parameters for different variants of the generic rule 5.50 which are given by:

$$\text{OSR/CR 1: } \widehat{\nu}_t = \phi_S^{z,cb} \widetilde{Z}_t \tag{5.55}$$

$$\text{OSR/CR 2: } \widehat{\nu}_t = \phi_S^{y} \widetilde{Y}_t + \phi_S^{z,cb} \widetilde{Z}_t \tag{5.56}$$

$$\text{OSR/CR 3: } \widehat{\nu}_t = \phi_S^{y} \widetilde{Y}_t + \phi_S^{z,cb} \widetilde{Z}_t + \phi_S^{z,sb} \widetilde{Z}_t^{SB} \tag{5.57}$$

$$\text{OSR/CR 4: } \widehat{\nu}_t = \rho^{\nu} \widehat{\nu}_{t-1} + \phi_S^{y} \widetilde{Y}_t + \phi_S^{z,cb} \widetilde{Z}_t + \phi_S^{z,sb} \widetilde{Z}_t^{SB} \tag{5.58}$$

The simplest rule given by equation 5.55 indicates that the regulator only adjusts capital requirements in response to a contemporaneous deviation of the commercial bank credit-to-GDP gap from the efficient steady state. In the rules given by equations 5.56 to 5.58, contemporaneous deviations of output and the shadow bank credit-to-GDP gap as well as an autoregressive term are iteratively introduced.

Table 5.4: Simple Rule Parameters

	Optimal Simple Rules (OSR)				**Constrained Rules (CR)**			
Parameter	OSR 1	OSR 2	OSR 3	OSR 4	CR 1	CR 2	CR 3	CR 4
ρ_S^{ν}				0.562				0.562
ϕ_S^{y}		0.133	0.241	0.243		1.729	1.729	1.729
$\phi_S^{z,cb}$	12.231	33.169	50.564	52.337	6.103	6.103	6.103	6.103
$\phi_S^{z,sb}$			-11.103	-38.424			-0.100	-0.100
Relative Loss	0.0005	0.0005	0.0003	0.0002	0.0014	1.9915	1.9915	5.5584

Note: Values of policy parameters in rules 5.55 to 5.58. Optimal simple rules (OSR) refer to rules with optimized parameters, while Constrained Rules (CR) indicate rules with parameters directly taken from the fully optimal rule 5.49 under the baseline calibration. Welfare losses under each rule are expressed relative to welfare losses obtained under the fully optimal policy regime.

The left column of table 5.4 indicates that for all variants, parameters can be chosen by the regulator such that the welfare loss relative to the fully optimal rule 5.49 is small. However, achieving the same level of welfare losses with optimal simple rules (OSR) requires large parameter values in absolute terms. Neglecting lags and additional variables such as short-term interest rates enforces stronger reactions to the contemporaneous variables under consideration. Strikingly, considering credit on a disaggregated level (OSR 3 given by equation 5.57) results in a strong increase in the parameter on commercial bank credit compared to simpler rules, as the sizeable negative coefficient on the shadow bank credit-to-GDP gap counteracts the effect of changes in commercial bank credit.

The last four columns of table 5.4 report constrained rules (CR) designed according to equations 5.55 to 5.58, but without optimized coefficients. Instead, the coefficients on the contemporaneous variables are fixed at the respective coefficient values derived for the fully optimal rule 5.49 reported in table 5.3. By incorporating additional contemporaneous variables (moving from CR 1 to CR 4) in the constrained rule, the relative welfare loss increases. Thus, even by incorporating more information in policy rules, welfare losses can increase if simple rule parameters are not separately optimized.

5.6.2 Simulation Analysis

As indicated in the previous section, the optimal dynamic policy response to exogenous disturbances particularly depends on movements in both shadow bank and commercial bank credit. In the following simulation exercise, I evaluate how the introduction of shadow banks alters the policy makers' ability to stabilize both the financial sector and real economic activity in response to exogenous macroeconomic shocks. Figures 5.4 and 5.5 show welfare-optimal dynamic responses to an unexpected tightening in monetary policy (aggregate demand shock) and to an exogenous improvement of firms' production technology (aggregate supply shock).[28] I simulate these responses under optimal policy for the cases with (blue lines) and without shadow banking (red dashed lines). Furthermore, I consider a scenario with shadow banks where capital requirements are not dynamically adjusted, but kept at the optimal steady-state level of 13.5 percent (black dotted lines).

The impulse responses allow for several observations. First, optimal dynamic macroprudential regulation is effective in stabilizing commercial bank credit, both in the presence and absence of shadow banks. However, even under optimal policy, the regulator is not able to completely neutralize credit leakage to shadow banks in response to macroeconomic shocks. As in chapter 4, unexpected monetary policy tightening induces a shift of credit intermediation towards shadow banks.[29] However, the quantitative effects of credit leakage are smaller compared to the response under the ad-hoc policy rules discussed in the previous chapter. Similarly, an unexpected positive technology shock increases entrepreneurs' production income and ultimately induces borrowing constraint 5.8 to be less binding. Lower credit constraints with respect to commercial bank credit in turn reduce entrepreneurs necessity to turn to shadow bank creditors, such that the share of credit intermediated by commercial banks increases.

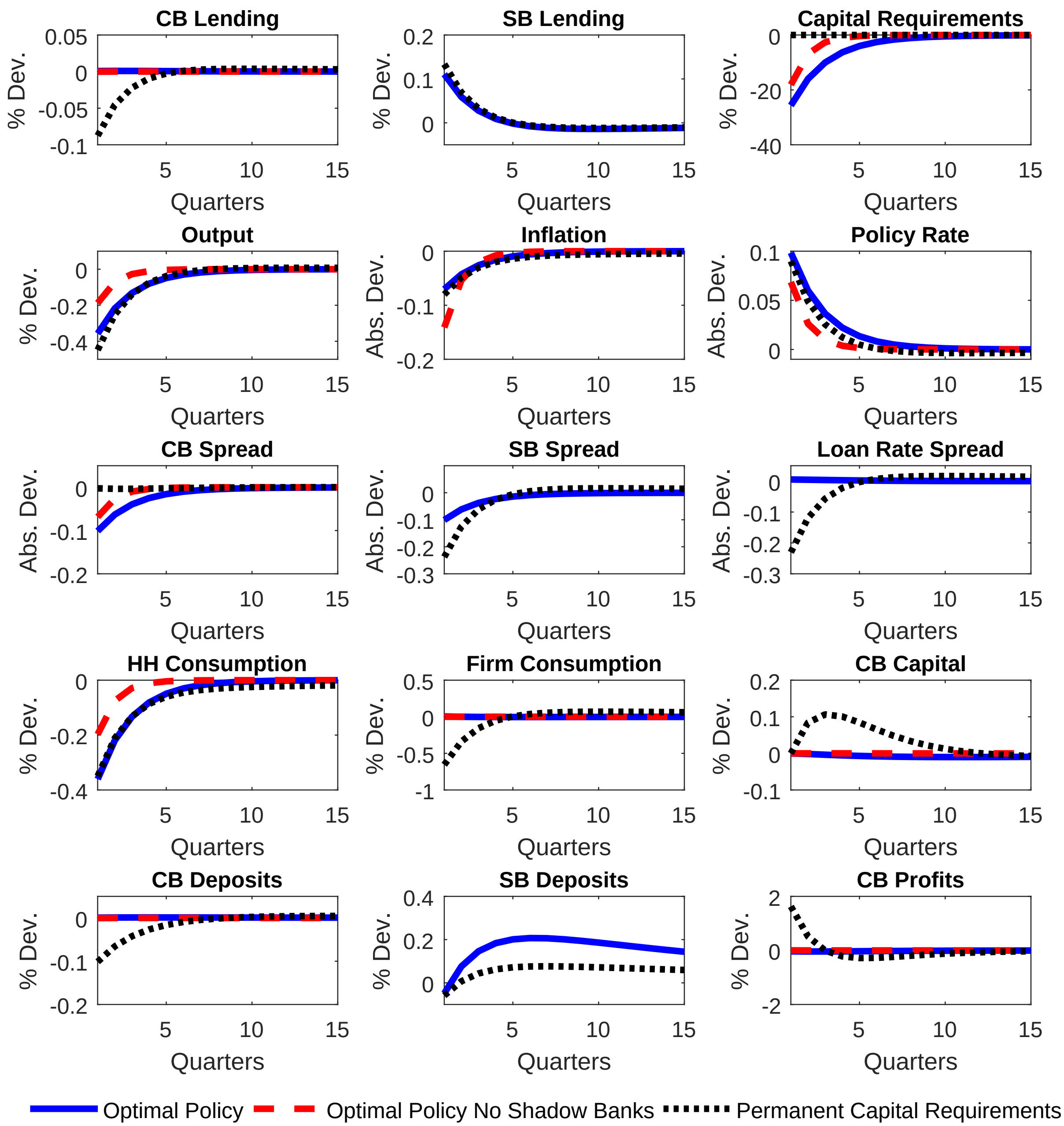
Second, capital requirements are adjusted countercyclically in response to macroeconomic shocks. In the case of an adverse demand shock (a monetary policy tightening), regulators lower capital requirements to stabilize commercial bank credit. Equally, an accommodative supply shock (positive technology shock) induces regulators to tighten commercial credit requirements to stabilize credit.

Third, and in line with policy rule 5.49, disturbances resulting in credit leakage, i.e. in *inverse* responses of commercial and shadow bank credit, induce regulators to adjust

[28]In appendix section B.2, I provide the same set of optimal impulse responses for an estimated version of the model for comparison.

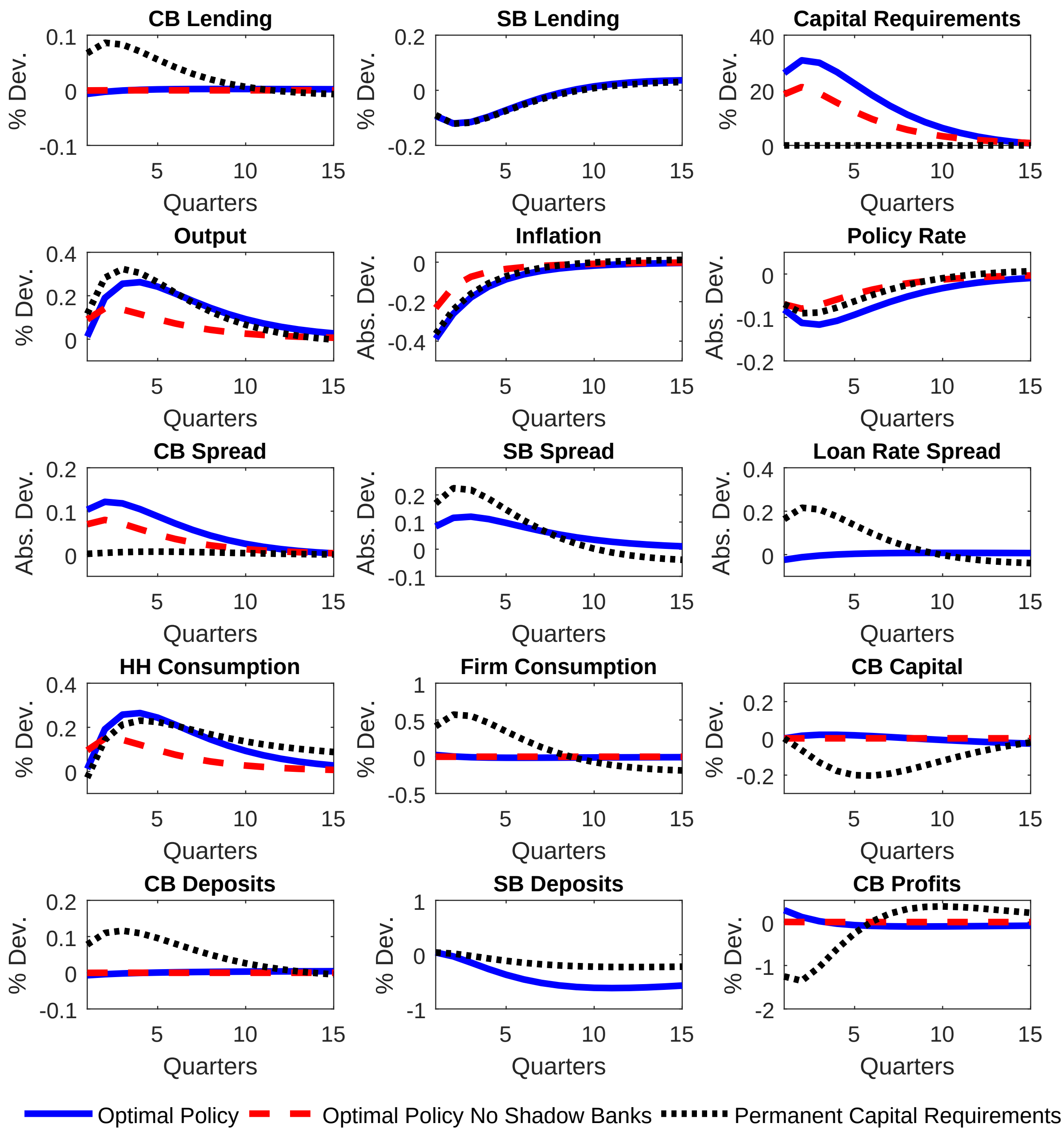
[29]Several studies found empirical evidence for credit leakage towards non-bank institutions in response to monetary policy shocks. See chapter 4.4.2.

Figure 5.4: Impulse Response Functions Monetary Policy Shock: With and Without Shadow Banks



Note: Impulse responses to a one-standard-deviation monetary policy shock with welfare-optimal response by macroprudential regulator. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

Figure 5.5: Impulse Response Functions Technology Shock: With and Without Shadow Banks



Note: Impulse responses to a one-standard-deviation technology shock with welfare-optimal response by macroprudential regulator. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

capital requirements more aggressively in the presence of shadow banking. In response to an unexpected monetary policy tightening, the regulator immediately decreases capital requirements by approximately 25 percent – which implies a decrease from 13.5 percent in the optimal steady state to 10.1 percent – whenever shadow banks are present. In the scenario with commercial banks only, capital requirements decrease by only 18 percent – from 13.5 to 11.1 percent – on impact.

Consequently, implications of shadow banking for cyclical macroprudential policy crucially depend on the direction in which commercial and shadow bank credit move in response to disturbances. As discussed in the previous section, macroeconomic disturbances leading to the *same* direction of commercial and shadow bank credit responses provide a motive for mitigating the regulatory response to commercial bank credit.[30] In contrast, the presence of credit leakage leading to inverse credit responses provides a rationale for a stronger policy response.

Fourth, the results for both monetary policy and technology shocks indicate that optimal capital regulation – while suited to stabilize commercial bank credit intermediation – fails to stabilize output efficiently in response to macroeconomic shocks. Even more, the additional policy trade-off between bank market power and shadow bank risk mitigates the ability of regulators to stabilize output in the presence of shadow banks, compared to the case where they can fully reach a homogeneous financial sector with their policies. In both scenarios, the direct link between macroprudential regulation and commercial bank credit allows regulators to stabilize commercial bank activity efficiently, while shadow bank intermediation and real economic activity are only partly stabilized. Therefore, while capital requirements might be suited to directly target volatility in commercial bank intermediation, additional policies targeting business cycle fluctuations or non-bank finance more directly are likely to increase economic and financial stability and to provide even further welfare improvements.

Fifth, regulators are particularly efficient in stabilizing commercial bank credit under dynamic optimal policy. Under the fixed-requirement scenario (black dotted line), an unexpected increase in the policy rate leads to a rise in deposit and commercial bank loan rates. In turn, higher commercial bank credit costs reduce lending by commercial banks (figure 5.4). Shadow bank lending increases slightly more compared to the optimal policy scenario, as the spread between shadow bank and commercial bank loan rates

[30] The finding is also in line with results from the counterfactual simulation in section 4.4.3. However, while the ad-hoc rules employed there do consider movements in *overall* credit, they do not feature the credit leakage motive of optimal policy. Still, as shown in figure 4.8, regulators concerned with overall credit would have tightened requirements less strongly in the years preceding the financial crisis – a period of growth in both commercial and shadow bank credit (figure 1.1) – compared to regulators that would have only considered commercial bank credit.

decreases. Furthermore, the drop in output and inflation is stronger under fixed capital requirements, even though the difference in the responses is relatively small in both scenarios. Welfare-optimal adjustments of capital requirements therefore provide only limited additional stabilization of business cycles, confirming the above findings. Again, the adjustment of capital requirements has a particular impact on commercial bank activities, as these institutions are directly affected.

Similarly, the unexpected productivity shock depicted in figure 5.5 results in an increase in commercial bank lending whenever capital requirements are fixed, while commercial bank credit is almost completely stabilized under the welfare-optimal policy. Again, an increase in capital requirements by 26 percent – from 13.5 to 17 percent – only mildly affects business cycle dynamics but has substantial impact on commercial banks' activity.

5.7 Conclusion

In this chapter, I study optimal macroprudential regulation for commercial banks in the presence of unregulated shadow banks. I analytically derive welfare-optimal policies under commitment in a New Keynesian DSGE model featuring both intermediaries. As in chapter 4, these intermediaries are based on different microfoundations. I compare my findings to a scenario where the financial sector only consists of regulated commercial banks.

The derived period loss functions resemble ad-hoc welfare criteria usually employed in the "revealed preferences" approach towards optimal macroprudential policy. However, in addition to output- and credit-related terms, they also include a stabilization criterion with respect to nominal short-term interest rates. Thus, even without any a-priori assumption on policy coordination, the results indicate potential welfare gains from cooperation between monetary and macroprudential authorities. Furthermore, introducing shadow banks substantially increases the relative importance of overall credit stabilization.

Due to commercial bank market power and shadow bank riskiness, steady-state lending volumes by both intermediaries permanently deviate from efficient levels: While commercial bank lending is below the optimal level, shadow bank intermediation is higher in the distorted steady state. Although bank capital regulation alone cannot mitigate inefficiencies in both credit markets, I show that a combination of static capital requirements and LTV ratios can resolve both steady-state distortions simultaneously. The welfare-optimal level of permanent capital requirements is 13.5 percent in the model including shadow banks, compared to 16 percent in a model where commercial banks are the only lenders. Raising capital requirements induces a shift of intermediation towards risky shadow banks, as the relative cost of commercial bank credit increases with tighter capital regulation. Thus, by neglecting credit leakage to shadow banks, the costs from tightening regulation are not fully internalized by regulators.

Finally, shadow bank presence affects the optimal dynamic response of macroprudential regulation to fluctuations in output and credit. Whenever macroeconomic disturbances imply credit leakage towards shadow banks, regulatory adjustments are more pronounced as in a model without shadow banks. For instance, after an unexpected increase in the policy rate by annualized 40 basis points, capital requirements decrease from 13.5 percent, the efficient steady-state level, to 10.1 percent in the presence of shadow banking. In the scenario without shadow banks, capital requirements decrease to only 11.1 percent.

My findings indicate that neglecting shadow banks potentially impairs the efficiency of macroprudential policies, as regulators do not internalize credit leakage and the trade-off related to the *composition* of credit. Thus, they should consider developments in the shadow banking sector, even if their policies only apply to traditional banks. Furthermore, the lack of macroprudential tools for shadow banks raises potential gains from coordinating different macroprudential measures. In addition, coordination with monetary policy can play a role, as shadow banks' activity is also related to the overall price of credit in the economy. Thus, nominal interest rate levels matter, and credit leakage may be aggravated when the effective lower bound (ELB) on nominal interest rates is reached.

However, my findings are prone to a few caveats I plan to address in future research. First, in deriving optimal policy, I relied on the linearized model instead of the full non-linear solution, and assumed that borrowing constraints are always binding. However, the quantitative effects of the credit leakage mechanism might be different whenever borrowing constraints do not always bind. Furthermore, as shown by Lindé and Trabandt (2018) for fiscal multipliers at the ELB constraint, quantitative policy effects can differ under the linearized and fully non-linear model when non-linear constraints exist. Similarly, the quantitative results on capital regulation derived in this chapter might be affected by the model choice once these constraints are only binding under certain circumstances. Second, allowing for non-linear constraints would also enable an adequate discussion of policy coordination in the presence of credit leakage between commercial and shadow banks when monetary policy is constrained at the ELB. I leave a deeper investigation of this link and implications for macroprudential policy for future research.

6 The Economic Effects of a European Deposit (Re-)Insurance Scheme

While the first two pillars of the European Banking Union have been implemented, a European deposit insurance scheme (EDIS) is still not in place. To facilitate its introduction, recent proposals argue in favor of a reinsurance scheme. In this chapter, we use a regime-switching open-economy DSGE model with bank default and bank-government linkages to assess the relative efficiency of such a scheme. We find that reinsurance by both a national fiscal backstop and EDIS is efficient in stabilizing the macro economy, even though welfare gains are slightly larger with EDIS and debt-to-GDP ratios rise under fiscal reinsurance. We demonstrate that risk-weighted contributions to EDIS are welfare-beneficial for depositors and discuss trade-offs policy makers face during the implementation of EDIS. In a counterfactual exercise, we find that EDIS would have stabilized economic activity in Germany and the rest of the euro area just as well as a fiscal backing of insured deposits during the financial crisis. However, debt-to-GDP ratios would have been lower with EDIS.

6.1 Introduction

While the first two pillars of the European Banking Union have been implemented, a European deposit insurance scheme (EDIS) is still not in place. To facilitate its introduction, recent proposals argue in favor of a reinsurance scheme, where European deposit insurance is used only if national deposit insurance is depleted. In this chapter, we assess the performance of such a deposit reinsurance scheme in the absorption of macroeconomic and financial shocks. To this end, we develop a two-country dynamic stochastic general equilibrium (DSGE) model and introduce bank default following Mendicino et al. (2018). Our framework features national deposit insurance (DI) schemes, as well as trade and financial linkages, allowing for heterogeneity between countries. We calibrate the model such that empirical moments in macroeconomic and financial time series for Germany (home) and the euro area excluding Germany (foreign) are matched. We then introduce EDIS as a risk-sharing device and study potential gains and losses with respect to welfare, macroeconomic and financial stability.[1]

This chapter is joint work with Marius Clemens and Tobias König.

[1]Our reinsurance scheme where EDIS would depict a second line of defense after national capacities have been exhausted also resembles closely to the proposals by a group of German and French economists (Bénassy-Quéré et al., 2018) and by the European Parliament (De Lange, 2016).

Our model incorporates three key elements that are important to take bank risk-taking into account and for adequately analyzing the performance of EDIS. First, home and foreign banks can default on their obligations and leave depositors and equity investors with losses. By allowing for bank default, we are able to study the costs and benefits of EDIS. Second, in each country exists a national deposit insurance which collects payments from national banks. However, in times of severe financial distress, the national deposit insurance can be limited and either national governments or EDIS have to step in to insure bank deposits. Thus, we incorporate regime switches in the model. Third, we introduce two linkages between banks and governments: Banks finance sovereign debt and the fiscal authority provides tax- and debt-financed guarantees in case of bank insolvencies.

We use our model to analyze the macroeconomic effects of a European deposit reinsurance mechanism in a situation where national deposit insurances are insufficient. We evaluate different forms of reinsurance: no reinsurance, a national fiscal backstop, and EDIS. In response to adverse bank default risk shocks in the home country, we find that both the national fiscal backstop and EDIS perform equally well in providing reinsurance, with the latter being more effective in stabilizing overall consumption. In the home economy, the drop in consumption is 20 percent lower from peak to trough with EDIS.

Under the fiscal backstop, insurance transfers directly affect the home country's public finances. While the country's debt-to-GDP ratio remains fairly stable with EDIS, it rises by almost two percent under the fiscal reinsurance. With EDIS, such an increase in government debt is avoided. However, as banks have to contribute both into the national DI and EDIS, the total burden for home banks is higher with EDIS. Even so, as contributions into EDIS are deductible from national DI payments, the national fund recovery takes longest with EDIS. Financial distress is transmitted to the foreign economy via international trade and financial markets, and foreign banks are also required to contribute more to cover default losses in the home economy with EDIS. This reduces margins for foreign banks, with resulting adverse effects for foreign lending and real economic activity.

With respect to welfare, we find that EDIS is particularly beneficial for savers in a country where national insurance funds are exhausted. Consequently, welfare gains from EDIS are largest in a scenario where national funds in both economies are insufficient to cover losses from bank default. In addition, we study the welfare implications related to two key points raised in recent proposals: the weighting of contributions and short-term implementation costs. With respect to the optimal design of contribution weights, we show that on the union-wide level, household welfare increases in the share of contributions of risky banks, justifying a risk-based contributions scheme if the ultimate objective of EDIS is depositor welfare.

With respect to short-term implementation costs, we assume that the fund is only activated once its target level has been reached. We show that diverting funds towards EDIS can temporarily lower national DIs' capacities if deductibility of EDIS contributions lowers bank payments into national systems. However, while removing deductibility can increase national DIs' capacities, an overburdening of banks through double contributions potentially limits intermediation capacities, with respective adverse effects for financial stability and the real economy. Extending the implementation horizon mitigates peak default rates in the short run, but as national DIs' capacities are lower for longer and contributions are more stretched out, the economic contraction is protracted.

Finally, we assess how EDIS would have performed in Germany and the rest of the euro area during the financial crisis in a counterfactual exercise. We compare EDIS with a benchmark policy, where we assume that national governments would have backed national deposit insurance schemes once their funds would have been exhausted. We find that the stabilization effects of EDIS for GDP and consumption would have been rather small, but debt-to-GDP ratios would have been lower with EDIS. The benefits of EDIS increase substantially once we assume that increases in sovereign bond yields are associated with declines in the value of government bond holdings by banks.

In section 6.2, we introduce our baseline DSGE model. We then describe the data and calibration procedure in section 6.3, and introduce regime switching and different forms of reinsurance in section 6.4. We report results of our theoretical and empirical analyses in section 6.5, and section 6.6 concludes.

6.2 An Open-Economy DSGE Model

In this study, we rely on an open-economy model in the spirit of the euro area banking models developed in Gerali et al. (2010) and Mendicino et al. (2018). In order to analyze risk-sharing via banking and fiscal policies, we extend the model by introducing a government sector and a detailed deposit insurance scheme on both the domestic and on a union-wide level. In the model, patient households in one country provide funds to impatient entrepreneurs in the same country.[2] Funds are intermediated by regulated banks which can also invest in domestic government bonds. Regulatory capital requirements are enforced by national regulators. Due to additional regulation on the loan market, entrepreneurs have to fulfill an externally set loan-to-value (LTV) ratio when demanding funds from banks. They can only borrow up to a certain amount of their collateral value at hand, which is given by the stock of physical capital that they own. They furthermore use their collateral capital for the production of consumption goods in the model.

[2]As in chapters 4 and 5, different values in the discount factors determine the borrower-lender relationship between entrepreneurs and households.

In line with Mendicino et al. (2018), we assume limited liability of banks. In response to idiosyncratic return shocks, banks can decide not to pay back their obligations and to default. Individual uninsured bank debt is priced to the expected aggregate bank default risk. Depositors face monitoring costs (state verification costs) when recovering defaulting banks' assets. This gives rise to containing systemic risk in the banking sector through regulation and deposit insurance.

6.2.1 Households

The representative patient household i in each country $c \in \{h, f\}$ maximizes expected utility

$$\max_{c_t^{P,c}(i),\, l_t^c(i),\, d_t^c(i)} E_0 \sum_{t=0}^{\infty} (\beta_P^c)^t \left[z_t^{c,c} \log[c_t^{P,c}(i) - a_P^c c_{t-1}^{P,c}(i)] - \frac{\varphi_P^c}{1+\phi_P^c} l_t^c(i)^{1+\phi_P^c} \right] \tag{6.1}$$

subject to the budget constraint

$$c_t^{P,c}(i) + d_t^c(i) \leq w_t^c l_t^c(i) + \tilde{R}_{t-1}^{d,c} d_{t-1}^c(i) + \Pi_t^{cp,c} + \Pi_t^{bank,c} - \tau_t^c \tag{6.2}$$

where $c_t^{P,c}(i)$ depicts current consumption prone to habit formation governed by a_P^c, and $z_t^{c,c}$ depicts a consumption preference shock described by an AR(1) process. Working hours are given by l_t^c and labor disutility is parameterized by ϕ_P^c. The flow of expenses includes current consumption, and real deposits to be made to domestic banks $d_t^c(i)$. Resources consist of wage earnings $w_t^c l_t^c(i)$ (where w_t^c is the real wage paid in the country the respective household resides) and gross interest income on last period's deposits placed in domestic banks, $\tilde{R}_t^{d,c}$. The fiscal authority charges lump-sum taxes τ_t^c to finance government consumption. Households receive profits $\Pi_t^{bank,c}$ transferred from exiting bankers and $\Pi_t^{cp,c}$ transferred from capital producers.

Following Mendicino et al. (2018), bank deposits are partially insured by a fraction κ_t^c. Insured bank deposits are always remunerated with the promised rate $R_t^{d,c}$. Uninsured deposits yield the promised rate $R_t^{d,c}$ if the bank is solvent and a fraction $(1 - \kappa_t^c)$ of the net recovery value of bank assets in case of default. Household return on bank deposits is thus given by:

$$\tilde{R}_t^{d,c} = R_t^{d,c} - (1 - \kappa_t^c) \frac{\Omega_{t+1}^c}{d_t^c(i)} \tag{6.3}$$

where $\frac{\Omega^c_{t+1}}{d^c_t(i)}$ is the average default loss per unit of deposits. The share of insured deposits, κ^c_t is time-varying and depends on available funds in the deposit insurance scheme. The scheme is financed by a tax imposed on the banking sector which is described in detail below.

6.2.2 Entrepreneurs

Entrepreneurs engaged in country c use the respective labor type provided by households as well as capital to produce intermediate goods purchased by retailers in a competitive market. Each entrepreneur i derives utility from consumption $c^{E,c}_t(i)$ and maximizes expected utility

$$\max_{c^{E,c}_t(i), l^{P,c}_t(i), k^{E,c}_t(i)} E_0 \sum_{t=0}^{\infty} (\beta^c_E)^t \log c^{E,c}_t(i) \tag{6.4}$$

subject to the budget constraint

$$c^{E,c}_t(i) + w^c_t l^c_t(i) + q^{k,c}_t k^{E,c}_t(i) + R^{E,c}_t b^{E,c}_{t-1}(i) \leq p^{E,c}_t y^{E,c}_t(i) + b^{E,c}_t(i) + q^{k,c}_t (1-\delta^c) k^{E,c}_{t-1}(i) \tag{6.5}$$

with $p^{E,c}_t = \frac{P^{E,c}_t}{P^c_t}$ denoting the price ratio of producer price level to consumer price level. Entrepreneurs in country c furthermore face borrowing constraints with respect to domestic bank lending, depending on the stock of capital they hold as collateral. Regulatory LTV ratios apply for funds borrowed in each country, and regulation is determined on the national level. The borrowing constraint is given by

$$R^{E,c}_{t+1} b^{E,c}_t(i) \leq m^c_E E_t \{ q^{k,c}_{t+1} (1-\delta^c) k^{E,c}_t(i) \} \tag{6.6}$$

where the LTV ratio for commercial banks m^c_E is set by a prudential regulator. Rearranging equation 6.6, one can derive the contractual return on one unit of corporate loans:

$$R^{E,c}_{t+1} = \frac{m^c_E E_t \{ q^{k,c}_{t+1} (1-\delta^c) k^{E,c}_t(i) \}}{b^{E,c}_t(i)}. \tag{6.7}$$

We follow Iacoviello (2005) and assume that the borrowing constraint binds around the steady state such that uncertainty is absent in the model. Thus, in equilibrium, equation 6.6 holds with equality. The production function is given by

$$y^{E,c}_t = a^{E,c}_t (k^{E,c}_t)^{(\alpha^c)} (l^c_t)^{(1-\alpha^c)}. \tag{6.8}$$

We can furthermore derive an expression for the law of motion of firms' net worth along the lines of Gambacorta and Signoretti (2014):[3]

$$NW_{t+1}^{c} = \alpha^{c}\frac{p_{t+1}^{E,c}y_{t+1}^{E,c}}{k_{t}^{E,c}} + q_{t+1}^{k,c}(1-\delta^{c})k_{t}^{E,c} - R_{t+1}^{E,c}b_{t}^{E,c}. \tag{6.9}$$

Entrepreneur consumption $c_t^{E,c}$ depends on firm net worth:

$$c_{t}^{E,c} = (1-\beta_{E}^{c})NW_{t}^{c}, \tag{6.10}$$

and entrepreneur's capital stock in each country depends on firms' net worth, the capital price and the entrepreneur's leverage in that country:

$$k_{t}^{E,c} = \frac{\beta_{E}^{c}NW_{t}^{c}}{q_{t}^{k,c} - \chi_{t}^{c}} \tag{6.11}$$

with $\chi_t^c = \frac{m_E^c q_{t+1}^{k,c}(1-\delta^c)}{R_{t+1}^{E,c}}$.

6.2.3 Bankers

Bankers in country c act as international investors. In each period, they invest equity $n_t^{c,c}$ into domestic banks, and $n_t^{c,\neg c}$ in foreign banks, where $\neg c$ denotes the opposite country to country c. In addition, bankers pay dividends div_t^c back to their belonging households. Both equity investment and dividends are financed by bankers' net worth $n_t^{b,c}$. Following Gertler and Kiyotaki (2011) we guess and verify that the value function is linear in net worth, $V_t^{b,c} = \nu_t^c n_t^{b,c}$ where ν_t^c is the shadow value of bankers net worth. The maximization of bankers' wealth can then be written as

$$n_{t}^{b,c}\nu_{t}^{c} = \max_{e_{t}^{aggr,c},div_{t}^{c}} \left\{ div_{t}^{c} + E_{t}\{\Lambda_{t+1}^{c}[(1-\theta_{b}^{c}) + \theta_{b}^{c}\nu_{t+1}^{c}]n_{t+1}^{b,c}\} \right\} \tag{6.12}$$

$$s.t. \begin{cases} e_{t}^{aggr,c} + div_{t}^{c} = n_{t}^{b,c} \\ e_{t}^{aggr,c} = n_{t}^{c,c} + n_{t}^{c,\neg c} \\ n_{t+1}^{b,c} = \rho_{t+1}^{c}n_{t}^{c,c} + \rho_{t+1}^{\neg c}n_{t}^{c,\neg c} \\ div_{t}^{c} \geq 0. \end{cases}$$

[3]See appendix section C.1.2 for the derivations of entrepreneurs' net worth, consumption, and capital.

The term $\Lambda^c_{t+1}[(1-\theta^c_b)+\theta^c_b\nu^c_{t+1}] = \Lambda^{b,c}_{t+1}$ describes the discount factor of bankers. Each period a fraction $(1-\theta^c_b)$ of bankers retires and transfers the net present value of net worth back to the owning households. Households provide a share of start-up equity χ_b to newly entering bankers, and the total amount of bankers stays constant over time. The law of motion for bankers' net worth is thus given by:

$$n^{b,c}_{t+1} = [\theta^c_b + \chi_b(1-\theta^c_b)](n^{c,c}_t \rho^c_{t+1} + n^{c,\neg c}_t \rho^{\neg c}_{t+1}) \tag{6.13}$$

where ρ^c_{t+1} is the return of equity invested in banks in the same country c and $\rho^{\neg c}_{t+1}$ is the return of equity invested in the other country's banks. In equilibrium it is not optimal to transfer dividends prior to retirement. Therefore, all net worth is invested in either domestic or foreign banks. The shadow value of bankers can then be determined as

$$\nu^c_t = E_t\{\Lambda^{b,c}_{t+1}[\zeta^{n,c}_t \rho^c_{t+1} + (1-\zeta^{n,c}_t)\rho^{\neg c}_{t+1}]\} \tag{6.14}$$

with $\zeta^{n,c}_t = \frac{n^{c,c}_t}{n^{b,c}_t}$ denoting the fraction of bankers' equity invested in domestic banks.

6.2.4 Corporate Banks

Home and foreign banks provide domestic corporate loans and invest in domestic government bonds. They acquire inside equity via home and foreign bankers, and by issuing deposits. The corporate banking sector features bank default, as the return on assets is prone to idiosyncratic risk ω^c_{t+1}, following a log-normal distribution.[4] Consequently, banks can default on their debts, and saving households face state-verification costs when recovering their deposits. The contracting problem between households and banks is based on the mechanism introduced by Bernanke et al. (1999). Corporate banks receive $e^c_t = n^{c,c}_t + RER_t n^{\neg c,c}_t = \zeta^c_e e^c_t + (1-\zeta^c_e)e^c_t$ units of equity from domestic and foreign investors. We denote the equity home bias on banks' balance sheets as ζ^c_e and RER_t depicts the real effective exchange rate. Banks maximize their net present value by deciding on the profit-maximizing amount of assets a^c_t and deposits d^c_t subject to a balance sheet constraint and a regulatory constraint governed by the capital requirement ϕ^c_t. Furthermore, each bank pays a contribution $\tau^{DI,c}_t$ to the national deposit insurance scheme, relative to the amount of its outstanding deposits:

$$\max_{d^c_t, a^c_t} \int_0^\infty \Lambda^{tot,c}_{t+1} \max\{\omega^c_{t+1} R^{a,c}_{t+1} a^c_t - R^{d,c}_t d^c_t - \tau^{DI,c}_t, 0\} \mathrm{d}F^c(\omega^c_{t+1}) - \zeta^c_e \nu^c_t e^c_t - (1-\zeta^c_e)\nu^{\neg c}_t e^c_t \tag{6.15}$$

[4] See appendix section C.1.4 for the shock's definition.

$$s.t. \begin{cases} a_t^c = d_t^c + e_t^c, \\ e_t^c \geq \phi_t^c a_t^c, \\ a_t^c = b_t^{E,c} + q_{t+1}^{k,c} b_t^{g,c}. \end{cases}$$

Total assets a_t^c earn the average return $R_{t+1}^{a,c}$ and consist of entrepreneur loans $b_t^{E,c}$ and nominal government bonds $q_{t+1}^k b_t^{g,c}$:

$$R_{t+1}^{a,c} = R_{t+1}^{E,c} \frac{b_t^{E,c}}{a_t^c} + R_{t+1}^{gov,c} \frac{q_{t+1}^{k,c} b_t^{g,c}}{a_t^c}.$$

Banks discount their expected net present value with the discount factor $\Lambda_{t+1}^{tot,c} = \zeta_e^c \Lambda_{t+1}^{b,c} + (1-\zeta_e^c)\Lambda_{t+1}^{b,\neg c}$, that is by weighting home and domestic bankers discount factor with the corresponding amount of equities. The equity investments $\zeta_e^c e_t^c$ and $(1-\zeta_e^c)e_t^c$ are valued at equilibrium opportunity costs ν_t^c and $\nu_t^{\neg c}$.

The bank is only willing to distribute funds as long as its net present value is positive. As shown in section C.1.4, the bank participation constraint in equilibrium is given by

$$E_t \left\{ \Lambda_{t+1}^{tot,c} [1 - \Gamma_c(\overline{\omega}_{t+1}^c)] \frac{R_{t+1}^{a,c}}{\phi_t^c} \right\} \geq \zeta_e^c \nu_t^c + (1-\zeta_e^c)\nu_t^{\neg c} \tag{6.16}$$

where $\overline{\omega}_{t+1}^c$ depicts the threshold of bank default

$$\overline{\omega}_{t+1}^c = \frac{R_t^{d,c} d_t^c}{R_{t+1}^{a,c} a_t^c} + \frac{\tau_t^{DI,c}}{R_{t+1}^{a,c} a_t^c} = (1-\phi_t^c)\left(\frac{R_t^{d,c}}{R_{t+1}^{a,c}} + \frac{\tau_t^{DI,c}}{R_{t+1}^{a,c} d_t^c} \right). \tag{6.17}$$

In equilibrium, condition 6.16 holds with equality to avoid an infinite supply of loans. By definition, the return on bank equity is given by $\rho_{t+1}^c = [1 - \Gamma_c(\overline{\omega}_{t+1}^c)] \frac{R_{t+1}^{a,c}}{\phi_t^c}$. Consequently, the opportunity cost of equity funding is pinned down in equilibrium by the following conditions:

$$E_t\{\Lambda_{t+1}^{tot,h} \rho_{t+1}^h\} = \zeta_e^h \nu_t^h + (1-\zeta_e^h)\nu_t^f \tag{6.18}$$

$$E_t\{\Lambda_{t+1}^{tot,f} \rho_{t+1}^f\} = \zeta_e^f \nu_t^f + (1-\zeta_e^f)\nu_t^h, \tag{6.19}$$

which describe the no-arbitrage conditions for international bankers.

6.2.5 National Government

Each national government can issue real debt $q_{t+1}^{k,c} b_t^{g,c}$ bought by banks across the union,

$$b_t^{g,c} = q_t^{k,c} R_t^{gov,c} b_{t-1}^{g,c} + g_t^c - \tau_t^c, \tag{6.20}$$

where g_t^c is government consumption and τ_t^c denotes the total (lump-sum) income tax paid by private households. Government consumption is often not directly affected by the business cycle, but rather by structural needs of the economy. Therefore, we assume an AR(1) process for government consumption:

$$g_t^c = (1-\rho_g^c)g^c + \rho_g^c g_{t-1}^c + \epsilon_t^g \tag{6.21}$$

Stabilization policy is conducted via a countercyclical income tax rule

$$\frac{\tau_t^c}{\tau^c} = \left(\frac{\tau_{t-1}^c}{\tau^c}\right)^{\rho_{tax}^c} \left[\left(\frac{y_t^c}{y^c}\right)^{\phi_y^c} \left(\frac{b_{t-1}^{g,c} q_t^{k,c}}{b^{g,c}}\right)^{\phi_d^c}\right]^{1-\rho_{tax}^c} \tag{6.22}$$

where $\phi_y^c \leq 0$ and $\phi_d^c \leq 0$ are the weighting parameters for the two target variables and ρ_{tax}^c is a smoothing parameter. The government reduces the lump-sum tax compared to steady state if actual production or real debt levels are below their steady-state values, y^c and $b^{g,c}$. After inserting the expenditure and the tax rules into the budget constraint, we can derive the following debt rule:

$$b_t^{g,c} = q_t^{k,c} R_t^{gov,c} b_{t-1}^{g,c} + g_t^c - \tau^c \left(\frac{\tau_{t-1}^c}{\tau^c}\right)^{\rho_{tax}^c} \left[\left(\frac{y_t^c}{y^c}\right)^{\phi_y^c} \left(\frac{b_{t-1}^{g,c}}{b^{g,c}}\right)^{\phi_d^c}\right]^{1-\rho_{tax}^c}. \tag{6.23}$$

New debt can be issued during a recession ($y_t^c < y^c$) or if actual debt is below its structural component ($b_t^{g,c} < b^{g,c}$). Governments have to pay an additional risk premium to banks if government debt is above its steady state. The return on government debt is thus described by a premium on the risk-free deposit rate increasing in debt levels:

$$R_{t+1}^{gov,c} = \tilde{R}_t^{d,c} + \Phi_{debt}^c [b_t^{g,c} - b^{g,c}]^2. \tag{6.24}$$

6.2.6 National Deposit Insurance Fund

The national DI guarantees some fraction κ_t^c of deposits by building up a fund that compensates depositors in case of bank default. The deposit insurance fund balance is given by

$$DI_{t+1}^c = DI_t^c + \tau_t^{DI,c} - \kappa_t^c \Omega_{t+1}^c \tag{6.25}$$

where a share κ_t^c of the total default costs Ω_{t+1}^c is insured by the national DI in each country. Banks pay a contribution $\tau_t^{DI,c}$ to the fund, and the fund capital target is set relative to total outstanding insured deposits in steady state:

$$DI^{target,c} = \gamma_{DI}^c \kappa^c d^c. \tag{6.26}$$

The costs of deposit default in each country are defined as the difference between forgone return on deposits, $R^{d,c}_{t-1} d^c_{t-1}$, and the share $(1-\mu^c)$ of gross assets $\omega^c_t R^{a,c}_t a^c_{t-1}$ that can be recovered:

$$\Omega^c_t = \int_0^{\overline{\omega}^c_t} \{R^{d,c}_{t-1} d^c_{t-1} - (1-\mu^c)\omega^c_t R^{a,c}_t a^c_{t-1} + \tau^c_{t-1}\} f(\omega^c) d\omega^c_t.$$

Rearranging yields

$$\Omega^c_t = [\overline{\omega}^c_t - \Gamma_c(\overline{\omega}^c_t) + \mu^c G^c(\overline{\omega}^c_t)] \frac{R^{a,c}_t}{1-\phi^c_{t-1}} d^c_{t-1}. \tag{6.27}$$

In each period, banks contribute the amount $\tau^{DI,c}_t$ to the fund. The contributions are inversely related to the fund level:

$$\tau^{DI,c}_t = \tau^{DI,c} + \chi^c_\tau [DI^{target,c} - E_t\{DI^c_{t+1}\}] \tag{6.28}$$

with χ^c_τ denoting the sensitivity to the domestic fund level. Furthermore, whenever national fund capital is below target, the share of covered deposits is reduced:

$$\kappa^c_t = \kappa^c - \chi^c_\kappa [DI^{target,c} - DI^c_{t+1}], \tag{6.29}$$

with $\chi^c_\kappa = \frac{\kappa^c}{DI^{target,c}}$.

6.2.7 Goods Market Clearing and Trade

Capital producing firms and the trade sector are described in detail in appendices C.1.6 and C.1.7. Here we shortly summarize essential market clearing conditions. In both regions, the goods market clearing condition holds in equilibrium:

$$y^{E,c}_t = Y^c_t = \zeta^c (p^{e,c}_t)^{-\eta^c} c^c_t + g^c_t + (1-\zeta^{\neg c}) \left(\frac{p^{e,\neg c}_t}{T_t}\right)^{-\eta^{\neg c}} c^{\neg c}_t \tag{6.30}$$

where $c^c_t = c^{P,c}_t + c^{E,c}_t + I^c_t$ denotes the aggregate demand for consumption and investment goods of domestic households and entrepreneurs and $c^{\neg c}_t$ denotes the aggregate demand of foreign households and entrepreneurs. Following Benigno (2004), the terms of trade are foreign producer prices relative to domestic producer prices: $T_t = \frac{P^{e,f}_t}{P^{e,h}_t}$. National government consumption g_t is assumed to be produced only by national firms. The clearing condition guarantees that the supply of domestically produced goods is equal to domestic and foreign demand.

The real exchange rate can be defined with the help of the terms of trade and the relative consumer prices in both countries:

$$RER_t = T_t \frac{p_t^{e,h}}{p_t^{e,f}}. \tag{6.31}$$

The trade balance – measured in domestic prices – is defined as the difference between real exports and real imports:

$$tb_t = ex_t^h + T_t im_t^h \tag{6.32}$$

with $ex_t^h = c_t^{P,fh} + c_t^{E,fh} + I_t^{fh}$ and $im_t^h = c_t^{P,hf} + c_t^{E,hf} + I_t^{hf}$.

6.3 Calibration

We rely on euro area data to validate the empirical fit of the model. To this end, we find a vector of structural parameter values for which the distance between first moments of empirical distributions and their counterparts generated by the model is minimized. We discuss the moment-matching methodology in more detail in the following sections.

6.3.1 Data

The empirical data moments are both collected from macroeconomic time series and micro-level data. Real macroeconomic variables for Germany and the euro area are drawn from the European System of Accounts (ESA 2010) quarterly financial and non-financial sectoral data, provided by the European Central Bank (ECB) and Eurostat, as well as from OECD data. The data set includes information on real GDP, real business investment, government consumption, total employment, exports and imports of goods and services, and the current account balance.[5] Banking statistics – corporate bank deposits held by private households, corporate bank loans granted to the non-financial domestic entrepreneur sector, bank holdings of domestic government bonds, the share of deposits covered by deposit insurance and return on bank equity – are in part obtained from the data set on "Monetary Financial Institutions" (MFIs) collected by the ECB, from the Bundesbank time series database and from the "Financial Soundness Database" of the IMF. Data on corporate bank interest rates on household deposits and firm loans are constructed from different sources within the ECB Statistical Data Warehouse and harmonized following Gerali et al. (2010). Bank default rates, price-to-book ratios and the home bias in bank equity are obtained by aggregating micro-level data series from Bloomberg, Thomson

[5] See appendix C.2 for a detailed description of the data set.

Reuters Eikon, and Datastream. For most time series, we employ data for 1999:Q1 to 2019:Q4.[6]

6.3.2 Methodology

The empirical validation of our model is provided by setting a subset of model parameters such that first moments in the data are matched by theoretical model moments. We split the subset of parameters to be estimated into two groups, depending on whether they affect the deterministic steady state (collected in Θ_{SS}) or not (collected in $\Theta_{\neg SS}$). The first subset of parameters can be calibrated by matching first moments in the data. We follow the approach by Mendicino et al. (2018) and minimize a loss function with equal weights on the distances between respective data moments and model moments.

Preset Parameters

Before initiating the matching process, we set the parameters not determined by moment matching to conventional values (table 6.1). They include parameters related to policy rules, the deposit insurance fund, or structural parameters on habit formation, the capital share in production, trade elasticity, and labor market characteristics. Furthermore, key parameters related to euro area-wide regulations are assumed to be identical in both countries. First, steady-state bank capital requirements, ϕ^c, are calibrated to 10.5 percent, the level implied by regulations under Basel III. Second, the steady-state LTV ratio for entrepreneur borrowing, m_E^c is assumed to be identical in both regions and set to 0.35, in line with Gerali et al. (2010).

Moment-Matched Parameters

Some parameters have a direct first moment counterpart. For these cases – the household discount factor, the home bias in bankers' equity holdings, the steady-state share of insured deposits and the steady-state government consumption-to-GDP ratio – we can immediately set the respective parameter value. We set $\kappa^{DI,c}$ in accordance with the JRC European Union Banking Sector Statistics. We calibrate the target level of deposit insurances $DI^{target,c}$ to 0.8 percent of outstanding insured deposits, as proposed by the European Commission (European Commission, 2015). The sensitivity of the coverage ratio is determined using empirical evidence on fund level and coverage ratio, $\chi_\kappa^c = \frac{\kappa^{DI,c}}{DI^{target,c}}$. The fund level together with the contribution sensitivity parameter determines the regime-switching threshold. For any given default rate above the threshold, $\Psi^c = 1.780$, the fund

[6] The only exceptions depict the share of deposits covered by deposit insurance, which we derive from the yearly estimates in the JRC European Union Banking Sector Statistics (2011 to 2015), bank default rates, which we calculate from CDS spreads of European banks that are available between 2004Q1 and 2019Q4, and domestic government bond holdings covered in the ECB Securities Holdings Statistics which are only available from 2013:Q4 onward. See appendix C.2.

Table 6.1: Calibrated Parameters

	Parameter	**Germany**	**Euro Area**
Inverse Frisch Elasticity of Labor Supply	ϕ_P^c	1	1
Labor Disutility	φ_P^c	1	1
Household Habit Parameter	a_P^c	0.8	0.8
Trade Elasticity	η^c	1.5	1.5
Home Bias in Traded Goods	ζ^c	0.6	0.6
Capital Share in Production Function	α^c	0.3	0.3
Bank Monitoring Costs	μ^c	0.3	0.3
Debt-Elastic Interest Rate Parameter	Φ_{debt}^c	0.1	0.1
Fiscal Rule, GDP Weight	ϕ_y^c	0.5	0.5
Fiscal Rule, Debt Weight	ϕ_d^c	1.5	1.5
Fiscal Rule, Tax smoothing	ρ_{tax}^c	0.4	0.4
DI Contribution Sensitivity Parameter	χ_τ^c	0.45	0.45
Bank Capital Requirement	ϕ^c	0.105	0.105
Loan-to-Value Ratio	m_E^c	0.35	0.35
EDIS Contribution Sensitivity Parameter	χ_τ^{EDIS}	0.45	0.45
Switching Function Scaling Parameter	α_1	100	100
Preference Shock AR Coefficient	ρ_c^c	0.75	0.75
Productivity Shock AR Coefficient	ρ_a^c	0.75	0.75
Bank Risk Shock AR Coefficient	ρ_b^c	0.75	0.75
Government Consumption Shock AR Coefficient	ρ_g^c	0.75	0.75

Note: Calibration of parameters not determined by moment matching. Policy parameters based on regulatory requirements in the euro area.

level will be close to zero. For the household discount factor, we assume market participants in both countries to have access to a global risk-free asset. We therefore calibrate the steady-state risk-free rates $R^{d,c}$ to the quarterly average of the long-term real rate on United States (US) treasuries. Thus, we end up with identical values for the patient households' discount factor $\beta_p^c = \frac{1}{R^{d,c}}$ in both economies.

For the remaining first moments, a direct mapping between the empirical values and the parameters of the model is not feasible. Instead, we set these parameters – the survival rate of bankers θ_b^c, bankers' endowment χ_b^c and the standard deviation for i.i.d. bank default risk σ_c – simultaneously to minimize the distance between the remaining model-implied moments and data moments. The firm-specific parameters – the capital depreciation rate δ^c, the adjustment cost parameter ψ_i^c, and the entrepreneur discount factor β_E^c – are set such that theoretical moments match data on investment-to-GDP ratios, firm loans-to-GDP ratios, and the spread between the corporate lending and the risk-free rate.

Table 6.2 summarizes the parameter values that minimize the distance between the empirical and theoretical first moments. For some parameter values, the differences between Germany and the rest of the euro area are significant. For instance, the home bias in bank equity, ζ_e^c, is larger in Germany than in the rest of the euro area. Since the banking sector in Germany relies to a larger degree on domestic equity, the home bias in equity provision amounts to approximately 80 percent.[7] Furthermore, bank default risk is larger in the rest of the euro area than in Germany, which is reflected in the higher standard deviation of i.i.d. bank risk σ^f. To provide information on the accuracy of the parameter estimates gathered via distance minimization, table 6.3 summarizes the distances between the time series mean values and the model-implied first moment values.

Table 6.2: Matched Parameters

	Parameter	**Germany**	**Euro Area**
Direct Match			
Discount Factor Households	β_P^c	0.996	0.996
Home Bias in Bank Equity	ζ_e^c	0.805	0.580
DI Fund Target Rate	γ_{DI}^c	0.008	0.008
Share of Insured Deposits	$\kappa^{DI,c}$	0.497	0.512
DI Coverage Ratio Sensitivity Parameter	χ_κ^c	41.058	30.861
EDIS Fund Target Rate	γ_{EDIS}^c	0.008	0.008
Share of Insured Deposits	$\kappa^{EDIS,c}$	0.497	0.512
EDIS Coverage Ratio Sensitivity Parameter	χ_κ^{EDIS}	17.310	17.850
Government Consumption/GDP	g^c	0.211	0.225
Regime-Switching Threshold	Ψ^c	1.780	1.780
Distance Minimization			
Bank Risk Standard Deviation	σ^c	0.041	0.043
Discount Factor Entrepreneurs	β_E^c	0.969	0.980
Household Transfer to Bankers	χ_b^c	0.969	0.710
Capital Depreciation Rate	δ^c	0.067	0.053
Banker Survival Rate	θ_b^c	0.250	0.927
Capital Adjustment Costs Parameter	ψ_i^c	5.709	5.398

Note: The table summarizes the parameter values found by first moments matching. The model parameters are set such that the distance between model-implied steady-state values and data moments is minimized.

6.4 Different Forms of Risk-Sharing

In the following, we evaluate how different risk-sharing policies perform in response to exogenous disturbances. In doing so, we study how different risk-sharing arrangements are able to absorb adverse macroeconomic effects in response to exogenous variations in bank default risk. These arrangements will resemble reinsurance frameworks, where either national governments, EDIS, or none of the two steps in once national deposit insurance schemes are exhausted.

[7] This can mainly be attributed to the high amount of state-owned "Landesbanken", as well as to the prominence of savings and cooperative banks in Germany.

Table 6.3: Targeted First Moments

	Moment	**Model**	**Data**
Germany			
Business Investment/GDP	$\frac{I^h}{Y^h}$	0.222	0.222
Bank Default Rate	$4 \times \psi^h$	1.255	1.065
Return on Equity	$400 \times (\rho^h - 1)$	10.710	6.386
Price-to-Book Ratio	ν^h	1.026	0.822
NFC Loans/GDP	$\frac{b_e^h}{Y^h}$	1.072	1.443
NFC Loan Rate Spread	$400 \times (R^{b,h} - \tilde{R}^{d,h})$	1.776	2.994
Euro Area			
Business Investment/GDP	$\frac{I^f}{Y^f}$	0.228	0.228
Bank Default Rate	$4 \times \psi_t^f$	1.918	1.398
Return on Equity	$400 \times (\rho^f - 1)$	8.154	4.548
Price-to-Book Ratio	ν^f	1.300	1.300
NFC Loans/GDP	$\frac{b_e^f}{Y^f}$	1.428	2.015
NFC Loan Rate Spread	$400 \times (R^{b,f} - \tilde{R}^{d,f})$	1.396	2.608
Total Distance			**2.837**

Note: The table summarizes the first moments matched via distance minimization during the calibration routine. The model parameters are set such that the distance between model-implied steady-state values and data moments is minimized.

6.4.1 Regime Switching: National Deposit Insurance

In the analysis, we allow for four states of the economy. In the baseline regime, both national deposit insurance schemes and fiscal policies operate as described in sections 6.2.5 and 6.2.6, and national deposit insurance is unconstrained (regime 1). In the other states of the economy, either one or both national deposit insurances are constrained as national insurance funds are exhausted and no insurance transfers can be provided anymore (table 6.4). The regime-switching rule is therefore given by

$$DI_t^c = \begin{cases} DI_t^{c'} & \text{if } \psi_t^c < \Psi^c \\ 0 & \text{if } \psi_t^c > \Psi^c \end{cases} \tag{6.33}$$

where

$$DI^{c'}_{t+1} = DI^{c'}_t + \tau_t^{DI,c} - \kappa_t^c \Omega_{t+1}^c \tag{6.34}$$

following equation 6.25. The transition probabilities between regimes underlying equation 6.33 and the regime-switching threshold values Ψ^c are discussed below. We therefore constrain national DI fund capital to be greater or equal to zero in all occasions.

Table 6.4: Regime Overview

		Home	
		Unconstrained	**Constrained**
Foreign	**Unconstrained**	Regime 1	Regime 2
	Constrained	Regime 3	Regime 4

Note: Countries are either in an unconstrained state where national DI is sufficient, or in a constrained state where national DI funds are exhausted.

The share of insured deposits depends on the level of available fund capital and is characterized by:

$$\kappa_t^c = \kappa^c - \chi_\kappa [DI^{target,c} - DI_{t+1}^c], \tag{6.35}$$

with $\chi_\kappa = \frac{\kappa^c}{DI^{target,c}}$. It follows that whenever the fund is exhausted, $DI_{t+1}^c = 0$, the economy enters the constrained regime and no insurance is provided, $\kappa_t^c = 0$. This case is consistent with a crisis scenario in which, due to (a sequence of) large shocks, fund capital is annihilated and no insurance can be provided by the national DI anymore. We develop a regime-switching framework[8] where agents, being in a certain state, anticipate that the economy transits with a certain Markov probability from one state to the other in each period. Therefore, expectations about future states of the economy are taken into account in agents' decision rules. This allows us to explicitly include potential moral hazard behavior of banks when governments and EDIS promise to bail out depositors.

Our analysis is counterfactual in nature since the euro area has not experienced episodes with explicitly exhausted national deposit insurance funds. The constrained regime is instead designed to resemble episodes of severe financial distress. We assume that during such episodes, bank default rates are extraordinarily high. We define to this end endogenous Markov switching probabilities

$$P_{1,2} = \frac{1}{1 + \exp[-\alpha_1(\psi_t^c - \Psi^c)]} \tag{6.36}$$

$$P_{2,1} = \frac{1}{1 + \exp[\alpha_1(\psi_t^c - \Psi^c)]} \tag{6.37}$$

that depend on the distance between actual bank default rates ψ_t^c and an imposed "high financial stress" threshold level Ψ^c of bank default rates. The transition probabilities follow a sigmoid activation function with scaling parameter α_1.

Empirical estimates for the probability of being constrained are hard to obtain. We define the switching threshold Ψ^c for each country as the level of default rates at which

[8] We use the RISE toolbox to model a regime-switching environment. See Maih (2015).

the insurance fund level, calibrated in table 6.1, would become negative.

6.4.2 Risk-Sharing Scenarios

Here, we discuss different forms of risk-sharing that apply once national DI capacity is exhausted. In all scenarios, national DI is in place and unconstrained whenever the economy is in regime 1 and the insurance framework outlined in section 6.2.6 applies.

A. Constrained National DI, No Additional Risk-Sharing

In this scenario, the national DI is constrained as the DI fund's capital has been annihilated ($DI_t^{c'} \leq 0$ such that $DI_t^c = 0$) and no further insurance can be provided according to equation 6.35. Bank defaults affect the risk premium on deposit rates unrestrained. The return on deposits net of defaults, given by equation 6.3, decreases, and becomes

$$\tilde{R}_t^{d,c} = R_t^{d,c} - \frac{\Omega_{t+1}^c}{d_t^c}, \tag{6.38}$$

when $\kappa_t^c = 0$ and no other form of insurance is provided.

B. Constrained National DI, National Fiscal Backstop

Under this scenario, depositor losses are compensated by national governments once national deposit insurance funds are exhausted. We assume the government to compensate the steady-state share of insured deposits, κ^c. The cost of deposit insurance enters the national government budget constraint given by equation 6.20 which therefore becomes

$$b_t^{g,c} = R_t^{gov,c} b_{t-1}^{g,c} + g_t^c - \tau_t^c + \kappa^c \Omega_{t+1}^c \tag{6.39}$$

such that obligations from government deposit insurance affect tax and expenditure decisions.

C. Constrained National DI, European Deposit Insurance

Our regime-switching approach closely aligns with the reinsurance system proposed by the European Commission, as EDIS only steps in once national funds are exhausted. Banks in member states are expected to contribute to a European-wide fund. Contributions to EDIS are designed to be ex-ante cost-neutral, i.e. banks can deduct these payments from contributions to national schemes. Therefore, EDIS fund capital evolves according to the law of motion:

$$DI_{t+1}^{EDIS} = DI_t^{EDIS} + \sum_{c=h,f} \tau_t^{EDIS,c} - \sum_{c=h,f} \kappa_t^{EDIS,c} \Omega_{t+1}^c. \tag{6.40}$$

As in the national insurance case, banks in member states are required to contribute to the fund in each period, such that equation 6.17 becomes

$$\overline{\omega}_{t+1}^{c} = (1-\phi_t^c)\left(\frac{R_t^{d,c}}{R_{t+1}^{a,c}} + \frac{\tau_t^{DI,c} + \tau_t^{EDIS,c}}{R_{t+1}^{a,c} d_t^c}\right). \tag{6.41}$$

The aggregate contributions to EDIS are given by

$$\tau_t^{EDIS} = \tau^{EDIS} + \chi_\tau^{EDIS}[DI^{target,EDIS} - E_t\{DI_{t+1}^{EDIS}\}] \tag{6.42}$$

with χ_τ^{EDIS} denoting the sensitivity to changes in the EDIS fund level. The aggregate contributions defined in equation 6.42 are the composite of national contributions into EDIS, whereas each country's share is defined by the risk in the national banking sector. We assume riskier banks to contribute more into the EDIS fund.[9]

Assumption 1 (Risk-weighted contributions to EDIS). *The national contributions $\tau_t^{EDIS,h}$ and $\tau_t^{EDIS,f}$ are allocated relative to the bank default rates of each country:*

$$\tau_t^{EDIS,c} = \frac{\psi_{t+1}^c}{\psi_{t+1}^c + \psi_{t+1}^{\neg c}} \tau_t^{EDIS} \tag{6.43}$$

As the design of bank contributions is a central obstacle in the policy discussions on the introduction of EDIS in Europe, we evaluate alternative specifications of the contribution rule in section 6.5.2. We then vary the contribution weights, and discuss how welfare is affected. A second key element of recent proposals depicts the deductibility of EDIS contributions from payments banks have to make into the national DI funds. In the baseline EDIS, we assume such deductibility of contributions.[10]

Assumption 2 (Deductibility of contributions). *To ensure that total bank contributions do not exceed the level in the scenario without EDIS, we require the contributions to EDIS to be deductible from contributions to national deposit insurances:*

$$\tau_t^{DI,c} = \tau^{DI,c} + \chi_\tau^c[DI^{target,c} - E_t\{DI_{t+1}^c\}] - \tau_t^{EDIS,c}. \tag{6.44}$$

The EDIS fund capital target is defined as the sum of the two national DI targets

$$DI^{target,EDIS} = \gamma^{EDIS}[\kappa^h d_t^h + \kappa^f d_t^f]. \tag{6.45}$$

[9]Our risk weighting hence resembles the "polluter-pays" principle, see Carmassi et al. (2018).

[10]In addition to relaxing assumption 1 in section 6.5.2, we also discuss the implication of relaxing assumptions 2 in section 6.5.2.

Finally, households receive additional compensation under EDIS in case of bank default, such that their risk-adjusted return is now given by

$$\tilde{R}_t^{d,c} = R_{t-1}^{d,c} - (1 - \kappa_t^c - \kappa_t^{EDIS,c})\Omega_{t+1}^c. \tag{6.46}$$

Under a reinsurance scheme, EDIS coverage of deposit default is only assumed once the national DI's insurance capacity is exhausted. The payout rule therefore follows

$$\kappa_t^{EDIS,c} = \begin{cases} 0 & \text{if } DI_t^{c'} > 0 \\ \kappa_t^{EDIS,c'} & \text{if } DI_t^{c'} \leq 0 \end{cases} \tag{6.47}$$

where

$$\kappa_t^{EDIS,c'} = \kappa^{EDIS,c} - \chi_\kappa^{EDIS}[DI^{EDIS} - DI_t^{EDIS}]. \tag{6.48}$$

EDIS is involved as long as the economy is in the constrained regimes, and the national insurance funds get reestablished by bank contributions. We assume that during the reestablishing phase, no insurance transfers can be made. Reinsurance via EDIS therefore provides additional risk-sharing, as it insures particularly against large crises. As intended in European Commission (2015), under each scenario, national DIs and EDIS are expected to jointly provide the same level of deposit insurance as present in the purely national system, i.e. deposits of up to 100,000 € are intended to still be covered. We therefore assume the same target of payout per unit of deposit for national DIs and EDIS, such that $\kappa^c = \kappa^{EDIS,c}$.

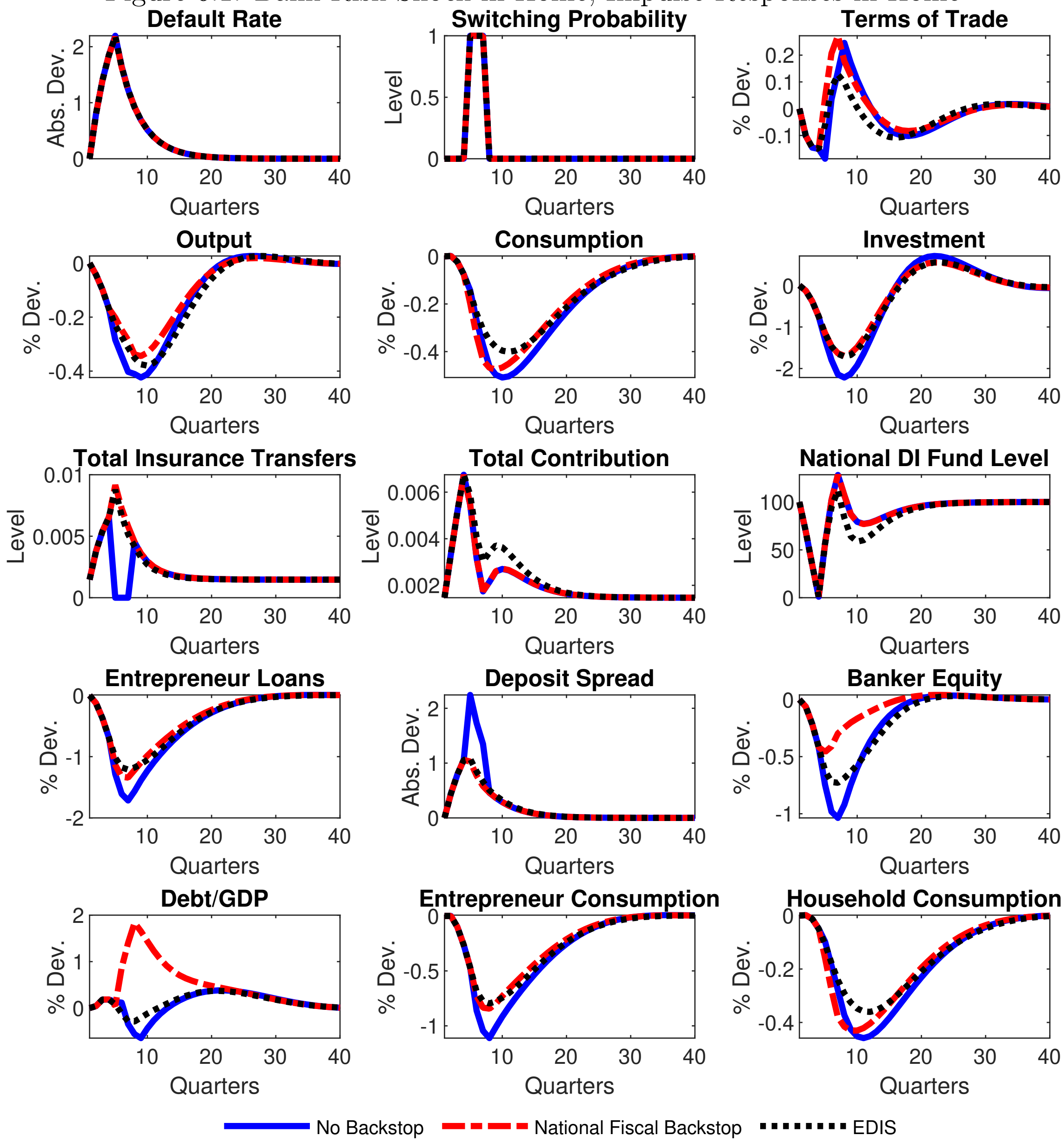
6.5 Results

Based on the policy scenarios defined in the previous section, we first evaluate how shocks emerging in the banking sector affect the financial sector and the macro economy. Second, we discuss welfare implications of bank risk shocks and alternative specifications of EDIS. Third, we investigate the short-term costs arising from the implementation of EDIS.

6.5.1 Bank Risk Shock

Figures 6.1 and 6.2 depict impulse responses to bank risk shocks occurring in the home country, with deviations from the *unconstrained regime's* deterministic steady state. We show responses under the policy scenarios described in chapter 6.4.2: no reinsurance, and reinsurance by a national fiscal backstop or EDIS. We simulate a four-period sequence of bank risk shocks driving up the bank default rate in the home country. The regime switch occurs in period five, after which regime 2 prevails for three periods.

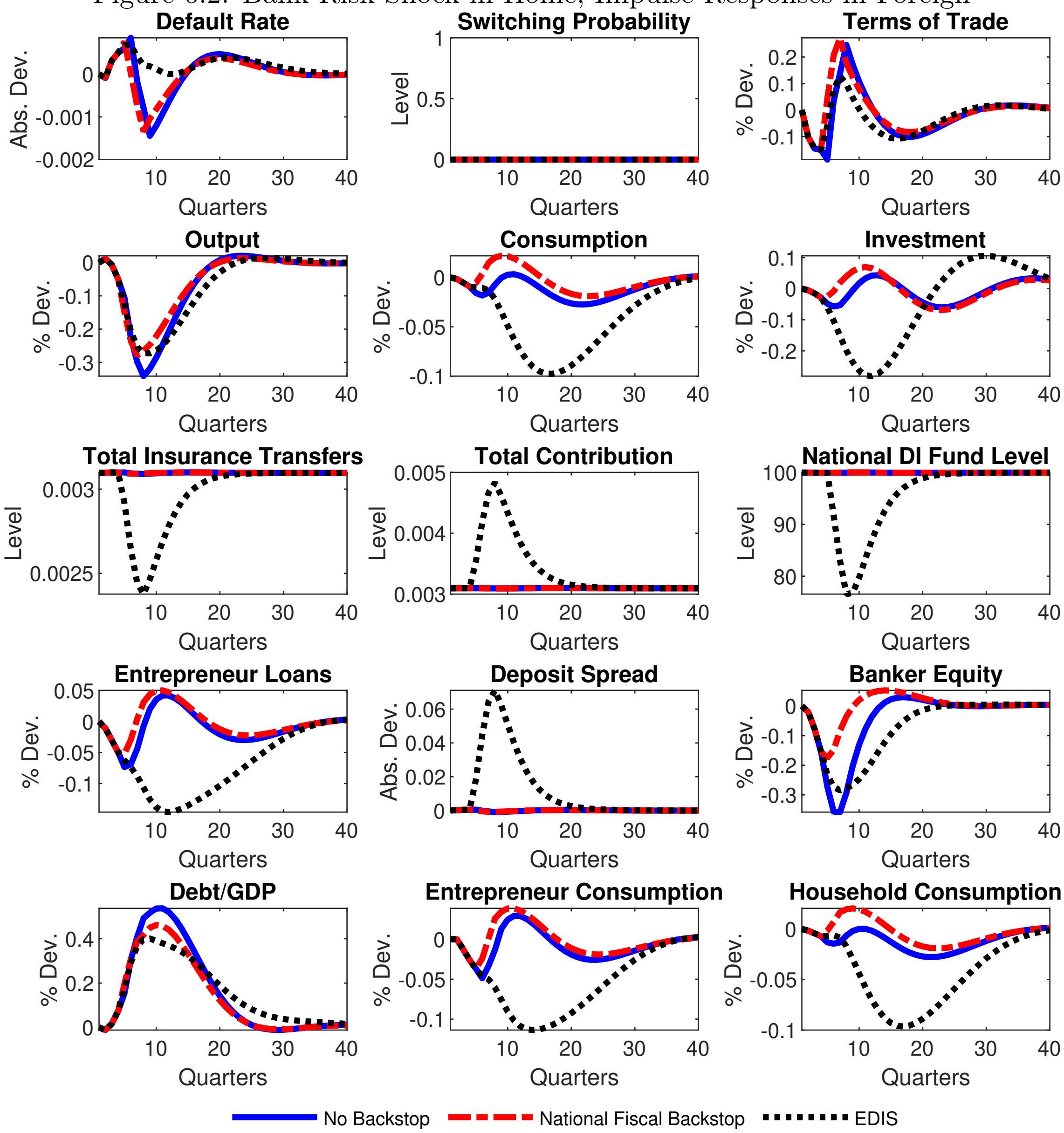
Figure 6.1: Bank Risk Shock in Home, Impulse Responses in Home



Note: Impulse responses to a sequence of bank risk shocks for different policy scenarios of section 6.4. Insurance Transfer depicts the amount of insurance provided by national DI, national government, or EDIS. Deposit Spread depicts the spread between the deposit rate and the risk-free rate. Insurance Transfer and Deposit Spread in absolute deviations from steady state, all other variables in percentage deviations.

Under all policy scenarios, an increase in the home country's bank risk leads to a pronounced economic contraction in both economies, resulting in higher risk premia on deposit rates. From peak to trough, the decline in GDP varies between 0.3 and 0.4 percent across scenarios, while the recession is deepest under the national DI without government

Figure 6.2: Bank Risk Shock in Home, Impulse Responses in Foreign



Note: Impulse responses to a sequence of bank risk shocks for different policy scenarios of section 6.4. Insurance Transfer depicts the amount of insurance provided by national DI, national government, or EDIS. Deposit Spread depicts the spread between the deposit rate and the risk-free rate. Insurance Transfer and Deposit Spread in absolute deviations from steady state, all other variables in percentage deviations.

bailout or EDIS intervention in the home country (blue line). The insurance transfers paid to households – for those scenarios where deposit insurance by national DIs, national governments, or EDIS is provided – increase to compensate depositors for their costs due to bank defaults.

However, consumption declines less under EDIS than in the other two scenarios. In the home economy, consumption declines by approximately 0.4 percent with EDIS from peak to trough (black dotted line). Compared to the other scenarios, the decline in consumption is therefore 20 percent lower. Furthermore, while differences in the decline of output are benign, the debt-to-GDP ratio increases significantly under the fiscal backstop (red dashed line), as taking over obligations from the constrained national DI directly affects the fiscal budget. With EDIS, the costs and risks of higher bank defaults are shared internationally, and covered by bank contributions instead of public debt. However, as banks are allowed to deduct EDIS contributions from the payments into the national DI, reestablishing both the initial national fund's level and the EDIS fund's level takes longest under EDIS. Still, the contribution burden is highest with EDIS, due to the contributions banks have to pay into both schemes.

The bank risk shock in the home country is transmitted to the foreign economy both via trade and international financial markets. Internationally active equity bankers' losses affect investment and lending conditions in the foreign country's banking system (figure 6.2). However, actual bank defaults barely increase on impact, with the volatility in the bank default rate being lowest under EDIS. However, under EDIS, international risk-sharing requires higher contributions by foreign banks to cover the costs of bank defaults in the home economy. As these contributions are deductible, fewer funding to cover regular bank defaults in the foreign economy can be collected, such that insurance transfers and the fund level of the national DI decline. In return, bank deposit spreads increase, which further limits foreign banks' lending capacities. In response to lower lending, foreign consumption declines.

In short, our results indicate that while EDIS can be beneficial to the country affected by the country-specific shock, consumers in the non-affected economy are hit hardest with EDIS. Consequently, the union-wide welfare implications of a common insurance scheme are not clear a priori.

6.5.2 Welfare Analysis

In the following, we investigate the welfare implications of the different forms of risk-sharing discussed in section 6.4.2. To do so, we first evaluate how the implementation of risk-sharing affects steady-state welfare. To account for uncertainty about to future shocks and potential regime switches, we evaluate welfare in the stochastic steady state. Second, we investigate how changes in risk weights that determine each country's contributions to EDIS affect welfare of borrowers and savers in both countries. Whether contributions from more risky banks should be larger or not, and if so, by how much, is not clear a priori, and a central point in the debate about EDIS. Third, while these analyses assume the existence of different risk-sharing devices in the first place, we also study welfare implications of the implementation of EDIS, i.e. of the transition from a scenario with only national deposit insurance to a new permanent steady state with EDIS. Furthermore, the deductibility of banks' contributions to a European fund are crucial in current proposals. Thus, we shed light on the desirability of such deductions from a welfare perspective.

Welfare Calculations

To measure welfare, we compute the stochastic steady states as described in Coeurdacier et al. (2011), relying on a second-order approximation of the structural model relations. Accordingly, the stochastic steady state is the permanent equilibrium where agents anticipate future uncertainty, but where contemporaneous realizations of economic shocks are zero. If the decision rule is given by

$$Y_t = g(Y_{t-1}, \varepsilon_t), \tag{6.49}$$

our stochastic steady state satisfies

$$Y = g(Y, 0). \tag{6.50}$$

In the following exercises, we express welfare under each policy variant in consumption equivalents, i.e. we compute the welfare cost λ^w of each policy scheme vis-à-vis a baseline policy scenario. The welfare loss is given by

$$\lambda^w = (1 - \exp[(V_0^{Pol} - V_0^{Base})(1 - \beta)]) \tag{6.51}$$

V_0^{Pol} refers to the welfare level under the respective policy scheme that is compared to welfare in the baseline scenario, V_0^{Base}. The discount parameter β refers to the respective discount factor in the respective country and for the respective agent.

We aggregate individual welfare of borrowers and savers with Pareto weights ω_j^c, where j refers to either patient households or entrepreneurs and c again to the respective country. Total welfare is thus given by

$$V_t \equiv \sum_{c=1}^{2} \sum_{j=1}^{2} \omega_j^c V_{j,t}^c \tag{6.52}$$

where

$$\omega_j^c = \frac{C^{c\zeta}_{j,t}}{\sum_{c=1}^{2} \sum_{j=1}^{2} C^{c\zeta}_{j,t}} \tag{6.53}$$

with the welfare weight $\zeta = 1$.[11]

Baseline Results

In table 6.5, we report conditional welfare expressed by the regime-specific stochastic steady states. We thereby condition on the presence of a bank risk shock, where we calibrate the size of the shock in one country to match the increase in bank risk necessary to trigger a regime switch.[12] Our conditional welfare measure therefore assumes that agents account for future risks associated to bank risk shocks.[13] We report the relative performance of both variants of EDIS introduced in section 6.4.2. While EDIS 1 refers to the baseline case, EDIS 2 refers to a design where assumption 2 is relaxed, i.e. where we abolish the deductibility of EDIS contributions from contributions to the national DI. Thus, in this exercise, the respective EDIS scenario represents V_0^{Pol} in equation 6.51. For the baseline V_0^{Base}, we choose the scenario described in section 6.4.2 where the national government is expected to step in once the national DI is exhausted.

Table 6.5: Conditional Welfare - Bank Risk Shock

	Regime 1		**Regime 2**		**Regime 3**		**Regime 4**	
	EDIS 1	EDIS 2	EDIS 1	EDIS 2	EDIS 1	EDIS 2	EDIS 1	EDIS 2
Domestic								
Households	0.00	0.01	-0.20	-0.19	0.11	0.12	-0.09	-0.09
Consumption Channel	0.01	0.01	-0.09	-0.09	0.10	0.10	0.00	0.00
Entrepreneurs	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03
Total	0.00	0.01	-0.17	-0.17	0.10	0.10	-0.08	-0.07
Foreign								
Households	-0.01	-0.01	0.02	0.02	-0.49	-0.49	-0.45	-0.46
Consumption Channel	0.00	-0.01	0.02	0.02	-0.24	-0.24	-0.21	-0.21
Entrepreneurs	-0.01	-0.01	0.00	0.00	0.01	0.02	0.02	0.02
Total	-0.01	-0.01	0.02	0.02	-0.43	-0.44	-0.40	-0.40
Union-Wide								
Households	0.00	0.00	-0.09	-0.09	-0.19	-0.19	-0.27	-0.27
Consumption Channel	0.00	0.00	-0.03	-0.03	-0.07	-0.07	-0.10	-0.10
Entrepreneurs	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02
Total	0.00	0.00	-0.08	-0.07	-0.17	-0.17	-0.24	-0.24

Note: Welfare is measured in consumption equivalents (equation 6.51, $100 \times \lambda^w$) and welfare of borrowers and savers in each country are weighted with Pareto weights (equations 6.52 and 6.53). Regimes are defined as in table 6.4. For Consumption Channel, we exclude the labor-related term from utility function 6.1.

While differences between the government backstop and the EDIS scenarios are generally small, relative welfare gains and losses depend on the regime agents find themselves in steady state. Whenever both economies are unconstrained - i.e. national deposit insurances are sufficient to cushion adverse effects from bank defaults - the welfare differences

[11] See Chang et al. (2018).

[12] We tested different shock sizes, and found that welfare effects are robust to smaller shock sizes where regime switches are unlikely. Also, quantitative differences to results in table 6.5 only matter for implausibly large shock sizes.

[13] We only condition on the bank risk shock to observe direct welfare effects associated to this specific shock.

between a government backstop and EDIS are close to zero in most cases (regime 1). Agents price in future uncertainty from bank risk shocks and the possibility to enter a regime where either national governments or EDIS has to step in. However, the associated welfare costs from these uncertainties are almost identical under both policy scenarios.

In contrast, whenever households live in a constrained economy (regimes 2 and 3), household welfare is higher under both EDIS variants than under government backstops. Thereby, the welfare improvements are in part driven by the consumption part of utility function 6.1. In addition, the labor component seems to play a significant role, as only a part of the welfare improvement can be explained by the consumption channel. Welfare differences for entrepreneurs under EDIS and the government bailout scenarios are almost negligible.

Strikingly, on the union-wide level, the benefits of EDIS turn out to be highest whenever both countries are constrained (regime 4). Both domestic and foreign households are better off in this scenario than if no European risk-sharing is provided and only national governments backstops exist.

Welfare Effects of Alternative Contribution Schemes

As we discussed in assumption 1, the design of EDIS contributions is still an open issue in policy negotiations. While some approaches favor risk-weighted contributions, such risk-based payments can, if applied on the sectoral level, act procyclical and increase financial cycles. We therefore show welfare under different relative contribution schemes in figure 6.3, where we choose regime 4, a world in which banks only have to contribute into EDIS, for the comparative static analysis. While in the baseline model, contributions to EDIS are assumed to be risk-weighted (see assumption 1), we allow the weighting of contributions to be governed by parameter α^{RW} in the exercise. The relative contributions from equation 6.43 thus become

$$\tau_t^{EDIS,h} = \alpha^{RW}\tau_t^{EDIS} \tag{6.54}$$

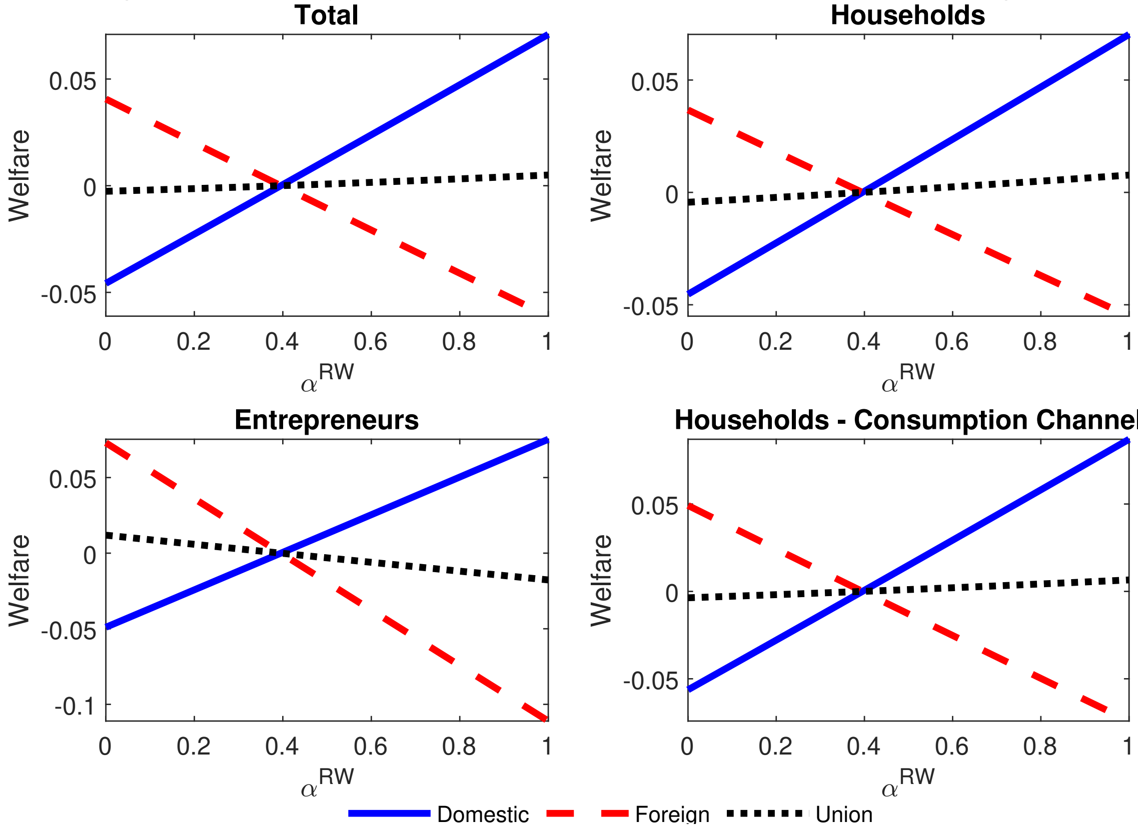
$$\tau_t^{EDIS,f} = (1-\alpha^{RW})\tau_t^{EDIS}. \tag{6.55}$$

We evaluate welfare in the deterministic steady state, and compare it to the steady-state level under the baseline calibration following the definition of consumption equivalents in equation 6.51.[14] For comparability, we fix the Pareto weights to the values

[14]We do not rely on the stochastic steady in this exercise, as under the baseline calibration, the risk weights are defined by the ratio of default rates (equation 6.43). Thus, the second-order approximations of the baseline model include additional terms that make the stochastic steady states of the baseline model with the ones according to equations 6.54 and 6.55 not comparable.

obtained under the baseline calibration, and evaluate the welfare implications that stem from changes in the welfare components only.

Figure 6.3: Steady-State Welfare for Alternative Contribution Weights

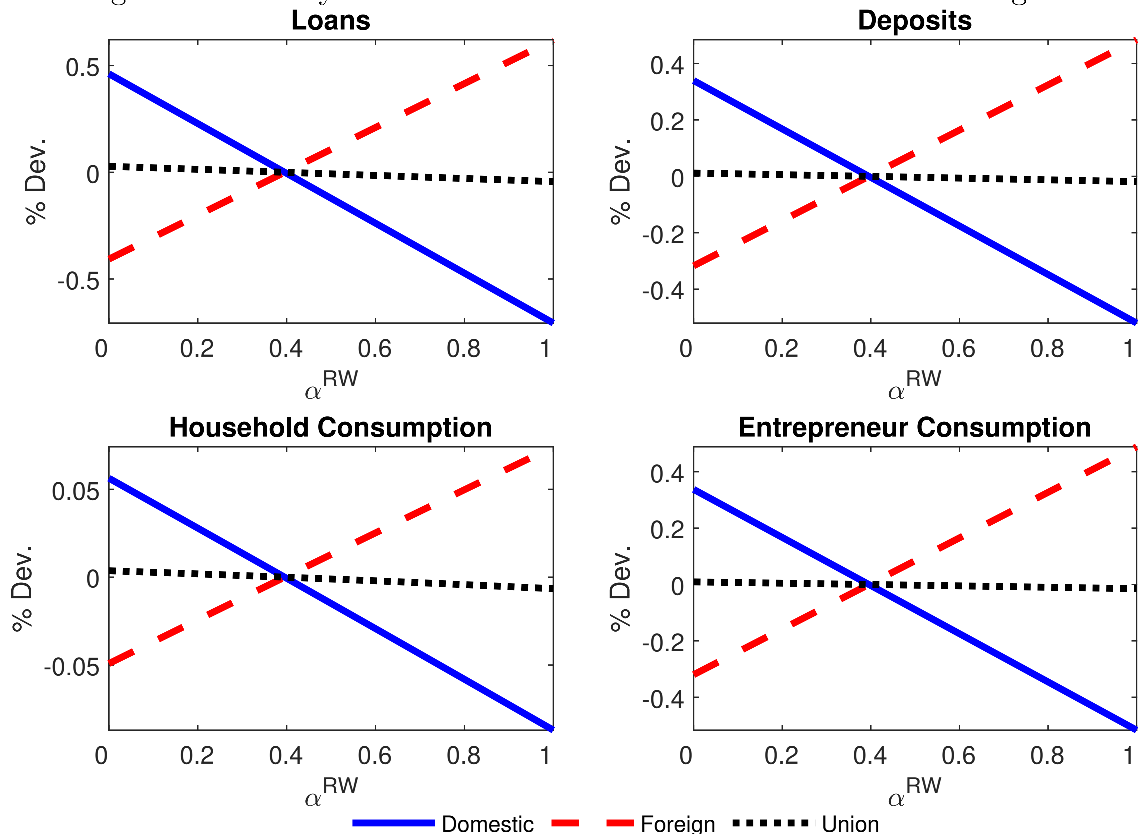


Note: Steady-state welfare for different contribution weights determined by α^{RW} in equations 6.54 and 6.55. Welfare expressed as consumption equivalents (equation 6.51). For Consumption Channel, we exclude the labor-related term from utility function 6.1.

In total, low levels of α^{RW} are welfare-improving for the home economy (upper left panel figure 6.3). For the foreign economy, the opposite holds as welfare losses are lowest for high values of the contribution parameter. In both economies, higher levels of EDIS contributions limit the funding capacity and increase intermediation costs of banks, such that loans and deposits decline with rising contributions in steady state (figure 6.4). For firms, the borrowers in the economy, lower lending limits their access to funding, which ultimately lowers entrepreneur consumption and welfare (lower left panel figure 6.3). As lower lending dampens economic activity, also households' income and ultimately consumption decline, leading to a reduction in household welfare if domestic contributions rise (upper right panel figure 6.3).

On the union-wide level, welfare differentials are small, even if union-wide welfare gains are largest when α^{RW} is close to zero, and contributions almost entirely accrue in

Figure 6.4: Steady-State Variables for Alternative Contribution Weights



Note: Steady-state levels for different variables for different values of α^{RW}. Deviations are expressed as percentage deviations from steady-state levels under the baseline calibration.

the foreign economy.[15] Due to higher Pareto weights, country-wide welfare is primarily driven by households (upper right panel figure 6.3). For entrepreneurs, a high value of α^{RW} is – on the union-wide level – associated with the largest welfare gains (lower left panel figure 6.3), but again, differences are minor. Our analysis indicates that an "excessive risk-sharing" scheme is welfare-optimal, i.e. that union-wide welfare losses are minimized whenever risky banks pay all contributions. However, welfare costs from deviating from such an extreme scheme – by increasing save banks' contributions – are negligible. Thus, on the union-wide level, a more moderate risk-sharing approach where both risky and save banks contribute, is almost equally beneficial.

[15] We conducted robustness checks using alternative population weights, including weightings based on discount factors used in chapter 5. Such "β-weights" commonly used in the literature, see for instance Lambertini et al. (2013) or Rubio (2011). Also under these alternative schemes, union-wide welfare differentials are negligible for different values of α^{RW}.

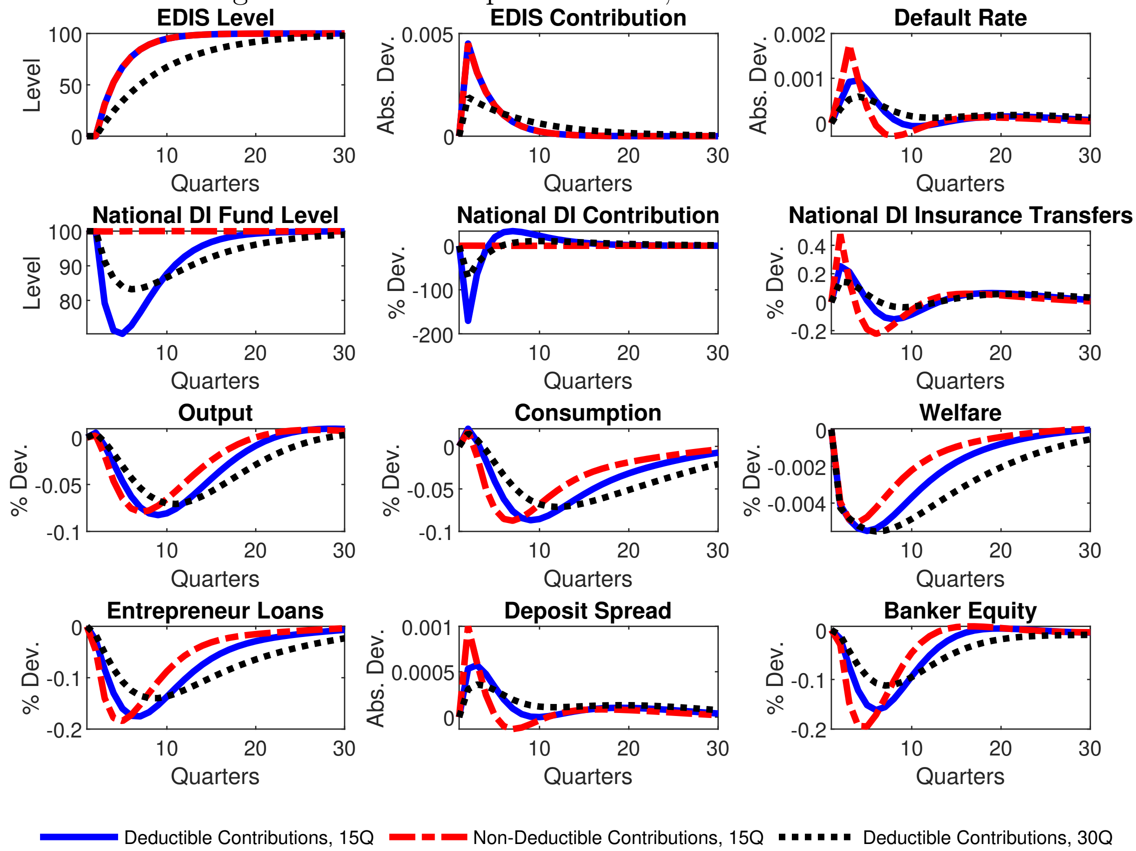
Welfare Effects of EDIS Implementation

So far, we showed that an adequately designed EDIS already in place can stabilize welfare in the presence of financial shocks. However, the implementation of an EDIS fund potentially causes short-term welfare costs, as upfront payments by banks are necessary. We evaluate the initial costs of implementing such a fund by assuming that EDIS is only able to provide insurance once the fund has been filled up to the target level. We assume that fund capital is accumulated over time, as banks contribute to EDIS each period following equation 6.43. The sensitivity of contributions, χ_{τ}^{EDIS}, is chosen such that after approximately 3.5 years the targeted fund level of EDIS is reached in the baseline scenario. Those payments are risk-weighted as under assumption 1, with the riskier foreign banks bearing the larger share. By assumption 2, contributions to EDIS are deductible in the baseline. We also study a scenario where we relax assumption 2 by removing the deductibility of EDIS contributions. In a third exercise, we increase the duration of EDIS implementation to 7.5 years.

In figures 6.5 and 6.6, we show the transition path during the introduction of EDIS. If bank contributions to EDIS increase, their payments to national deposit insurances decline in case of deductibility (blue line). Given ongoing transfers, the national fund levels and ultimately the share of insurance coverage decline. Households anticipate the lower insurance coverage by demanding a higher risk premium on the deposit rate, resulting in lower financial intermediation and a drop in economic activity, together with a decline in welfare.

Relaxing assumption 2 ensures constant national DI coverage, but at the same time, the total transfers banks have to absorb increase (red dashed line). The higher total costs result in initially lower bank profits and in less lending as under deductibility, and eventually in a higher rate of bank defaults. Ultimately, real economic activity declines to a similar degree as under the baseline scenario. Thus, wile non-deductible contributions ensure that the national DI's capacities are on target, the double burden due to bank contributions to both insurance schemes can destabilize the financial system, with respective adverse real economic effects. However, stress in the financial sector is relatively short-lived, such that financial and real variables, and ultimately welfare return to their initial levels more rapidly as in the baseline scenario. Thus, under both deductible and non-deductible contribution schemes, an intertemporal trade-off between the mitigation of the initial adverse effects for aggregate economic and financial activity, and the duration of the downturn exists. With deductibility, the policy maker can resolve this trade-off by smoothening out the adverse economic and financial effects over a longer horizon.

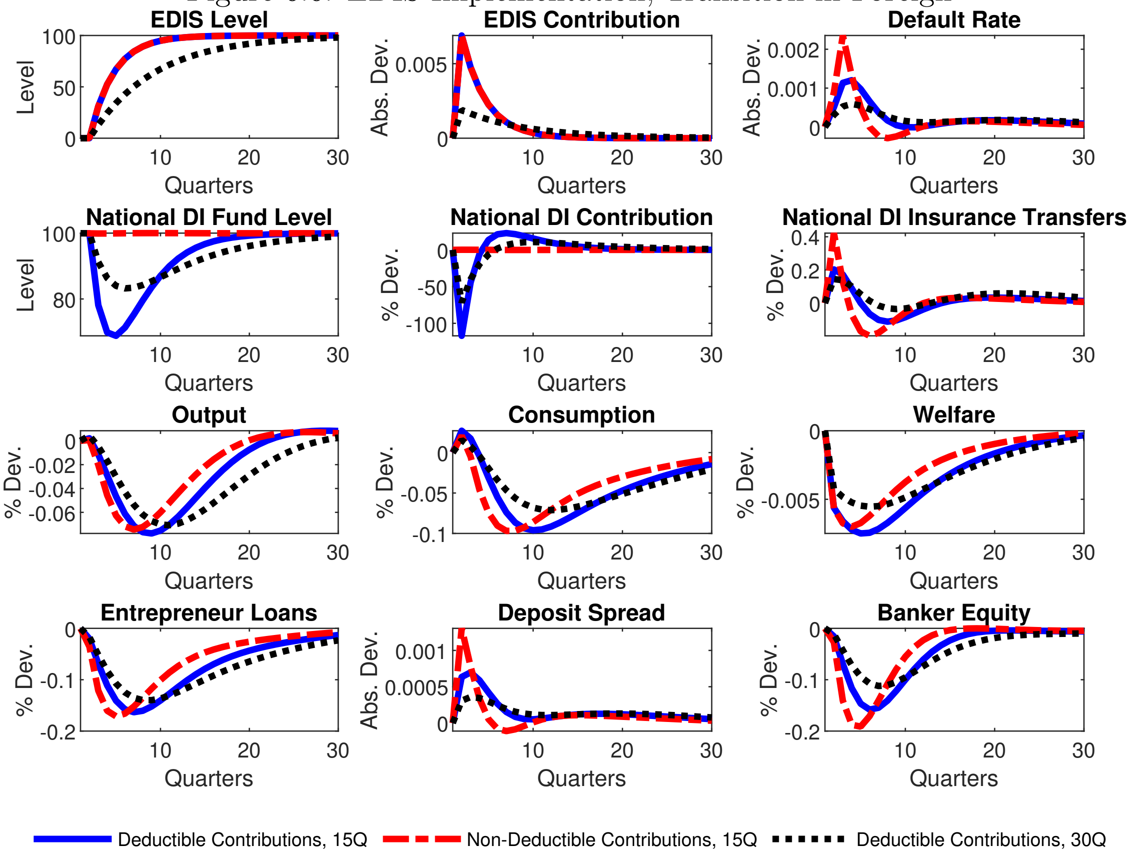
Figure 6.5: EDIS Implementation, Transition in Home



Note: Transition path of the home economy after the introduction of EDIS in period one. The target EDIS fund level is reached after around 3.5 years in the baseline (red and blue), and after 7.5 years (gray line).

This intertemporal trade-off is accentuated when the implementation phase of the fund is prolonged. To mitigate short-run costs, the introduction of EDIS could be extended, such that the fund can be established with lower per-period contributions (black dotted line). Figures 6.5 and 6.6 reveal that a prolonged implementation of EDIS can indeed mitigate initial costs from a temporarily lower national DI coverage. However, as bank defaults can only partly be insured during the implementation, default costs remain higher for longer. Consequently, the associated decline in economic output and financial activity extends over a longer period. In the home economy, the prolonged phase of economic distress ultimately yields an equally pronounced decline and a longer recovery of social welfare compared to the baseline. In the foreign economy, welfare losses are initially lower as in the other two scenarios. However, as in the home country, recovery is slower when implementation takes longer. Consequently, while a prolonged implementation phase can mitigate short-term disruptions in financial markets, these gains are potentially confronted with a protracted decline in economic activity.

Figure 6.6: EDIS Implementation, Transition in Foreign



Note: Transition path of the foreign economy after the introduction of EDIS in period one. The target EDIS fund level is reached after around 3.5 years in the baseline (red and blue), and after 7.5 years (gray line).

6.5.3 The Financial Crisis: Stabilization Effects of EDIS

In the following, we conduct a counterfactual analysis that serves two purposes. First, we investigate how EDIS would have performed in Germany and the rest of the euro area, had it been in place during the financial crisis. Second, we study the empirical validity of the model by comparing our model simulations to actual macroeconomic developments between 2008:Q4 and 2012:Q4.

Characterizing the Financial Crisis

In order to analyze how EDIS would have affected the macro economy, we follow Christiano et al. (2015) and suppose that the financial crisis in the euro area was triggered by four major shocks: a preference shock, a financial market shock, a TFP shock and a government spending shock. We extract these shocks by using the procedure proposed by Christiano et al. (2015). Thereby, we calculate for each variable of interest the linear trend from date $x \in \{1991{:}Q1, \ldots, 2004{:}Q1\}$ to 2008:Q4. From 2008:Q4 onward, the trend growth rate is extrapolated by an AR(1) process, to derive trend forecasts without the shocks that caused the financial crisis.[16] We then calculate "target gaps", i.e. the differences between actual and projected values at different time horizons. Target gaps represent the estimates of shocks and their economic effects after the 4th quarter 2008. Since their true values are not known, we construct the min-max range of the computed gaps.[17] As a first objective of the exercise, we assess the model predictions relying on such target gaps. Second, we evaluate whether a regime switch would have occurred, and compare the outcome of the presumed status quo – a situation where a nationally financed deposit insurance becomes insufficient – with the EDIS scenario.

Following Christiano et al. (2015), for the preference shock, we define a "wedge" which describes a disturbance to the household Euler equation. A positive realization of the consumption wedge can be interpreted as an increasing demand for risk-free assets:[18]

$$\Delta_t^{C,c} = \frac{E_t\{\pi_{t+1}^c\}}{\beta R_t^c} - 1.$$

In order to get an observable time series of the consumption wedge, we use the country-specific deposit rates, and the one-quarter ahead core CPI-inflation forecasts from the ECB's Survey of Professional Forecasters. Differences in the consumption wedge between Germany and the rest of the euro area are determined by differences in inflation and deposit rates.

The bank risk shock is modelled as a shock to the default rate. In order to extract an empirical series, we rearrange the default rate equation

$$\Delta_t^{\psi,c} = \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right) \tag{6.56}$$

where $\Phi(z)$ is the standard normal distribution. We calculate the inverse of the standard normal distribution and solve the equation for the shock term $z_t^{b,c}$.[19] The bank risk shock occurs earlier in Germany, mainly because some German banks had solvency problems already in 2007,[20] before bank default increased further after the collapse of Lehman Brothers (upper second panel). After the provision of additional government aid for failing

[16] In Europe, the drop in GDP in the 3rd quarter of 2008 was primarily driven by falling exports, while consumption and loans dropped below long-term levels mainly in the 4th quarter, We therefore set the starting point of our analysis, to the 4th quarter 2008.

[17] For some of the euro area time series, such as GDP and components, we have a limited amount of observations, starting only in the mid-1990's. For all countries, only few default rate observations are available. Thus, particularly in this case, the min-max ranges are tight.

[18] See Fisher (2015).

[19] The resulting quadratic equation is solved with the quadratic formula and provides only one economic plausible solution. In this exercise, we also assume that ρ_b^c in equation C.1.39 is equal to zero.

[20] See Hellwig (2018).

institutes in the beginning of 2009, bank risk decreased temporarily.[21] With the onset of the European debt crisis and increasing doubts about the stability of the euro area, the probability of bank defaults increased again, also in Germany (upper and lower second panel).

To simulate a government spending shock we use quarterly time series data for government consumption divided by the trend component of factor productivity γ_t^c:

$$\Delta_t^{G,c} = \frac{g_t^c}{\gamma_t^c}. \tag{6.57}$$

In Germany, the permanent increase of government consumption can be explained with the implementation of substantial spending programs that were already approved in previous years, mainly to foster innovation and education (upper third panel).[22] Due to these programs, the increase in government spending can only in part be attributed to the financial crisis, as purely crisis-related packages terminated in 2010/2011 (red line). In the rest of the euro area, the strong reduction of government consumption (lower third panel) after 2009 can not only be explained by the termination of stimuli packages. If the packages would be the only determinants of government consumption, the decline in spending should resemble its increase during the implementation of these packages. The larger part of the decrease was therefore most probably triggered by austerity policies conducted in several euro area economies at the time.

Finally, the total factor productivity shock is measured as a residual in the production function:

$$\Delta_t^{A,c} = \frac{y_t^{E,c}}{(k_t^{E,c})^{(\varepsilon^{TFP,c})}(l_t^{P,c})^{(1-\varepsilon^{TFP,c})}}. \tag{6.58}$$

In contrast to the other shocks, we use the European Commission's unobserved component model which relies on the Kalman filter to extract the trend component.[23] However, disentangling the TFP shock's transitory from the permanent component proves difficult, as agents became only gradually aware of the persistence in the decline in euro area productivity during the crisis.[24] Thus, for the rest of the euro area, we assume a highly persistent shock, while in Germany the transitory component dominates.

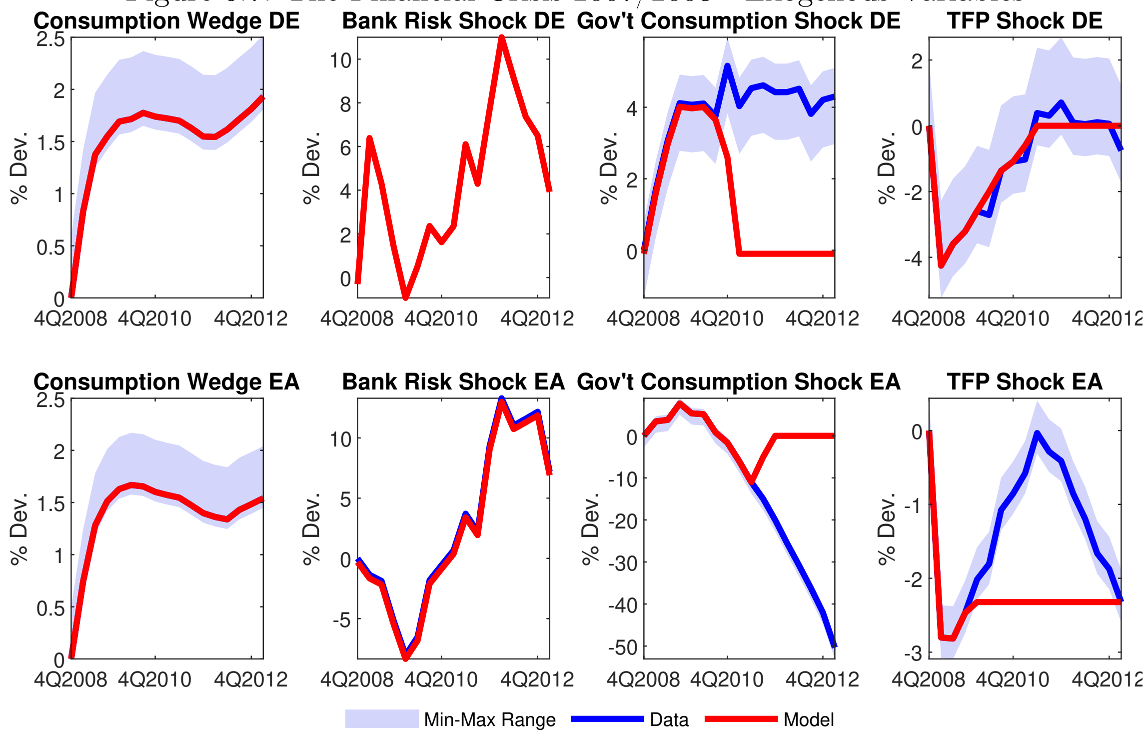
[21]The time series used to determine the steady-state default rates ψ^c include the crisis years, such that a negative realization of the bank risk shock of default rates in figure 6.7 is still associated with elevated default levels.

[22]The programs included, inter alia, the "Exzellenzinitiative I", the "Hochschulpakt I", and the "Innovationsoffensive".

[23]See Havik et al. (2014).

[24]See Christiano et al. (2015).

Figure 6.7: The Financial Crisis 2007/2008 - Exogenous Variables



Note: Exogenous processes used in the counterfactual analysis. Consumption wedges are computed following Christiano et al. (2015). All variables in percentage deviations from steady state.

Solving and Simulating the Baseline Model

We solve the model by incorporating the shock vectors of the post-2008:Q4 period assuming the law of motions and information sets about the shocks as discussed. For the shock series, we suppose that at date t each agent observes the historical values of the shocks. At each date $s = 15$ during the post-2008:Q4 period, they compute forecasts with model-consistent AR(1) forecast rules. For macroeconomic variables, we follow an analogous procedure. In a first step, we run the model given the shock in period t, assuming that the economy is initially in steady state. In a next step, we adjust initial conditions for each subsequent period $t + s$ to the previous state of the economy and run the model for each period separately.[25] This yields a 1×15 vector for each variable with the actual and the expected values given adjusted information. Finally, to compute the final series we collect all actual values from each period's simulation.

[25] Although agents consider the switching probabilities, we exclude the possibility of switching into a new steady state. Thus, in each simulation the agents expect to converge back to the deterministic steady state of regime 1.

Counterfactual Analysis

The simulated series for six macroeconomic variables are depicted in figure 6.8 (blue line), together with the empirically observed values (black line) and the min-max range (gray shaded area). As our baseline, we choose the national fiscal backstop scenario, where governments provide deposit insurance once the national DI fund is exhausted (red solid line). In principle, the model is able to replicate the observed dynamics of these variables quite well.[26] However, three aspects have to be taken into account while comparing baseline model results with observed variables.

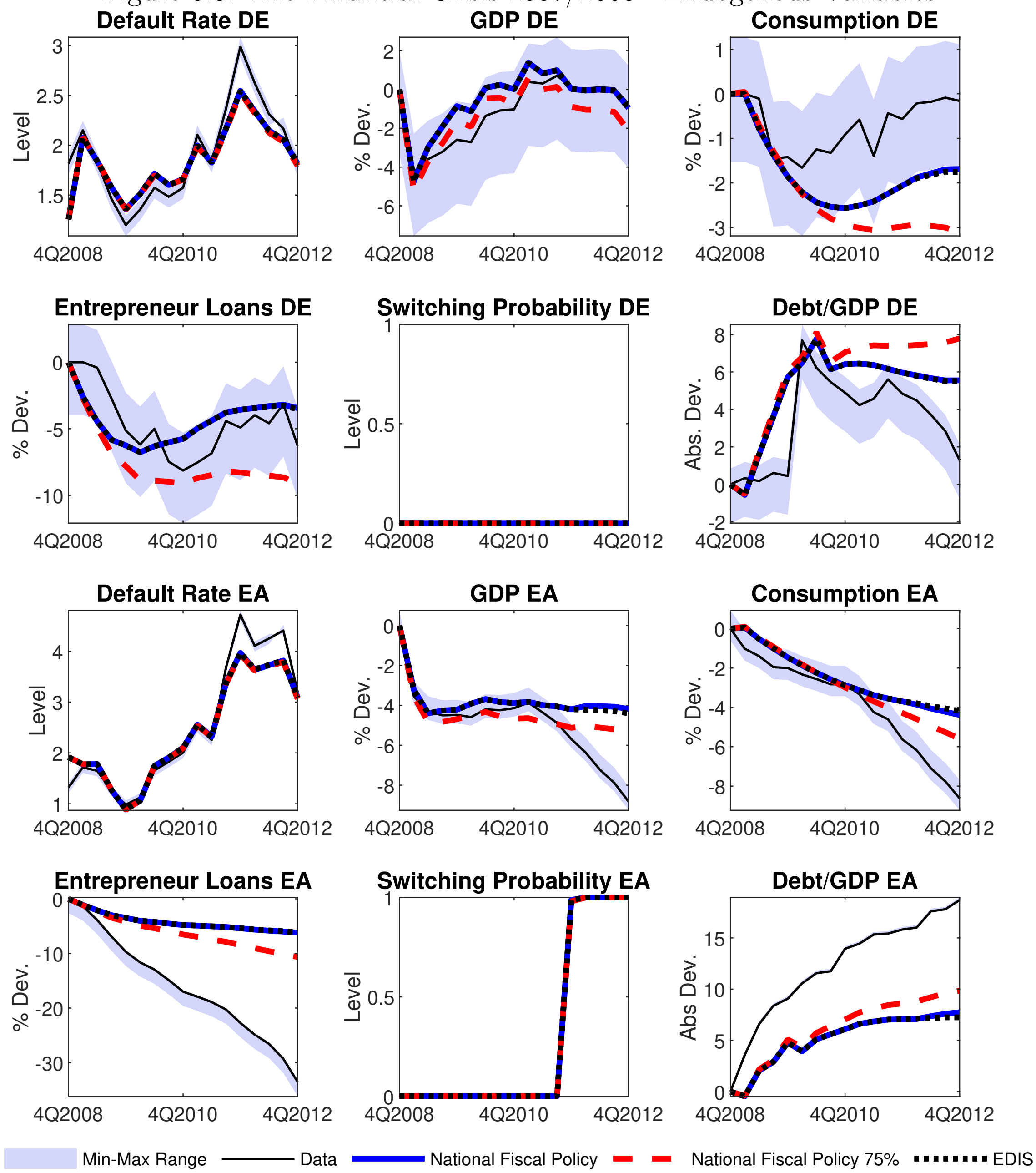
First, as none of the European national DI schemes actually ran out of funds during the financial crisis, we do not observe a true "regime switch" in the data. However, governments provided both explicit bank bailouts and implicit deposit guarantees during the financial crisis, which we do not explicitly address in the model. Without these measures, the probability of bank defaults would have potentially been higher than observed, which most probably would have led to an exhaustion of national DI funds. Since our model does not consider bank bailouts, it indicates a regime switch instead. Furthermore, while national deposit insurance is mainly privately financed in most EU countries, some countries have explicit fiscal backstops or public-private coinsurance schemes. Since we model the deposit insurance schemes as purely privately financed entities, funds are more rapidly depleted as the real-world data might suggest. Thus, our baseline result can be interpreted as a counterfactual scenario where government bailouts would not have circumvented the depletion of the purely privately financed part of national deposit insurances.

Second, during the European sovereign debt crisis which started in 2010/2011 and which we do not explicitly consider, country-specific shocks played a significant role. For instance, consolidation policies of the German government had small effects because the economic recovery was rapid. In other countries, i.e. Italy, Spain, or Greece, the austerity measures had a strong negative impact on GDP and consumption. We only account for the reduction of government consumption, but not for additional government spending shocks, such as tax and labor market policies that would have further reduced consumption in affected countries to different degrees.

Third, due to bank bailouts government debt increased substantially in some countries. In return, financial markets questioned the sustainability of high debt levels in some member states, which led to large risk spreads and negative feedback effects to the macro economy and the banking sector. While banks holding sovereign bonds potentially benefit

[26] Christiano et al. (2015) use data for the US back to 1980 and report ranges of roughly 3-5 percentage points for GDP and consumption. With data for Germany, we get similar ranges for GDP and consumption. However, for the euro area, the range is at 2 percentage points such that our min-max range in the euro area should be interpreted as a rather narrow band.

Figure 6.8: The Financial Crisis 2007/2008 - Endogenous Variables



Note: Endogenous variables simulated with exogenous processes in figure 6.7. Default rates and switching probabilities in levels, debt-to-GDP ratios in absolute percentage point deviations from steady state. All other variables in percentage deviations steady state.

from higher yields on sovereign debt, the negative effects of rising bond yields, particularly in times of financial distress, need to be adequately considered: (1) As bond yields and the underlying bond value are inversely related, rising risk premia and sovereign bond yields are also associated with a decline in bond prices. Consequently, falling bond prices negatively affect the asset side of banks' balance sheets. (2) While this mainly linear yield-price link already affects banks' balance sheets in normal times, bank bailouts can trigger a highly non-linear feedback loop in times of financial distress. As we only partially account for the second channel, we potentially underestimate the negative feedback effect and the macroeconomic dynamics after 2008 in the baseline simulation. We account for the potentially higher non-linear crisis effects by simulating an alternative baseline (red dashed line in figure 6.8) where we assume that banks face a 75 percent lower return on government bonds than in the baseline.

Besides the two described scenarios, we assume in a third scenario that EDIS, designed as in section 6.4.2, was already in place before 2008 (black dotted line). The counterfactual scenario with EDIS delivers two key results. First, once the euro area economy switches, the decline in GDP is slightly lower in case of the fiscal backstop. The difference can be explained by differences in the terms of trade reaction (not shown). In case of EDIS, the relative competitiveness of the euro area declines stronger, and the trade balance in the rest of the euro area deteriorates by more.

Second, although macroeconomic differences between the baseline scenario and EDIS are small, the rise in government debt would have been lower with EDIS: The debt-to-GDP ratio increase is approximately half a percentage point lower than in the baseline case. Furthermore, the relative advantage of EDIS increases significantly once we assume that banks' benefits from higher sovereign bond yields are limited due to the fiscal backstop (red dashed line). In both economies, consumption and GDP losses due to the crisis diminish by approximately 2 percent (annualized) with EDIS. The increase of debt-to-GDP ratio is even 2 to 3 percentage points lower.

In short, our results suggests that EDIS would have potentially reduced the risks stemming from a bank-sovereign doom loop. Implicit and explicit costs from bank defaults and bailouts would have been more effectively covered by EDIS funds, which would have limited the burden for constrained sovereigns. Furthermore, the exercise shows that with EDIS, gains and losses from higher bank risks are shared between bank owners, and do not accrue via higher taxes to all economic agents.

6.6 Conclusion

This chapter investigates the macroeconomic and financial effects of a European deposit insurance scheme (EDIS). We analyze the economic effects of a reinsurance scheme in a regime-switching open-economy DSGE model calibrated to match key euro area data moments, and discuss different forms of reinsurance.

We find that a national fiscal backstop and EDIS are able to insure almost equally well against unanticipated increases in bank default risk. However, overall consumption is more stabilized with EDIS in the economy where the shock occurs. Also, debt levels remain broadly stable, while the country's debt-to-GDP ratio rises if a fiscal backstop has to incur deposit insurance. At the same time, the total insurance burden for banks increases as banks are required to contribute to both the national and the European fund, and the national fund's recovery takes longest with EDIS. As financial risks are shared on the European level, foreign banks also need to contribute more with EDIS, with resulting adverse effects for lending and real economic activity.

Welfare gains from EDIS over fiscal reinsurance are largest in a scenario where national DI funds in both economies are exhausted. On the union-wide level, risk-based contribution schemes deliver the largest welfare gains, supporting the "polluter-pays" principle underlying most policy proposals. However, such schemes particularly benefit savers, while borrowers across the union might be better off if the largest part of payments falls to the least risky national banking system.

We also discuss how short-term costs from installing an EDIS fund can be mitigated. We show that whenever the fund has to be filled from bank contributions, the deductibility of EDIS contributions can lower bank payments into national systems, which temporarily lowers national DIs' capacities. Without deductibility, national DIs' capacities are less affected. At the same time, double contributions in both systems potentially lower bank margins and limit their capacities to provide lending. Finally, longer implementation horizons can mitigate bank defaults in the short run, as the bank burden from up-front contributions is stretched over a longer period. However, at the same time, the economic contraction is protracted.

In a counterfactual exercise, we analyze how EDIS would have affected the euro area economy during the financial crisis. Therefore, we extract specific financial crisis shocks. We then simulate a benchmark scenario, where we assume that national governments would have provided deposit insurance once the national schemes would have been exhausted. We find that the differences in the stabilization of GDP and consumption between EDIS and the fiscal backstop would have been rather small. However, the debt-to-GDP ratio would have been lower with EDIS. The benefits of EDIS become significantly larger once we assume that banks profit only partly from increasing debt-elastic government interest rate.

Our findings suggest that a European deposit reinsurance scheme can provide welfare gains on a union-wide level, even though several trade-offs need to be considered in policy decisions. First, while European risk-sharing can enhance macroeconomic and financial stability and increase welfare, overburdening banks with contributions in both national and European insurance schemes can limit lending capacities. Thus, regulators need to adequately design contribution and deductibility schemes to avoid tensions in credit markets. Second, while the long-term benefits of EDIS are potentially significant, short-term costs during the implementation phase need to be taken into account. While expanding the implementation horizon can help mitigating short-run distress in financial markets, smoothing out bank contributions into the future potentially prolongs an economic downturn. If bank contributions are channeled towards EDIS for a longer time, deposit insurance can be insufficient to cover depositor losses in times of distress. Thus, policy makers need to make sure that EDIS, once introduced, is able to provide insurance instantaneously. Also, temporary suspensions of EDIS contributions could be considered during times of acute distress, if EDIS payments are not (yet) available.

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A Appendix Chapter 4

A.1 Appendix: Credit Leakage in a Two-Period Model

A.1.1 Benchmark Model

In the following, we present a stripdown version of the full DSGE model we derive in section 4.2. We use the simple model to explain the key mechanism, i.e. the effects of regulatory changes in the commercial banking sector (a change in capital requirements) and the interplay of the two intermediaries, shadow and commercial banks.[1] The complete model presented in section 4.2 implements the key mechanism in an infinite horizon general equilibrium framework where we introduce a multitude of features such as habit formation in consumption, labor and capital decisions by households and firms, monopolistic competition in the goods and commercial banking sectors, nominal rigidities, and adjustment costs for investment and bank capital that aim to increase the richness and fit of our model. We abstract from all those features here to shed light on the distinct working of exogenous changes in capital requirements in our model. The model we describe in this section is a two-period model in which agents can borrow (lend) in the first period, either via commercial or shadow banks, and repay (receive) outstanding principle plus interest in the second period. The funds intermediated are used for consumption purposes, and all resources are used by the end of the second period.

Savers

There is an infinite amount of identical savers[2] that use resources for consumption of real goods.[3] The saver can transfer consumption from the first to the second period by placing deposits in one of the two financial intermediaries, and he withdraws his funds in period two, receives interest, and uses the gross return for period-two consumption. Only deposits placed with the commercial bank will act as safe assets, as they are covered by full deposit insurance, which will not be the case for shadow bank deposits. When considering shadow banks, the savers face a probability p of retaining full shadow bank deposits and interest

[1]The model presented here partly relies on the two-period version of the Gertler and Karadi (2011) model derived by Lawrence Christiano and Tao Zha. The material can be found here: http://faculty.wcas.northwestern.edu/ lchrist/course/IMF2016/syllabus.html.

[2]In our full model, savers will be households and borrowers will be entrepreneurs.

[3]In this version of the model, we abstract from nominal price changes, such that all variables and interest rates are expressed in real terms.

return in period two, and a probability $1-p$ with which they will receive zero, affecting period-two consumption respectively. The first-period budget constraint of the saver is given by

$$c + d^c + d^s \leq y \tag{A.1.1}$$

where c depicts the level of consumption in period one, and d^c and d^s constitute the amount of deposits placed in commercial and shadow banks, respectively. The saver funds these expenses with an initial output endowment, y, that he receives at the beginning of period one.

In the second period, the saver either receives full deposit returns from both banks to fund period-two consumption (C^+), or has only his returns from commercial bank deposits at hand to fund consumption (C^-), due to an exogenous default of shadow bank deposits. The second-period budget constraint in case of full repayment is thus given by

$$C^+ \leq (1 + r^{dc})d^c + (1 + r^{ds})d^s \tag{A.1.2}$$

and in case of shadow bank deposit default by

$$C^- \leq (1 + r^{dc})d^c \tag{A.1.3}$$

where

$$1 + r^{ds} \equiv \frac{1 + r^{dc}}{1 - \tau^s} \tag{A.1.4}$$

with

$$0 \leq \tau^s \leq 1.$$

The saver earns net interest r^{dc} and r^{ds} on each type of deposits, and receives profits π which are exogenous to the saver, as he is the ultimate owner of firms and banks in the model. The interest rate spread between commercial and shadow bank deposits is determined by the parameter τ^s, and the saver takes the interest rate returns, and thus τ^s, as given.

The maximization problem of the saver is thus given by

$$\max_{c, C^+, C^-, d^c, d^s} u(c) + \beta^s[pu(C^+) + (1-p)u(C^-)] \tag{A.1.5}$$

where β^s depicts the discount factor savers apply.

Subject to constraints A.1.1, A.1.2 and A.1.3 in equation A.1.5, the first-order conditions of the saver can be combined to yield:

$$1 + r^{dc} = \frac{u'(c)}{\beta^s[pu'(C^+) + (1-p)u'(C^-)]} \tag{A.1.6}$$

$$1 + r^{ds} = \frac{u'(c)}{\beta^s[pu'(C^+)]}. \tag{A.1.7}$$

With log-utility, taking ratios of equations A.1.6 and A.1.7, we get

$$\frac{1 + r^{ds}}{1 + r^{dc}} = 1 + \frac{1-p}{p}\frac{C^+}{C^-} \tag{A.1.8}$$

and plugging in constraints A.1.2 and A.1.3 yields

$$\frac{d^s}{d^c} = \frac{(1 + r^{ds})p - (1 + r^{dc})}{(1 + r^{ds})(1-p)}. \tag{A.1.9}$$

Proposition 1. *The ratio of shadow bank vs. commercial bank deposits is*

- *increasing in the shadow bank deposit return r^{ds} and*
- *increasing in the no-default probability p*

We make sure that no negative amount of deposits are placed with any of the two banks and exclude cases where no deposits are placed with shadow banks. Even though a possible outcome, no placement with shadow banks would eliminate shadow bank intermediation completely in our model, and we exclude this case from our analysis.[4] This implies that

$$(1 + r^{ds})p - (1 + r^{dc}) \geq 0$$

and thus

$$p \geq \tfrac{1+r^{dc}}{1+r^{ds}}$$

and thus

$$1 + r^{ds} \geq \frac{1 + r^{dc}}{p}. \tag{A.1.10}$$

This condition has to hold and implies that a higher shadow bank default probability $1-p$ (a decrease in p) has to be compensated with a higher gross return on shadow bank

[4]In the simulation, we will choose parameters such that $\frac{d^s}{d^c} > 0$ holds.

deposits $(1 + r^{ds})$ to make savers invest a positive amount in shadow banks at all, ceteris paribus. If we rewrite the condition with equality such that

$$1 + r^{ds} = \frac{1 + r^{dc}}{p} \tag{A.1.11}$$

and define a relation between the spread parameter τ^s and the no-default probability p such that

$$\tau^s = 1 - p$$

we get the relationship

$$1 + r^{ds} = \frac{1 + r^{dc}}{1 - \tau^s}. \tag{A.1.12}$$

Proposition 2. *The deposit rate spread τ^s is negatively related to the no-default probability p, indicating the higher the probability of shadow banks meeting their obligations, the lower the risk spread between deposit rates savers demand to place funds in shadow banks.*

We can now derive an expression for commercial bank deposits from equation A.1.9:

$$d^c = \frac{(1+r^{ds})(1-p)}{(1+r^{ds})p-(1+r^{dc})} d^s.$$

We furthermore get from equation A.1.7 that

$$d^s = \frac{\beta^s p}{1+\beta^s p} y - \frac{(1+r^{ds})\beta^s p + (1+r^{dc})}{(1+r^{ds})(1+\beta^s p)} d^c$$

and using equation A.1.9 we get

$$d^s = \frac{\beta^s p}{1+\beta^s p} y - \frac{(1+r^{ds})\beta^s p + (1+r^{dc})}{(1+r^{ds})(1+\beta^s p)} \frac{(1+r^{ds})(1-p)}{(1+r^{ds})p-(1+r^{dc})} d^s.$$

Solving for d^s yields

$$d^s \frac{(1+\beta^s p)[(1+r^{ds})p-(1+r^{dc})] + (1-p)[(1+r^{ds})\beta^s p + (1+r^{dc})]}{(1+\beta^s p)[(1+r^{ds})p-(1+r^{dc})]} = \frac{\beta^s p}{1+\beta^s p} y.$$

Defining the numerator of the term on the left-hand side as x, such that

$$x \equiv (1 + \beta^s p)[(1 + r^{ds})p - (1 + r^{dc})] + (1 - p)[(1 + r^{ds})\beta^s p + (1 + r^{dc})],$$

we get

$$x \equiv (1 + r^{ds})p(1 + \beta^s) - (1 + r^{dc})p(1 + \beta^s).$$

Plugging back in yields

$$d^s = \frac{\beta^s}{1+\beta^s}\frac{(1+r^{ds})p-(1+r^{dc})}{r^{ds}-r^{dc}}y. \tag{A.1.13}$$

Whenever equation A.1.10 holds with equality, savers are indifferent between commercial and shadow bank deposits, and place zero deposits with shadow banks according to equation A.1.13. By choosing adequate calibration, we will make sure that a share of funds is placed with shadow banks by savers, such that shadow banking exists in our model. Commercial bank deposits are thus given by

$$d^c = \frac{\beta^s}{1+\beta^s}\frac{(1+r^{ds})(1-p)}{r^{ds}-r^{dc}}y. \tag{A.1.14}$$

Finally, using equations A.1.13 and A.1.14 in constraint A.1.1, with equality we get

$$c = y(\frac{1}{1+\beta^s}). \tag{A.1.15}$$

Thus, the saver always consumes a fixed share of endowment y in the first period, which depends only on the discount factor β_S. A higher discount factor, i.e. a higher appreciation of utility derived from period-two consumption by the saver, reduces period-one consumption and results in a higher share of y being invested in deposits. Compared to a standard Fisher consumption/saving problem where there is only one intermediary and therefore one savings rate, the introduction of the second intermediary (shadow banks) changes the decision rules of the saver fundamentally. Now, the problem is not one of intertemporal saving vs. consumption anymore, where the single savings rate determines *in addition* to the discount factor the amount consumed in period one and the amount consumed in period two. Here, the difference in the two rates r^{dc} and r^{ds}, in combination with the default probability $1-p$, determines how much is invested in commercial vs. shadow bank, whereas the *total* amount of investment and of consumption are only dependent on the discount factor β^s.

Proposition 3. *The saver always consumes a fixed share of endowment y in the first period, which depends only on the discount factor β^s. Compared to a standard Fisher consumption/saving problem with only one intermediary and one savings rate, the introduction of the second intermediary (shadow banks) changes the decision rules of the saver: The difference in the two rates r^{dc} and r^{ds}, in combination with the default probability $1-p$, determines how much is invested in commercial vs. shadow bank, whereas the* total *amount of investment and of consumption are only dependent on the discount factor β^s.*

We know from the first-order condition for shadow bank deposits that

$$C^{+} = c\beta^{s} p(1 + r^{ds}),$$

such that

$$C^{+} = \beta^{s} p(1 + r^{ds}) y(\frac{1}{1 + \beta^{s}}). \tag{A.1.16}$$

Using equation A.1.8, we finally get

$$C^{-} = \tfrac{1-p}{p} \tfrac{1+r^{dc}}{r^{ds}-r^{dc}} C^{+},$$

such that

$$C^{-} = \frac{(1-p)(1+r^{dc})}{r^{ds} - r^{dc}} \beta^{s}(1 + r^{ds}) y(\frac{1}{1 + \beta^{s}}). \tag{A.1.17}$$

Borrowers

Borrowers fund consumption in period one by taking up loans from either commercial or shadow banks. For now, the two credit types act as perfect substitutes in the model, such that one can aggregate total credit holdings. The first period budget constraint of the borrower is thus given by

$$c^{b} \leq \underbrace{b^{c} + b^{s}}_{b}. \tag{A.1.18}$$

In the second period, borrowers receive an exogenous endowment y^{b} that they use to fund period-two consumption C^{b} and to repay period-one debt plus interest. The second-period budget constraint is thus given by

$$C^{b} + (1 + r^{bC}) b^{c} + (1 + r^{bS}) b^{s} \leq y^{b}$$

or, assuming interest on both homogeneous loan types to be equal,

$$C^{b} + (1 + r^{b}) b \leq y^{b}. \tag{A.1.19}$$

The maximization problem of the borrower is given by

$$\max_{c^{b}, C^{b}, b^{c}, b^{s}} u(c^{b}) + \beta^{b} u(C^{b}). \tag{A.1.20}$$

Plugging in constraints A.1.18 and A.1.19, the maximization yields

$$\max_{b^{c}, b^{s}} u(b) + \beta^{b} u(y^{b} - (1 + r^{b}) b) \tag{A.1.21}$$

which implies

$$1 + r^b = \frac{u'(c^b)}{\beta^b u'(C^b)}. \tag{A.1.22}$$

Assuming log-utility, we get

$$1 + r^b = \frac{C^b}{\beta^b c^b}. \tag{A.1.23}$$

Solving equation A.1.19 for b and plugging in equation A.1.18 yields the intertemporal budget constraint

$$c^b + \frac{C^b}{1 + r^b} \leq \frac{y^b}{1 + r^b}. \tag{A.1.24}$$

Equation A.1.24 states that the present discounted value of borrower consumption cannot exceed present discounted wealth. Solving A.1.23 for C^b and substituting in A.1.24 yields

$$c^b \leq \frac{y^b}{(1 + r^b)(1 + \beta^b)}, \tag{A.1.25}$$

indicating that period-one consumption decreases in the lending rate r^b and in the discount factor β^b. Combining equations A.1.18 and A.1.25 ultimately gives

$$b \leq \frac{y^b}{(1 + r^b)(1 + \beta^b)}. \tag{A.1.26}$$

From the intertemporal budget constraint A.1.24 we get with equality

$$C^b = y^b - (1 + r^b)c^b$$

such that

$$C^b = y^b \frac{1}{1 + \beta^b}. \tag{A.1.27}$$

Proposition 4. *An increase in the borrowing rate r^b decreases marginal utility from consumption in period one, as financing the marginal unit of period-one consumption (c^b) becomes more costly. Also, period-one consumption decreases in the discount factor β^b. Borrowers trade period one consumption for now relatively more attractive consumption in period two (C^b). In addition, present discounted value of borrower consumption cannot exceed present discounted wealth.*

Banks

Our model features two financial intermediaries (commercial banks and shadow banks) that are structurally different in terms of business model, market power, and regulatory coverage, but ultimately fulfill the same task, channeling funds from savers to borrowers. We first derive the benchmark case in which shadow banks act under perfect competition, with the main difference between the two banks being given by the degree of regulatory coverage. We then introduce a financial friction to the shadow banking sector leading to potentially positive returns on shadow bank intermediation.

Commercial Banks In this version of the model, there is a continuum of commercial banks that consist of two entities, a wholesale unit and a retail loan unit. The wholesale unit of the representative commercial bank holds net worth n^c and collects deposits d^c from savers on which it pays the deposit rate r^{dc}. The wholesale unit also issues wholesale loans b^c on which it earns the wholesale rate R^b. Furthermore, commercial banks have to fulfil a regulatory capital requirement, and face a cost whenever they hold a level of net worth relative to assets that deviates from the target capital-to-asset ratio.

The wholesale unit of the representative commercial bank thus faces two constraints it has to take into account when maximizing the discounted sum of real cash flow:

$$b^c = n^c + d^c \tag{A.1.28}$$

$$c^b = \frac{\kappa}{2}(\frac{n^c}{b^c} - \nu)^2 n^c. \tag{A.1.29}$$

The first constraint A.1.28 describes the balance sheet constraint, whereas the second constraint A.1.29 depicts the capital adequacy constraint, stating the quadratic cost whenever the capital-to-asset ratio deviates from the target value ν set by the regulating authority. The wholesale branch chooses deposits and loans to maximize profits, taking both constraints into account:

$$\max_{d^c, b^c} R^b b^c - r^{dc} d^c - \frac{\kappa}{2}(\frac{n^c}{b^c} - \nu)^2 (b^c - d^c). \tag{A.1.30}$$

The first-order condition gives

$$R^b = r^{dc} - \kappa(\frac{n^c}{b^c} - \nu)(\frac{n^c}{b^c})^2. \tag{A.1.31}$$

We assume that the retail branch of the bank has some market power and is thus able to set a markup when granting loans to borrowers. The retail unit takes on wholesale loans, differentiates them at no cost and resells them to borrowers. Thereby, the retail branch charges a markup μ^c on the wholesale borrowing rate.[5] The retail loan rate r^b is

[5] In the simplified version of the model, we assume the markup to be constant and additive. In the full DSGE model of chapter 4, the markup will be multipilicative, as in Gerali et al. (2010). This will then, as in the original model, introduce a positive correlation between the commercial bank spread and the policy rate.

thus given by

$$r^b = R^b + \mu^c \tag{A.1.32}$$

$$r^b = r^{dc} - \kappa(\frac{n^c}{b^c} - \nu)(\frac{n^c}{b^c})^2 + \mu^c. \tag{A.1.33}$$

Shadow Banks Shadow banks engage in a similar type of intermediation as commercial banks, i.e. they take on deposits from savers and lend them out to borrowers in period one and earn profits in period two on the intermediation activity. However, they differ from commercial banks in terms of competition and regulatory coverage. In contrast to commercial banks, shadow banks provide lending under perfect competition, and therefore take rates on the loan markets as given. For now, we assume a universal loan market where both commercial and shadow bank loans are not differntiable and thus shadow banks take the rate determined by commercial banks on the loan market as given, such that $r^b = r^{bC} = r^{bS}$. Furthermore, shadow banks are not subject to banking supervision but intermediate outside the regulated banking system. Thus, they do not have to comply to capital requirements, in contrast to commercial banks. Furthermore, as they are not part of the deposit insurance scheme set up by the regulator, placing deposits in shadow banks is risky from the point of savers. As depositors are aware of the issue, they will limit the amount of deposits they place in the shadow bank whenever shadow banks hold too little net worth. We therefore later introduce a moral hazard friction by allowing shadow banks to take on deposits and invest in loans in period one, and divert funds for private use before returns to savers materialize. This "running-away" problen has been introduced in Gertler and Karadi (2011).

Before introducing the moral hazard friction, we solve the frictionless benchmark optimization problem where shadow banks are as efficient as commercial banks, but are not affected by regulation. Shadow banks, like commercial banks, fund their lending activity b^s in period one by issuing shadow bank deposits d^s and fixed shadow bank capital n^s:

$$b^s = n^s + d^s. \tag{A.1.34}$$

Like regulated banks, they maximize their profits in period two, which are given by

$$\max_{d^s, b^s} (1 + r^b)b^s - (1 + r^{ds})d^s - b^s + d^s, \tag{A.1.35}$$

taking r^b and r^{ds} as given.

Benchmark Equilibrium

We are now able to define a benchmark equilibrium in which we assume no frictions in deposit or loan markets. Thus, the main difference between the two banks is regulatory coverage. Commercial banks are required to back a certain share of their assets (loans) by a minimum level of capital and face costs whenever they deviate from the requirement. Shadow banks, however, are unconstrained in their intermediation decisions. We will subsequently introduce the key financial friction we are implementing in the full DSGE model, i.e. a moral hazard problem existing between shadow banks and savers (Gertler and Karadi, 2011).

In total, we have 13 endogenous variables in the model: c, C^+, C^-, c^b, C^b, d^c, d^s, b^c, b^s, b, r^{dc}, r^{ds}, r^b.

We therefore need 13 equations to solve the model:

(i) Equations A.1.13 to A.1.17 solve the saver problem,

(ii) equations A.1.25 to A.1.27 solve the borrower problem, and

(iii) equations A.1.28 and A.1.33 solve the commercial bank problem.

(iv) The shadow bank problem A.1.35 is solved, see below.

(v) We furthermore have the securities market clearing condition

$$b = b^c + b^s \tag{A.1.36}$$

and

(vi) condition A.1.10 which has to hold such that negative and zero values for deposits placed are excluded.

We derive the equilibrium condition emerging from the shadow bank maximization problem given by equation A.1.35. We derive this condition by making one further assumption about the exclusion of (uninteresting) corner solutions where we have either no or implausibly high intermediation. Let an *interior equilibrium* be defined as a case where c, C^+, C^-, c^b, C^b, d^c, d^s, b^c, $b^s > 0$. We can then verify that, given an interior equilibrium, the shadow bank maximization problem gives

$$r^b = r^{ds}.$$

We can proof this by contradiction. Suppose we have an equilibrium with $r^b > r^{ds}$. In this case, the value of b^s that solves the shadow bank problem is $b^s = +\infty$. However, this value exceeds the maximum possible amount of borrowing for borrowers, which is given by $b^s \leq y^b$. In this situation, (iii) is not satisfied and we do not have an equilibrium. Suppose now we have an equilibrium candidate with $r^b < r^{ds}$. In this case, the value of shadow bank borrowing that solves the maximization problem A.1.35 is given by $b^s = 0$, which contradicts the assumption of an interior equilibrium as this would indicate that no intermediation via shadow banks takes place at all. Thus, we can conclude that if we have an interior equilibrium, we have $r^b = r^{ds}$.

Furthermore, due to equation A.1.33, we know that $r^b > r^{dc}$ whenever $\mu^c > 0$, and thus $r^{ds} > r^{dc}$ in this case, which is consistent with equation A.1.10.

Proposition 5 (Benchmark equilibrium)**.** *In a benchmark equilibrium in which we assume both banks to be identical in their structure, such that the only difference between commercial and shadow banks is regulatory coverage, we can verify that, given an interior equilibrium, the shadow bank maximization problem gives*

$$r^b = r^{ds}$$

such that shadow banks do not earn profits on intermediation in the benchmark case.

A.1.2 Financial Friction: Incentive Constraint

In the benchmark model, shadow banks were assumed to intermediate funds without frictions, which lead to the finding that they earn zero profits and solely intermediate funds efficiently whenever conditions for non-zero intermediation activity are met. We now introduce a financial friction to the shadow banker's problem that allows the shadow bank to earn a rent on intermediation activity, such that $r^b = r^{ds}$ does not hold in all circumstances anymore. We thereby rely on the incentive constraint framework as developed in Gertler and Karadi (2011).

Shadow Banks

The friction is located on the shadow bank deposit market, and the shadow banker faces two options now:

- **no-default:** The shadow bank issues deposits d^s in period one, combines them with capital n^s to lend out b^s. It earns profits $r^b b^s - r^{ds} d^s$ in period two. Whenever shadow banks do not default, we are in the case of the benchmark equilibrium.

- **default:** The shadow bank issues deposits d^s in period one, combines them with capital n^s to lend out b^s. In period two, the bank decides to take a share $\theta(1 + r^b)b^s$ for private benefit and not to pay the promised returns $(1 + r^{ds})d^s$ back to savers. Depositors thus only receive the part of returns not taken by the bank, i.e. $(1 - \theta)(1 + r^b)b^s$.

For the shadow bank, "running away" with some of the funds secretly and not repaying their obligations is only worthwile if it increases profits compared to behaving honestly. Thus, the bank will choose the "no-default" option if, and only if

$$(1 + r^b)b^s - (1 + r^{ds})d^s \geq \theta(1 + r^b)b^s$$

i.e. if the returns from behaving honestly exceed returns from defaulting. Rearranging yields the *incentive constraint* of the shadow banker

$$(1 - \theta)(1 + r^b)b^s \geq (1 + r^{ds})d^s. \tag{A.1.37}$$

Savers are aware of the potential moral hazard problem between them and the shadow banker. Thus, they would not place any deposit d^s in a shadow bank whenever constraint A.1.37 does not hold. If constraint A.1.37 would be violated, the respective shadow bank would pay a return on d^s that is below the market return r^{ds}. The shadow bank problem in equation A.1.35 is thus changed to

$$\max_{d^s, b^s} (1 + r^b)b^s - (1 + r^{ds})d^s - b^s + d^s \tag{A.1.38}$$

subject to constraint A.1.37.

Incentive Constraint Equilibrium

Introducing the moral hazard problem between savers and shadow banks changes the maximization problem of shadow banks. Thus, the resulting equilibrium differs from the benchmark case.

In total, we still have 13 endogenous variables in the model: c, C^+, C^-, c^b, C^b, d^c, d^s, b^c, b^s, b, r^{dc}, r^{ds}, r^b.

The 13 equations to solve the model are given by:

(i) Equations A.1.13 to A.1.17 solve the saver problem,

(ii) equations A.1.25 to A.1.27 solve the borrower problem, and

(iii) equations A.1.28 and A.1.33 solve the commercial bank problem.

(iv) The shadow bank problem A.1.38 is solved, see below.

(v) We furthermore have the securities market clearing condition

$$b = b^c + b^s \tag{A.1.39}$$

and

(vi) condition A.1.10 which has to hold such that negative values for deposits placed are excluded.

The key distinction between the benchmark and the incentive friction equilibrium depicts the possibility of two types of equilibria instead of one, one type where the spread $r^b - r^{ds}$ is equal to zero (as in the benchmark case) and another type with $r^b > r^{ds}$. We can rewrite constraint A.1.37 such that

$$(1-\theta)(1+r^b)n^s \geq [\theta(1+r^b) - (r^b - r^{ds})]d^s. \tag{A.1.40}$$

In the case where the shadow banker chooses the no-default option, we know that he makes zero profits and thus the equilibrium value of shadow bank deposits d^s is determined by savers, i.e. by equation A.1.13. Furthermore, we know that $r^b = r^{ds}$. Plugging in the derived term for d^s in equation A.1.40 therefore yields

$$(1-\theta)(1+r^b) \geq [\theta(1+r^b) - (r^b - r^{ds})]\tfrac{\beta^s}{1+\beta^s}\tfrac{(1+r^{ds})p-(1+r^{dc})}{r^{ds}-r^{dc}}\tfrac{y}{n^s}.$$

Define

$$B \equiv \tfrac{\beta^s}{1+\beta^s}\tfrac{(1+r^{ds})p-(1+r^{dc})}{r^{ds}-r^{dc}}\tfrac{y}{n^s}$$

such that

$$(1-\theta)(1+r^b) \geq [\theta(1+r^b) - (r^b - r^{ds})]B$$

and thus

$$0 \leq \theta \leq \frac{1}{1+B}. \tag{A.1.41}$$

Given our assumptions on the spread between the two deposit rates, equation A.1.11, and on the non-negativity of model paramters p, β_S and endowments y and n^s, we know that $B > 0$. Whenever θ is relatively small, i.e. the divertible share of assets is small, and when net worth n^s is relatively large, constraint A.1.40 is satisfied and shadow banks do not default and earn zero profits. In this case, the incentive friction and the benchmark equilibrium coincide.

Whenever condition A.1.40 is violated for $r^b = r^{ds}$ and the no-default equilibrium value of d^s, we know that the amount of deposits savers want to place exceeds the amount consistent with the incentive constraint. From the expression of shadow bank deposits demanded by savers, equation A.1.13, we know that d^s is increasing in r^{ds}. Thus, to reach equilibrium at a lower value of d^s as in the case where constraint A.1.40 holds, r^{ds} has to decrease such that we find an equilibrium with $r^b > r^{ds}$.

To find the equilibrium value of d^s, we introduce the term $d^{s,S}$ to indicate the level of deposits shadow banks want to supply, whereas the term d^s still describes the demand for shadow bank deposits by savers, given by equation A.1.13. Whenever $r^b > r^{ds}$, we know that shadow bank profits are strictly increasing in $d^{s,S}$, such that shadow banks will provide the maximum amount of deposits feasible under the incentive constraint A.1.40. Solving the constraint for $d^{s,S}$ with equality gives:

$$d^{s,S} = \frac{(1-\theta)(1+r^b)}{r^{ds} - (1-\theta)r^b + \theta} n^s. \tag{A.1.42}$$

Thus, $d^{s,S}$ is a function of r^{ds} defined over the interval

$$((1-\theta)r^b - \theta, r^b],$$

as we set the assumptions of strictly positive deposits and a non-negative spread $r^b - r^{ds}$. As r^{ds} converges towards the upper limit of the interval, we get

$$d^{s,S} \rightarrow \tfrac{1-\theta}{\theta} n^s.$$

We see from equation A.1.42 that $d^{s,S}$ is strictly increasing when r^{ds} decreases and approaches $+\infty$ as r^{ds} converges towards to lower limit of the interval, $(1-\theta)r^b$. At the same time, deposit demand by savers, d^s, is strictly decreasing as r^{ds} falls towards $(1-\theta)r^b$ and is a well-defined and positive number under the assumptions set on rates and model parameters. Given that

$$d^s > d^{s,S} \text{ as } r^{ds} \rightarrow r^b$$

$$d^s < d^{s,S} \text{ as } r^{ds} \rightarrow (1-\theta)r^b$$

and given the continuity and monotonicity of functions A.1.13 and A.1.42 we know that a unique $r^{ds} \in ((1-\theta)r^b, r^b]$ exists such that $d^s = d^{s,S}$. To find the equilibrium shadow bank deposit rate, we have to equate shadow bank deposit demand (equation A.1.13) with supply of deposits by shadow banks (equation A.1.42) and solve for r^{ds}:

$$\frac{\beta^s}{1+\beta^s} \frac{(1+r^{ds})p - (1+r^{dc})}{r^{ds} - r^{dc}} y = \frac{(1-\theta)r^b}{r^{ds} - (1-\theta)r^b} n^s. \tag{A.1.43}$$

Thus, whenever condition A.1.41 is satisfied, the incentive constraint friction and the benchmark equilibrium coincide. If condition A.1.41 is violated, the incentive constraint friction equilibrium is characterized by $r^b > r^{ds}$ and a unique value for r^{ds} that solves the market for shadow bank deposits can be found.

Proposition 6 (Incentive constraint equilibrium)**.** *Whenever the share of divertible funds θ is sufficiently small or shadow bank net worth n^s is sufficiently large, the incentive constraint does not bind and the benchmark and financial friction equilibrium coincide. In this case, shadow banks do not earn profits. Otherwise, the incentive constraint is binding, and shadow banks earn a positive spread on intermediation, i.e. $r^b > r^{ds}$.*

A.1.3 Financial Friction: Borrowing Constraint

So far, we discussed potential implication from an incentive constraint friction for shadow banks on deposit markets but treated conditions on loan markets in a rather rudimentary fashion. We simply assumed loans from both shadow banks and commercial banks to be perfect substitutes both intermediaries provide to the same type of borrowers. Consequently, the rates charged on both shadow bank and commercial bank loans turned out to be identical.

We therefore introduce heterogeneity in loan markets and motivate differences in loan rates and volumes by a different degree of regulatory coverage in the two sectors: Whereas the regulator can directly affect the minimum amount of collateral a commercial bank demands from potential borrowers, we assume that such loan-to-value (LTV) ratios cannot be introduced in the shadow banking sector. With respect to shadow bank lending, any constraint borrowers face emerges without direct regulation but only depends indirectly on commercial bank regulation as well as on the underlying risk with respect to the value of the collateral asset the borrower can provide. To do so, we introduce a second friction to the model which is located between the borrower and the intermediaries, affecting lending of both shadow banks and commercial banks. We follow Iacoviello (2005) and require borrowers to pose collateral to any bank whenever they want to borrow funds. In our model, both the commercial and the shadow bank require a certain share of their lending b^c and b^s to be backed by collateral, whereas commercial bank requirements are affected by direct regulation.

Borrowers

As in section A.1.1, borrowers can acquire funding from both commercial and shadow banks. However, we introduce two additional constraints on borrowing, each related to one type of bank. Now, both banks lend funds only against some collateral the borrower has to provide. To introduce collateral to the model, we assume that borrowers, on top of the resource endowment y^b they receive at period two, are holders of an externally given capital good k that they receive at the beginning of period one. In this simple version of the model, k depicts some wealth endowment that borrowers hold but cannot use for consumption or sell/rent out on a secondary market.[6] They simply own the stock of k, which is only of value for them as it is accepted by intermediaries as collateral. Whereas the borrowers receive the endowment k in the first period, some uncertainty about the capital holdings in period two, K, remain. More precisely, we assume that due to some external disturbances, some share of period-one capital k could be destroyed in period two, and we assume two potential outcomes for the collateral holdings of the borrower in the second period:

$$K = \begin{cases} k^+ = k & \text{with probability } p^b \\ k^- & \text{with probability } 1 - p^b. \end{cases}$$

We assume that whenever the bad state occurs in period two, borrowers suffer from some destruction of capital, such that $k^- < k$. The probability for remaining in the good state where no capital is destructed in period two is given by p^b. The expected period-two holdings of capital are thus given by

$$E\{K\} = p^b k + (1 - p^b)k^-. \tag{A.1.44}$$

When granting loans to borrowers, each intermediary can claim a share of collateral in case the borrower cannot repay his funds. However, we assume heterogeneity in the way the collateral claims emerge. In the case of commercial banks, we assume that borrowers have to fulfill an exogenous loan-to-value ratio $m^E \in \{0, 1\}$ such that each unit of lending taken on in period one plus respective interest payments due in period two must be backed by a minimum amount of capital. While deciding on the level of m^E, the prudential regulator is aware of the fact that some capital might be destructed in period two, and therefore sets a limit on the amount commercial banks can lend to borrowers based on the expected level of collateral available in period two:

$$(1 + r^{bC})b^c \leq E\{K\}. \tag{A.1.45}$$

Equation A.1.45 states that borrowers can only borrow up to the limit to which their debt with commercial banks and the agreed interest payments in period two are backed by the expected amount of capital they hold in period two. By rewriting equation A.1.45 such that

$$(1 + r^{bC})b^c \leq \frac{E\{K\}}{k} k \tag{A.1.46}$$

[6] In the complete DSGE model of section 4.2, entrepreneurs which act as borrowers can provide physical capital they use in production as collateral to banks.

we get the commercial bank collateral constraint

$$(1 + r^{bC})b^c \leq m^E k \tag{A.1.47}$$

with $m^E = \frac{E\{K\}}{k}$. As the expected value of collateral held in period two depends on the probability p^b, the loan-to-value ratio demanded by the regulator depends on the probabilitiy of being in the good state. A higher likelihood of being in the good state where no capital is destroyed in period two raises the expected value of collateral $E\{K\}$, and therefore borrowers can aquire more funds relative to period-one capital holdings, as the loan-to-value ratio m^E rises.

For shadow bank lending, we do not assume an explicit regulatory loan-to-value ratio that borrowers have to adhere to. We assume that even though aware of the risk of the occurence of the low-capital state in period two, shadow banks are willing to provide funds beyond the level borrowers can acquire from commercial banks. Thus, whereas in expectation all lending by commercial banks will be backed with collateral K in period two, some share of shadow bank loans might not be backed by collateral and shadow bankers are aware of the risk that they will not be able to draw on borrower collateral in period two. They thus face potential losses in period two and are only willing to provide extra funding beyond the level backed by the expected period-two value of collateral in return for higher interest on their loans in comparison to commercial banks. The loan rate spread will depend on the probability of ending up in the high-capital regime p^b:

$$1 + r^{bS} = \frac{1 + r^{bC}}{p^b}. \tag{A.1.48}$$

Due to the higher rate charged on shadow bank loans whenever $0 < p^b < 1$, borrowers will turn to commercial banks first to acquire funding and only turn to shadow banks when they have reached the maximum amount of funding they can acquire under regulation m^E.[7] By receiving adequate compensation, shadow banks are willing to provide lending up to total capital holdings in period one, and given that borrowers only tap on shadow bank funding once the limit with commercial bank funding is reached, the shadow bank borrowing constraint is given by

$$(1 + r^b)b^s \leq k - E\{K\}$$

[7] Generally, borrowers could decide not to tap on the full borrowing capacity and not turn to shadow bank borrowing if their expected capital holdings are large enough to back their demand for lending with commercial bank credit. In this case, there would be no need for shadow banking and all loan demand could be met by commercial banks. We assume that the marginal benefit from period-one consumption is sufficiently large in relation to interest rate charges by shadow banks, such that acquiring further funds from shadow banks is profitable for borrowers.

or

$$(1+r^b)b^s \leq (1-\tfrac{E\{K\}}{k})k$$

or

$$(1+r^b)b^s \leq (1-m^E)k. \tag{A.1.49}$$

In any case, borrowers will be able to borrow against the total amount of capital k they hold in period one, independent of the risk of capital losses in period two. Whenever commercial banks refuse to provide funding beyond the expected value of period-two capital, $E\{K\}$, shadow banks will step in and provide more risky funding, $k - E\{K\}$. In this way, shadow bank lending now resembles some form of "subprime lending". Such risky lending to borrowers poses a major threat to financial stability and played a major role during the global financial crisis of 2007/2008.[8] The budget constraints for periods one and two are thus given by

$$c^b \leq b^c + b^s \tag{A.1.50}$$

and

$$C^b + (1+r^{bC})b^c + (1+r^{bS})b^s \leq y^b + k. \tag{A.1.51}$$

The maximization problem of the borrower is now given by

$$\max_{c^b, C^b, b^c, b^s} \; u(c^b) + \beta^b u(C^b) \tag{A.1.52}$$

or

$$\max_{b^c, b^s} u(b^c + b^s) + \beta^b u(y^b + k - (1+r^{bC})b^c - (1+r^{bS})b^s) \tag{A.1.53}$$

s.t. constraints A.1.47 and A.1.49. From constraint A.1.49 we know that

$$\frac{(1+r^{bS})b^s}{1-m^E} \leq k \tag{A.1.54}$$

and thus, assuming equality of constraints A.1.47 and A.1.49[9], we get

$$(1+r^{bC})b^c = m^E \frac{1+r^{bS}}{1-m^E} b^s \tag{A.1.55}$$

[8]See Christiano et al. (2018).

[9]We assume that borrowers tap on the complete borrowing capacity, as we will assume the respective constraints to be binding in the steady state of the DSGE model described in chapter 4.2.

or

$$b^c = \frac{m^E}{1-m^E} \underbrace{\frac{1+r^{bS}}{1+r^{bc}}}_{\frac{1}{p^b}} b^s. \tag{A.1.56}$$

The maximization problem is thus given by

$$\max_{b^s} u(\frac{m^E}{1-m^E}\frac{1}{p^b}b^s + b^s) + \beta^b u(y^b + k - (1+r^{bC})\frac{m^E}{1-m^E}\frac{1}{p^b}b^s - (1+r^{bS})b^s). \tag{A.1.57}$$

Again, we assume log-utility such that the first-order condition yields

$$C^b = \beta^b[\frac{(1+r^{bC})\frac{1}{p^b}(\frac{m^E}{1-m^E}+1)}{\frac{m^E}{1-m^E}\frac{1}{p^b}+1}]c^b. \tag{A.1.58}$$

By using constraints A.1.47, A.1.49 and A.1.50 as well as equation A.1.56, we can simplify such that

$$C^b = \beta^b k. \tag{A.1.59}$$

Using this expression for C^b in the period-two budget constraint A.1.51, assuming equality and using condition A.1.48 and equation A.1.56 again, yields

$$b^s = [y^b + k(1-\beta^b)]\frac{p^b(1-m^E)}{1+r^{bC}}. \tag{A.1.60}$$

Plugging equation A.1.60 in equation A.1.56, we can derive

$$b^c = \frac{m^E}{1+r^{bC}}[y^b + k(1-\beta^b)]. \tag{A.1.61}$$

Finally, we can derive an expression for period-one consumption c^b by combining equation A.1.61 and the period-one budget constraint A.1.50:

$$c^b = \frac{m^E + p^b(1-m^E)}{1+r^{bC}}[y^b + k(1-\beta^b)]. \tag{A.1.62}$$

Borrowing Constraint Equilibrium

Having introduced a second set of financial frictions, we are now able to state the equilibrium conditions for the model featuring both an incentive constraint problem on the deposit market as well frictions arising from collateral constraints on the loan market.

By introducing heterogeneity to loan markets, the model now features interest rates on both shadow bank and commercial bank loans – r^{ds} and r^{dc}, respectively – instead of a single loan rate as in the previous section. Thus, the model now features 14 endogenous variables: c, C^{+}, C^{-}, c^{b}, C^{b}, d^{c}, d^{s}, b^{c}, b^{s}, b, r^{dc}, r^{ds}, r^{bC}, r^{bS}.

The 14 equations solving the model are now given by:

(i) Equations A.1.13 to A.1.17 solve the saver problem,

(ii) equations A.1.59, to A.1.62 solve the borrower problem, and

(iii) equations A.1.28 and A.1.33 solve the commercial bank problem.

(iv) The shadow bank problem A.1.35 is solved as in section A.1.2, assuming a binding incentive constraint.

(v) We furthermore have the securities market clearing condition

$$b = b^{c} + b^{s} \tag{A.1.63}$$

and

(vi) condition A.1.10 which has to hold such that negative values for deposits placed are excluded.

The results for borrowers derived in the section A.1.3 can be summarized as in proposition 7.

Proposition 7 (Borrowing constraint equilibrium)**.** *Whenever regulators set the loan-to-value ratio m^{E} equal to the expected value of period-two capital holdings, $E\{K\}$, borrowers will use period-one collateral not reserved for commercial bank loans and turn to shadow banks, once the borrowing capacity for commercial bank funds is exhausted. As shadow bank lending is not necessarily backed by collateral, the spread between shadow bank and commercial bank loan rates is positive.*

A.1.4 Evaluation

Deposit Market Equilibrium: The Incentive Constraint Friction

We now evaluate the effects of changes in capital requirements in the benchmark model and how introducing the incentive constraint to the shadow bank problem affects responses to regulation. In the analysis, we evaluate the reactions on – and interplay between – the two markets for shadow bank and commercial bank deposits whenever capital requirements are changed. Our parameterization ensures that a positive amount of deposits is placed with shadow banks and that the wholesale units of commercial banks operate at the capital requirement ν in the benchmark equilibrium. For the incentive constraint model, we choose parameters such that the friction and benchmark equilibria do not coincide. When introducing the incentive constraint friction, we calibrate θ, and set all other parameters as in the benchmark case, see table A.1.[10] We also choose parameters such that commercial banks operate at the regulatory capital requirement in equilibrium, such that the positive spread earned on intermediation by commercial banks is determined by the markup retail banks can charge, μ^c alone (equation A.1.33).

Table A.1: Parameter Values Benchmark Model

Parameter	**Value**
p	0.9951
β^s	0.95
β^b	0.9
n^c	0.02
n^s	0.0011
y	1
y^b	1
κ	100
ν	0.075
μ^c	0.01
θ	0.5

Note: Calibration following in part chapter 4.

In figure A.1, we report equilibrium values of endogenous variables for a grid of values of the capital requirement ν, both for the benchmark model (blue solid line) and the incentive constraint model (red dashed line) described above. In both versions of the model, the total amount of lending is determined on the loan market only by demand for loans from borrowers, and thus not (directly) affected by capital requirements. The shares of lending undertaken by commercial and shadow banks, however, are affected by the level of capital requirements set by the regulator for commercial banks, with increasing capital requirements resulting in an increasing share of shadow bank lending. We now evaluate both deposit markets in detail to shed more light on the causes of the shift towards shadow bank deposits whenever commercial bank capital requirements increase. Figures A.2 and A.3 depict both deposit markets in a stylized fashion. On both markets, savers *supply* deposits according to an upward-sloping supply curve, as indicated by equations A.1.13 and A.1.14. Banks *demand* deposits, whereas commercial banks are characterized by

[10]We set most parameters close to the values later used in the DSGE model calibration. For deviating parameters, for instance the shadow bank net wort n^s and the commercial bank capital adjustemnt cost κ, values are chosen to get interpretable results in the simulation exercise.

a downward-sloping demand curve, as indicated by equation A.1.33 and assuming that borrowing b^c and deposits d^c move in the same direction (figure A.3). In the shadow bank deposit market described by the benchmark model, we know that $r^b = r^{ds}$ and therefore shadow bank deposit demand is characterized by a horizontal demand curve, d^s_{d1}.

According to equation A.1.33, an increase in capital requirements widens the gap between the actual level of capital to assets the commercial bank holds and the regulatory capital-to-asset ratio, if we assume that commercial banks originally operated with capital-to-asset ratios equal to the requirement.[11] In this case, the marginal cost of intermediation, indicated by the right-hand side of equation A.1.31, rises. To reduce marginal costs, commercial banks reduce their lending, b^s, and, given bank capital n^c to be fixed in the short run, reduce their demand for household deposits. Consequently, the deposit demand curve d^c_{d1} of commercial banks shifts to the left in figure A.2 (d^c_{d2}). In return, deposit levels and rates fall with rising capital requirements, as observed in the simulation results in figure A.1. Thus, higher capital requirements for commercial banks, by raising marginal costs of intermediation, result in lower lending activity and ultimately squeeze marginal profits of commercial banks.

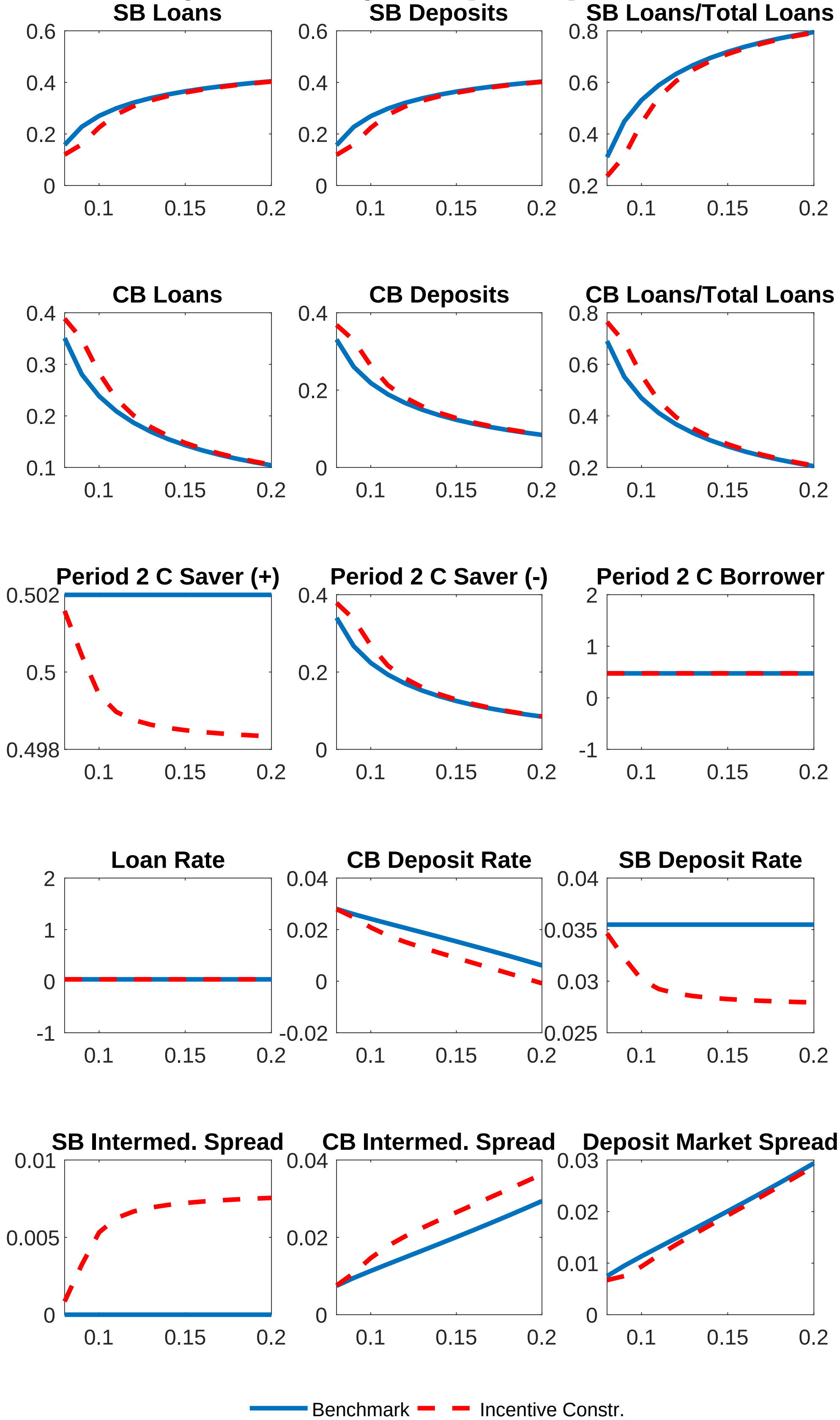
Turning to the market for shadow bank deposits (figure A.3), we see that a relative decrease in commercial bank intermediation due to tighter regulation is compensated by an increase in shadow bank intermediation, as the total demand for bank loans, b, is determined independently from the deposit market movements and not affected by regulatory changes in the commercial banking sector.[12] Falling rates on commercial bank deposits increase the deposit rate spread $r^{ds} - r^{dc}$, and, according to equation A.1.13, raise savers supply of deposits, d^s, resulting in a shift of the deposit supply curve d^s_{s1} to the right in figure A.3 (d^s_{s2}). As a consequence, shadow bank deposits, and ultimately lending, increase whenever capital requirements for commercial banks are raised.

We now consider the impact of introducing the incentive constraint friction in the model on the markets for commercial and shadow bank deposits. As stated in proposition 5, whenever condition A.1.41 is violated, as in the cases we evaluate, the spread on shadow bank intermediation, $r^b - r^{ds}$ turns out to be positive. Therefore, shadow banks are no longer characterized by a horizontal, but by a downward-sloping demand curve d^s_{d2} when the incentive constraint friction is introduced. By introducing a positive spread between

[11] We do not consider cases where $\frac{n^c}{b^c} \geq \nu$ for two reasons. First, whenever $\frac{n^c}{b^c} \geq \nu$, commercial banks would hold more capital than required by the regulator and thus hold inefficiently high levels of costly capital compared to deposits, which would only be justfied in the case of precautionary motives, which we do not consider here. Furthermore, according to equation A.1.33, $\frac{n^c}{b^c} \geq \nu$ would indicate a negative spread between commercial bank lending and deposit rates, in which case optimal intermediation by commercial banks would be zero.

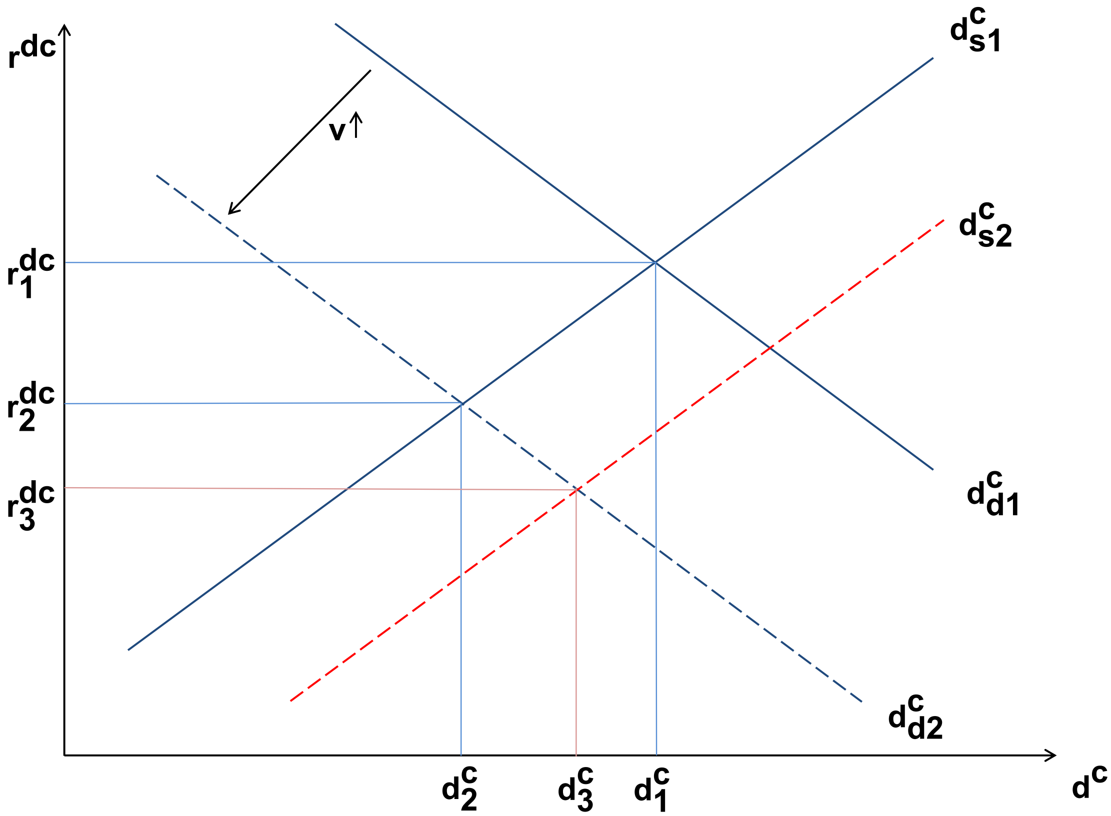
[12] In the full model presented in section 4.2, loan demand will be determined by the real side of the economy, namely by production decisions of entrepreneurs.

Figure A.1: Changes in Capital Requirements



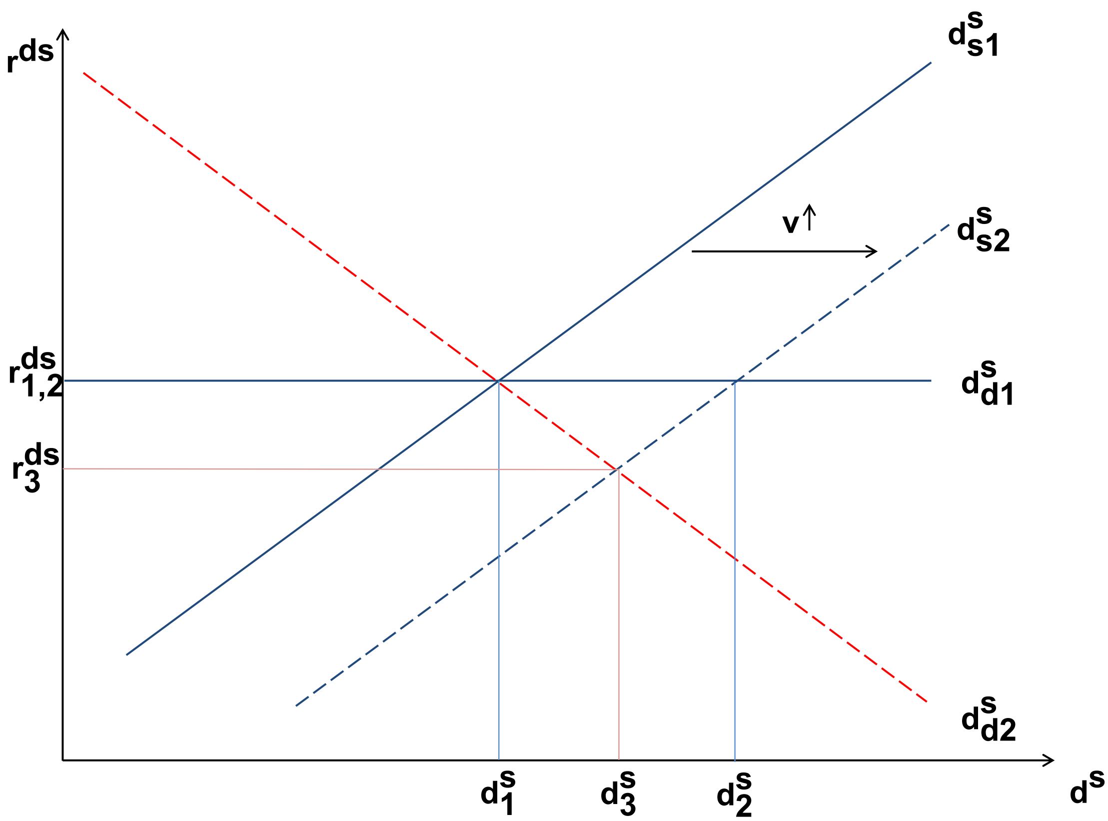
Note: Levels of model variables for different values of capital requirements ν.

Figure A.2: Commercial Bank Deposit Market



Note: Stylized commercial bank deposit market. An increase in capital requirements ν shifts bank deposit demand (d^c_{d1}) according to equation A.1.33.

Figure A.3: Shadow Bank Deposit Market



Note: Stylized commercial bank deposit market. An increase in capital requirements ν shifts bank deposit demand (d^c_{d1}) according to equation A.1.13.

loan and deposit rates, shadow banks are, as their commercial counterparts, willing to accept more deposits whenever the rate they have to pay on deposits r^{ds} decreases. On the shadow bank deposit market, as depicted in figure A.3, the same shift of deposit supply due to tighter commercial bank regulation still results in an increase in shadow bank deposits. However, the level of deposits is relatively lower as induced by a similar shift in the benchmark model, given that the original equilibrium was the same. Furthermore, and as indicated by proposition 5, the rate on shadow bank deposits r^{ds} is now lower than r^b; both increasing shadow bank deposits and decreasing deposit rates are again indicated by simulations in figure A.1.

The fall in shadow bank deposit rates once the incentive constraint friction is introduced, ceteris paribus, reduces the spread between shadow and commercial bank deposit rates, $r^{ds} - r^{dc}$ compared to the benchmark case. Therefore, commercial bank deposits become relatively more attractive in the financial friction case, such that commercial bank deposit supply by savers shifts to the right in figure A.2. Increasing capital requirements still induce the same shift of deposit demand by commercial banks as in the benchmark case (d^c_{d2}). However, the now contemporaneously induced shift in commercial bank supply of savers (d^c_{s2}), driven by developments in the shadow bank deposit market (figure A.3), ultimately leads to a new equilibrium in the commercial bank deposit market. Deposits still fall due to an increase in capital regulation, but to a lower extent than in the benchmark case. Furthermore, commercial bank deposit rates fall by more whenever capital requirements are raised in the financial friction model compared to the benchmark. Again, simulations in figure A.1 highlight these developments.

Overall, increasing capital requirements for commercial banks provide some scope for leakage of financial intermediation towards shadow banks in the two-period model. However, the magnitude of credit leakage is somewhat reduced when we pose restrictions on shadow banks, i.e. introduce a moral hazard problem between shadow banks and savers. In this case, interest rate adjustments cushion some of the quantity effects relative to the benchmark case. In our setup, relative changes on deposit markets due to regulation are transmitted, via balance sheets of intermediaries, to the credit markets, which we assume to be homogeneous in the setup.

Loan Market Equilibrium: The Borrowing Constraint Friction

In section A.1.4, we discussed the effects of changes in capital requirements in the benchmark case without financial frictions and evaluated how introducing an incentive constraint in the spirit of Gertler and Karadi (2011) affects equilibrium values. For the sake of brevity, we do not again discuss the model mechanism of how changes in capital requirements affect deposit markets, as the key mechanism is not affected by the introduction of heterogeneity in the loan market.

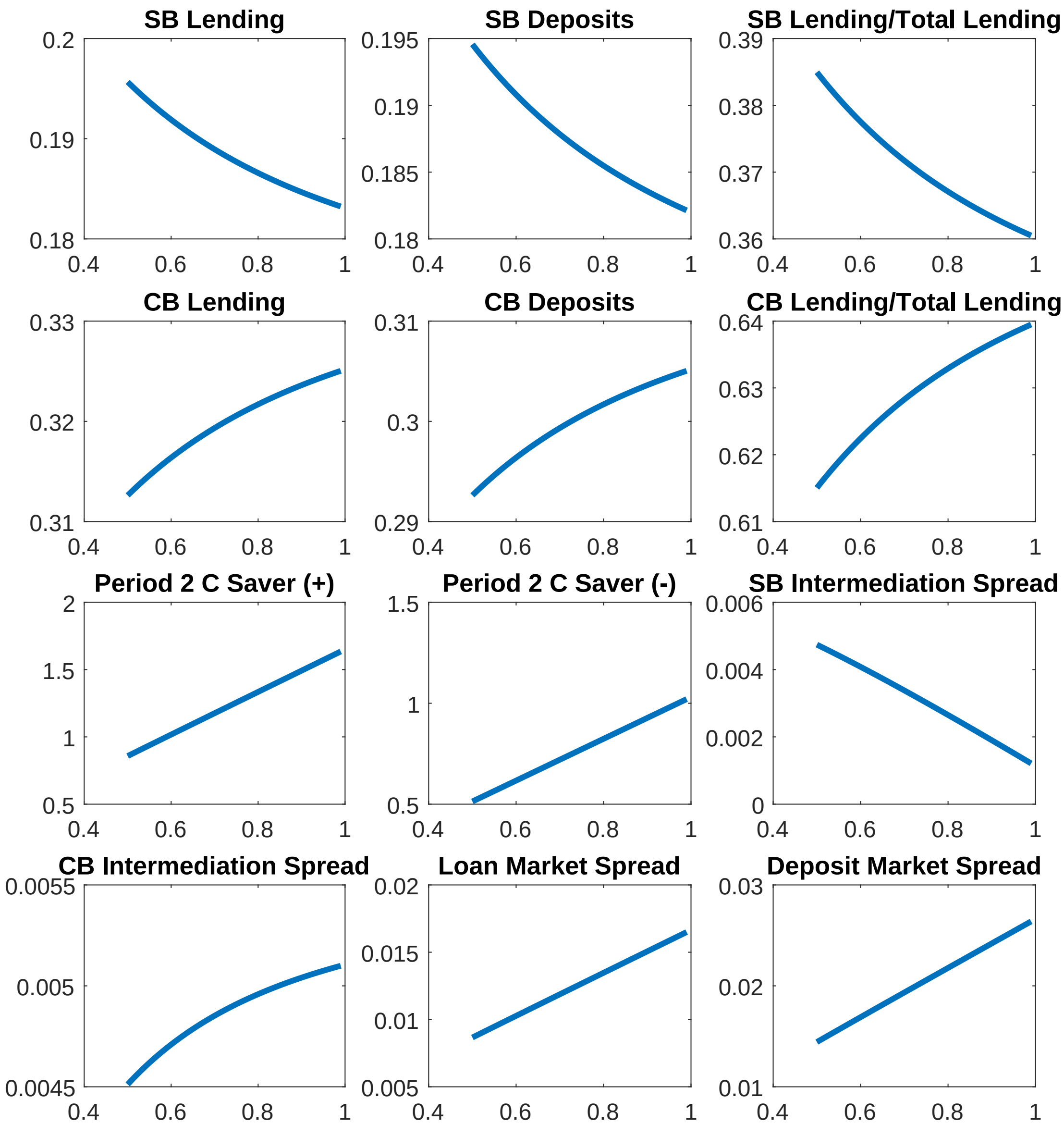
In the following, we study how changes in LTV ratios for commercial banks, the second macroprudential tool that we introduced in the previous section, affect model variables in equilibrium. In figure A.4, we show simulation results for changes in the LTV ratio over a grid of 50 to 100 percent. As we linked the level of the LTV ratio to the probability of being in the high-value collateral state, an increase in the LTV ratio leads to an increase in the borrowers' probability to have high collateral value at hand in the second period. We again set calibration as in table A.1, and assume the probability p^b of borrowers ending up with a low value of collateral k^- in period two to be equal to the probability p of savers being confronted with a low outcome for period-two consumption, C^-. In this sense, we can assume that both events are related: whenever borrower collateral turns out to be of low value, shadow bank loans will surely not be backed by collateral, and in the model, they consequently default. In this case, savers cannot reclaim their investments and therefore only receive returns on deposits placed with commercial banks, which ultimately reduces their consumption possibilities in period two.

As described by equations A.1.60 and A.1.61, an increase in the LTV ratio increases lending of commercial banks and reduces shadow bank lending. An increase in the commercial bank LTV ratio allows borrowers to draw more extensively on funding provided by commercial banks as constraint A.1.47 is relaxed. As shadow banks charge higher interest due to the collateral risk they face, increasing the LTV ratio raises borrower demand for commercial bank credit and crowds out shadow bank lending. Ceteris paribus, an increase in demand for commercial bank loans raises the rate charged on commercial bank lending, and the intermediation spread for commercial banks, $r^{bC} - r^{dc}$, widens. In contrast, demand for shadow bank loans decreases, and both the volume of shadow bank lending, b^s, and the spread earned by shadow banks on intermediation, $r^{bS} - r^{ds}$, decrease.

At the same time, also credit supply is affected by a changes in regulation. Raising the LTV ratio for commercial banks also increases the amount of lending commercial banks can provide, and they will do so if the spread they earn on intermediation is positive. This dampens the positive effect of increasing demand for commercial bank credit on commercial bank loan rates. Contemporaneously, shadow bankers know that borrowers will prefer commercial bank lending due to the lower rate charged, and also anticipate that higher levels of LTVs reduce the share of borrowers' collateral they can claim in case of default, which is given by $(1-m^E)k$ according to constraint A.1.49. Consequently, shadow bankers reduce their credit supply, which mitigates the increase in the shadow bank loan rate, ceteris paribus.

In reality, whether the spread between the rates charged on the two loan markets, $r^{bS} - r^{bC}$, should increase or not whenever commercial bank regulation is changed, is not

Figure A.4: Changes in Commercial Bank LTV Ratio



Note: Levels of model variables for different values of the commercial bank loan-to-value ratio m^E.

clear a priori and crucially depends on the function of shadow banks and the type of borrowers attracted. For instance, if shadow banks are perfect substitutes for commercial bank lending, indicating that business models and customer bases are similar, one would expect the spread between rates charged on shadow bank and commercial bank loans to decrease. Lowering commercial bank regulation by raising LTV ratios should then result in a decrease in the shadow bank lending rate, as customers prefer loans from regulated and safe banks, at least in relative terms.

However, whenever the asset structure of commercial banks' and shadow banks' balance sheets is differently affected by changes in regulation, the development of loan rates might change. For instance, if shadow banks are primarily engaged in subprime lending, lower regulatory standards for commercial banks could foster adverse selection: Borrowers who were not able to receive funding from commercial banks under previously tighter regulatory standards potentially turn to safer and cheaper commercial bank lending once regulation is eased. Due to such crowding-in of borrowers to the commercial banking sector, the risk profile of borrowers in the pool of shadow bank borrowers could deteriorate. Furthermore, as relatively solvent subprime borrowers turn to commercial banks, also the average quality of borrowers in the pool of shadow bank borrowers deteriorates. As a consequence, both commercial and shadow banks potentially charge higher rates on average to compensate for the increasing level of risk. Depending on the relative increase in risk premia, the spread between shadow bank and commercial bank loan rates potentially widens.

Thus, the development of the spread between the rates charged on the two loan markets, $r^{bS} - r^{bC}$, depends on both borrower and banking conditions, or, turning to our model, on the steepness of the supply and demand curves on both deposit markets, as well as on the parameterization. With the chosen specification, the model described in this section appears to be a representation of the second case, as the loan market spread increases in response to higher LTV ratios.[13] We furthermore observe that developments on the loan market are transmitted towards deposit markets, as the deposit rate spread $r^{ds} - r^{dc}$ rises: A higher share of lending conducted by commercial banks in response to lower regulatory burden increases the supply of deposits by commercial banks, as they require – with fixed bank capital in the short run – external funds to engage in intermediation. This depicts a rightward shift of the deposit supply curve in figure A.2, and a consequent fall in the commercial bank deposit rate. Conversely, shadow bankers reduce their demand for external funding, as they are less engaged in intermediation whenever LTV ratios for commercial banks are raised. Consequently, the shadow bank deposit supply curve in

[13] As we rely on a shortcut in our DSGE model where we do not explicitly introduce heterogeneous loan markets, the conditions of the model extension presented in this section are not directly translatable to the DSGE model introduced in section 4.2.

figure A.3 shifts to the left, and the shadow bank deposit rate increases.

A.2 Appendix: The Full Non-Linear DSGE Model

A.2.1 Households

The representative patient household i maximizes the expected utility

$$E_0 = \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\varepsilon_t^z \log[c_t^P(i) - a^P c_{t-1}^P] - \frac{l_t^P(i)^{1+\phi^P}}{1+\phi^P} \right] \tag{A.2.1}$$

which depends on current individual consumption $c_t^P(i)$ as well as lagged aggregate consumption c_t^P and working hours l_t^P. Labor disutility is parameterized by ϕ^P. Preferences are subject to a disturbance affecting consumption, ε_t^z. Household choices are undertaken subject to the budget constraint:

$$c_t^P(i) + d_t^{P,C}(i) + d_t^{P,S}(i) \leq w_t l_t^P(i) + (1+r_{t-1}^{dC})d_{t-1}^{P,C}(i) + (1+r_{t-1}^{dS})d_{t-1}^{P,S}(i) + t_t^P(i). \tag{A.2.2}$$

The flow of expenses includes current consumption and real deposits to be made to both commercial and shadow banks, $d_t^{P,C}(i)$ and $d_t^{P,S}(i)$. Due to the difference in the discount factor for households (β_P) and entrepreneurs (β_E), households only place deposits, but do not borrow any funds from financial market agents. Resources consist of wage earnings $w_t^P l_t^P(i)$ (where w_t^P is the real wage rate for the labor input of each household), gross interest income on last period deposits $(1+r_{t-1}^{dC})d_{t-1}^{P,C}(i)$ and $(1+r_{t-1}^{dS})d_{t-1}^{P,S}(i)$, and lump-sum transfers t_t^P that include dividends from firms and banks (of which patient households are the ultimate owners). First-order conditions yield the consumption Euler equation and labor-supply condition:

$$\frac{\varepsilon_t^z}{c_t^P(i)} = \beta_P^t E_t \left[\frac{1+r^{dC}}{c_{t+1}^P(i)} \right], \tag{A.2.3}$$

$$l_t^P(i)^{\phi^P} = \frac{w_t}{c_t^P(i)}. \tag{A.2.4}$$

A.2.2 Entrepreneurs

Entrepreneurs use labor provided by households as well as capital to produce intermediate goods that retailers purchase in a competitive market. Each entrepreneur i derives utility from consumption $c_t^E(i)$, which it compares to the lagged aggregate consumption level of all entrepreneurs. He maximizes expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \log[c_t^E(i) - a^E c_{t-1}^E)] \tag{A.2.5}$$

by choosing consumption, the use of physical capital k_t^E, loans from both commercial and shadow banks ($b_t^{E,C}$, $b_t^{E,S}$), and labor input from households. He faces the following budget constraint:

$$\begin{aligned} c_t^E(i) + w_t l_t^P(i) + (1 + r_{t-1}^b) b_{t-1}^{E,C}(i) + (1 + r_{t-1}^b) b_{t-1}^{E,S}(i) + q_t^k k_t^E(i) \\ \leq \frac{y_t^E(i)}{x_t} + b_t^{E,C}(i) + b_t^{E,S}(i) + q_t^k (1 - \delta^k) k_{t-1}^E(i) \end{aligned} \tag{A.2.6}$$

with δ^k depicting the depreciation rate of capital and q_t^k the market price for capital in terms of consumption. As we assume that intermediate goods are sold on a wholesale market at price P_t^w and are transformed by retailers in a composite final good whose price index is P_t, we define $x_t \equiv \frac{P_t}{P_t^w}$ as the price markup of the final over the intermediate good. We thus express output y_t^E produced by the entrepreneur in terms of the relative competitive price of the wholesale good, given by $\frac{1}{x_t}$ and which is produced according to the Cobb-Douglas technology

$$y_t^E(i) = a_t k_{t-1}^E(i)^\alpha l_t^E(i)^{1-\alpha} \tag{A.2.7}$$

where the (stochastic) total factor productivity (TFP) is given by a_t.

Entrepreneurs face constraints on the amount they can borrow from commercial and shadow banks as discussed in section 4.2:

$$(1 + r_t^{bC}) b_t^{E,C}(i) \leq m_t^E E_t\{q_{t+1}^k (1 - \delta^k) k_t^E(i)\} \tag{A.2.8}$$

$$(1 + r_t^{bS}) b_t^{E,S}(i) \leq (1 - m_t^E) E_t\{q_{t+1}^k (1 - \delta^k) k_t^E(i)\} \tag{A.2.9}$$

where the LTV ratio for commercial banks m_t^E is set exogenously by the regulator and follows an exogenous AR(1) process.

A.2.3 Loan and Deposit Demand

Following Gerali et al. (2010), we model market power in the banking sector by applying a Dixit-Stiglitz framework. Thus, loan and deposit units acquired by households and firms are composite constant elasticity of substitution baskets of differentiated financial claims, each issued by a bank branch j. Elasticity terms are given by ε_t^{μ} and ε_t^d, and we assume stochastic processes governing these terms.[14] Loan demand of entrepreneur i seeking total lending $\overline{b}_t^{E,C}(i)$ can be derived by

$$\min_{b_t^{E,C}(i,j)} \int_0^1 r_t^{bC}(j) b_t^{E,C}(i,j) dj$$

subject to

$$\left[\int_0^1 b_t^{E,C}(i,j)^{\frac{\varepsilon_t^{\mu}-1}{\varepsilon_t^{\mu}}} dj\right]^{\frac{\varepsilon_t^{\mu}}{\varepsilon_t^{\mu}-1}} \geq \overline{b}_t^{E,C}(i)$$

By aggregating over symmetric entrepreneurs, aggregate loan demand is given by

$$b_t^{E,C}(j) = \left(\frac{r_t^{bC}(j)}{r_t^{bC}}\right)^{-\varepsilon_t^{\mu}} b_t^{E,C}, \tag{A.2.10}$$

where $\varepsilon_t^{\mu} = \frac{\mu_t}{\mu_t - 1}$ and

$$r_t^{bC} = \left[\int_0^1 r_t^{bC}(j)^{1-\varepsilon_t^{\mu}} dj\right]^{\frac{1}{1-\varepsilon_t^{\mu}}}.$$

Aggregate loan demand at bank j thus depends on the overall level of loans to entrepreneurs, and the charged rate by bank j relative to the loan rate index for the differentiated loan type. Deposit demand by household i seeking total deposits $\overline{d}_t^{P,C}(i)$ can be derived by

$$\max_{d_t^{P,C}(i,j)} \int_0^1 r_t^{dC}(j) d_t^{P,C}(i,j) dj$$

subject to

$$\left[\int_0^1 d_t^{P,C}(i,j)^{\frac{\varepsilon_t^{d}-1}{\varepsilon_t^{d}}} dj\right]^{\frac{\varepsilon_t^{d}}{\varepsilon_t^{d}-1}} \leq \overline{d}_t^{P,C}(i)$$

Combining first-order conditions yields aggregate demand for bank j's deposits

$$d^{P,C}(j) = \left(\frac{r_t^{dC}(j)}{r_t^{dC}}\right)^{-\varepsilon_t^{d}} d_t^{P,C}, \tag{A.2.11}$$

where $\varepsilon_t^{d} = \frac{\mu_t^d}{\mu_t^d - 1}$ and the deposit rate index is given by

$$r_t^{dC} = \left[\int_0^1 r_t^{dC}(j)^{1-\varepsilon_t^{d}} dj\right]^{\frac{1}{1-\varepsilon_t^{d}}}.$$

[14] See section A.2.7.

A.2.4 Financial Intermediaries

In our model, we have two financial market agents that intermediate funds between households and firms: commercial banks and shadow banks. While they both engage in intermediation in a similar fashion, we assume the two types of agents to be structurally different along various dimensions, as discussed in section 4.2.

Commercial Banks

In the following, we discuss the maximization problem of the wholesale unit of the commercial bank as the capital requirement set by regulators applies directly to this branch of the commercial bank. We also discuss the maximization problems of the monopolistically competitive retail loan and deposit branches.

Wholesale Unit The wholesale branches of commercial banks operate under perfect competition and are responsible for the capital position of the respective commercial bank. On the asset side, they hold funds they provide to the retail loan branch, b_t^C, which ultimately lends these funds to entrepreneurs at a markup in the form of loans, $b_t^{E,C}$. On the liability side, it combines commercial bank net worth, or capital, k_t^C, with wholesale deposits, d_t^C, that are provided by the retail deposit branch, but originally stem from deposits placed in the retail branch by patient households ($d_t^{P,C}$). The wholesale bank balance sheet is thus given by

$$b_t^C = k_t^C \varepsilon_t^{Kb} + d_t^C. \tag{A.2.12}$$

Furthermore, the capital position of the wholesale branch is prone to a regulatory capital requirement, ν_t^C. Moving away from the regulatory requirement imposes a quadratic cost c_t^C to the bank, which is proportional to the outstanding amount of bank capital and parameterized by κ_k^C:

$$c_t^C = \frac{\kappa_k^C}{2}\left(\frac{k_t^c}{b_t^C} - \nu_t^C\right)^2 k_t^C. \tag{A.2.13}$$

The wholesale branch thus maximizes the discounted sum of real cash flows:

$$\mathcal{L}^w = \max_{b_t^C,\, d_t^C} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \Big[(1+r_t^C)b_t^C - b_{t+1}^C\Pi_{t+1} + d_{t+1}^C\Pi_{t+1} - (1+r_t^{dC})d_t^C + \\ + (k_{t+1}^C\Pi_{t+1} - k_t^C) - \frac{\kappa_k^C}{2}\left(\frac{k_t^C}{b_t^C + b_t^S} - \nu_t^C\right)^2 k_t^C\Big] \tag{A.2.14}$$

where we assume the net wholesale loan rate r_t^C and the deposit rate r_t^{dC} to be given from the perspective of the maximizing bank. We can use the objective together with the balance sheet constraint A.2.12 to get:

$$r_t^C b_t^C - r_t^{dC} d_t^C - \frac{\kappa_k^C}{2}\left(\frac{k_t^C}{b_t^C} - \nu^C\right)^2 k_t^C.$$

We can thus express the maximization problem as:

$$\mathcal{L}^w = \max_{b_t^C,\, d_t^C} \; r_t^C b_t^b - r_t^{dC} d_t^C - \frac{\kappa_k^C}{2}\left(\frac{k_t^C}{b_t^C} - \nu_t^C\right)^2 k_t^C. \tag{A.2.15}$$

The first-order conditions yield the following expression:

$$r_t^b = r_t^{dC} - \kappa_k^C\left(\frac{k_t^C}{b_t^C} - \nu_t^C\right)\left(\frac{k_t^C}{b_t^C}\right)^2. \tag{A.2.16}$$

As the commercial bank has access to central bank funding in the model, we assume that the rate paid on wholesale deposits gathered from the retail deposit unit of the commercial bank (and so originally from households and firms) has to be equal to the risk-free policy rate, r_t, by arbitrage:

$$r_t^{dC} = r_t$$

such that the spread between the loan and deposit rates on the wholesale level is given by

$$r_t^b - r_t = -\kappa_k^C\left(\frac{k_t^C}{b_t^C} - \nu_t^C\right)\left(\frac{k_t^C}{b_t^C}\right)^2. \tag{A.2.17}$$

Assuming symmetry between banks and reinvestment of profits in banks, aggregate bank capital K_t^C is accumulated from retained earnings only:

$$K_t^C = (1-\delta^C)K_{t-1}^C + J_{t-1}^C \tag{A.2.18}$$

where J_t^C depicts aggregate commercial bank profits derived from the three branches of the bank, see Gerali et al. (2010). Capital management costs are captured by δ^C.

Retail Loan Unit The retail loan branch j acts under monopolistic competition and obtains wholesale loans $b_t^{E,C}(j)$ at rate r_t^b. It repackages them at no cost and resells differentiated loans to entrepreneurs at a markup. Each retail loan branch faces quadratic loan rate adjustment costs governed by κ^{bE}. The loan branch objective is given by:

$$\mathcal{L}^l = \max_{r_t^{bC}(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t^{bC}(j) b_t^{E,C}(j) - r_t^b b_t^C(j) - \frac{\kappa^{bE}}{2}\left(\frac{r_t^{bC}(j)}{r_{t-1}^{bC}(j)} - 1\right)^2 r_t^{bC} b_t^{E,C}\right] \tag{A.2.19}$$

subject to loan demand A.2.10. After imposing a symmetric equilibrium, first-order conditions yield:

$$1-\varepsilon_t^{\mu}+\varepsilon_t^{\mu}\frac{r_t^b}{r_t^{bC}}-\kappa^{bE}\left(\frac{r_t^{bC}}{r_{t-1}^{bC}}-1\right)\frac{r_t^{bC}}{r_{t-1}^{bC}}+ \\ +\beta_p E_t\left\{\frac{\lambda_{t+1}^p}{\lambda_t^p}\kappa^{bE}\left(\frac{r_{t+1}^{bC}}{r_t^{bC}}-1\right)\left(\frac{r_{t+1}^{bC}}{r_t^{bC}}\right)^2\frac{b_{t+1}^C}{b_t^{E,C}}\right\}=0 \quad \text{(A.2.20)}$$

where λ_t^p is the Lagrange multiplier on budget constraint A.2.2.

Retail Deposit Unit Similarly, a bank's deposit branch j acts under monopolistic competition, collects deposits $b_t^C(j)$ from households, and passes funds to the wholesale branch as wholesale deposits $d_t^C(j)$. In doing so, the deposit branch applies a markdown on retail deposits, and remunerates households at rate $r_t^{dC}(j)$. The deposit branch faces quadratic rate adjustment costs which are determined by κ^d, and the branch's objective is thus given by:

$$\mathcal{L}^d = \max_{r_t^{dC}(j)} E_0\sum_{t=0}^{\infty}\Lambda_{0,t}^P\left[r_t d_t^C(j)-r_t^{dC}(j)d_t^{P,C}(j)-\frac{\kappa^d}{2}\left(\frac{r_t^{dC}(j)}{r_{t-1}^{dC}(j)}-1\right)^2 r_t^{dC}d_t^{P,C}\right] \quad \text{(A.2.21)}$$

subject to deposit demand A.2.11. After imposing a symmetric equilibrium, first-order conditions yield:

$$-1+\varepsilon_t^d-\varepsilon_t^d\frac{r_t}{r_t^{dC}}-\kappa^d\left(\frac{r_t^{dC}}{r_{t-1}^{dC}}-1\right)\frac{r_t^{dC}}{r_{t-1}^{dC}}+ \\ +\beta_p E_t\left\{\frac{\lambda_{t+1}^p}{\lambda_t^p}\kappa^d\left(\frac{r_{t+1}^{dC}}{r_t^{dC}}-1\right)\left(\frac{r_{t+1}^{dC}}{r_t^{dC}}\right)^2\frac{d_{t+1}^{P,C}}{d_t^{P,C}}\right\}=0 \quad \text{(A.2.22)}$$

where λ_t^p is the Lagrange multiplier on budget constraint A.2.2.

Shadow Banks

The balance sheet of each shadow bank j in each period is given by

$$q_t^k b_t^{E,S}(j)=d_t^{P,S}(j)+k_t^S(j) \quad \text{(A.2.23)}$$

where the asset side is given by the funds lend to entrepreneurs, $b_t^{E,S}(j)$, multiplied with the relative price for these claims, q_t^k. Shadow banks' liabilities consist of household deposits $d_t^{P,S}(j)$ and net worth, or shadow bank capital $k_t^S(j)$.

Shadow bankers earn an interest rate on their claims r_t^{bS}. The net profits of shadow banks, i.e. the difference between real earnings on financial claims and real interest payments to depositors, determine the evolution of shadow bank capital:

$$k_{t+1}^S(j) = (1 + r_t^{bS})q_t^k b_t^{E,S}(j) - (1 + r_t^{dS})d_t^{P,S}(j) \tag{A.2.24}$$

or

$$k_{t+1}^S(j) = (r_t^{bS} - r_t^{dS})q_t^k b_t^{E,S}(j) + (1 + r_t^{dS})k_t^S(j). \tag{A.2.25}$$

For the shadow banker, as long as the real return on lending, $(r_t^{bS} - r_t^{dS})$ is positive, it is profitable to accumulate capital until it exits the shadow banking sector. Thus, the shadow bank's objective to maximize expected terminal wealth, $v_t(j)$, is given by

$$v_t(j) = \max E_t \sum_{i=0}^{\infty} (1 - \sigma^S){\sigma^S}^i {\beta_S}^{i+1} k_{t+1+i}^S(j) \tag{A.2.26}$$

or

$$v_t(j) = \max E_t \sum_{i=0}^{\infty} (1 - \sigma^S){\sigma^S}^i {\beta_S}^{i+1} [(r_{t+i}^{bS} - r_{t+i}^{dS})q_{t+i}^k b_{t+i}^{E,S}(j) + (1 + r_{t+i}^{dS})k_{t+i}^S(j)]. \tag{A.2.27}$$

We introduce a moral hazard problem discussed in section 4.2. Diverting funds and "running away" is equivalent to declaring bankruptcy for the shadow bank, such that it will only do so if the return of declaring bankruptcy is larger than the discounted future return from continuing and behaving honestly:

$$v_t(j) \geq \theta^S q_t^k b_t^{E,S}(j). \tag{A.2.28}$$

Equation A.2.28 is the infinite-horizon version of incentive constraint A.1.37 in the two-period model the shadow banker faces when demanding funds from households. Following Gertler and Karadi (2011), we can rewrite it as:

$$v_t(j) = \nu_t^S q_t^k b_t^{E,S}(j) + \eta_t^S k_t^S(j) \tag{A.2.29}$$

with

$$\nu_t^S = E_t\{(1 - \sigma^S)\beta_S(r_t^{bS} - r_t^{dS}) + \beta_S \sigma^S \chi_{t,t+1}^S \nu_{t+1}^S\} \tag{A.2.30}$$

and

$$\eta_t^S = E_t\{(1-\sigma^S) + \beta_S \sigma^S z_{t,t+1}^S \eta_{t+1}^S\} \tag{A.2.31}$$

where $\chi_{t,t+i}^S \equiv \frac{q_{t+i}^k b_{t+i}^{E,S}(j)}{q_t^k b_t^{E,S}(j)}$ depicts the gross growth rate in financial claims between t and $t+i$, whereas $z_{t,t+i}^S \equiv \frac{k_{t+i}^S(j)}{k_t^S(j)}$ determines the gross growth rate of shadow bank capital. With these definitions, we can express the incentive constraint as

$$\eta_t^S k_t^S(j) + \nu_t^S q_t^k b_t^{E,S}(j) \geq \theta^S q_t^k b_t^{E,S}(j). \tag{A.2.32}$$

With constraint A.2.32 being binding, bank capital determines the amount that the shadow banker can lend out:

$$q_t^k b_t^{E,S}(j) = \frac{\eta_t^S}{\theta^S - \nu_t^S} k_t^S(j) = \phi_t^S k_t^S(j) \tag{A.2.33}$$

where ϕ_t^S is the asset-to-capital ratio, or the shadow bank leverage ratio. As shadow banks' incentive to divert funds increases with leverage, equation A.2.33 limits the shadow bank's leverage ratio to the point where costs and benefits of cheating are exactly leveled. Thus, due to the financial friction, shadow banks, even not facing an externally set capital requirement that limits their leverage, are prone to an endogenous capital constraint that limits their ability to increase leverage.[15]

Rewriting bank capital as

$$k_{t+1}^S(j) = [(r_t^{bS} - r_t^{dS})\phi_t^S + (1 + r_t^{dS})]k_t^S(j) \tag{A.2.34}$$

we get

$$z_{t,t+1}^S = \frac{k_{t+1}^S(j)}{k_t^S(j)} = (r_t^{bS} - r_t^{dS})\phi_t^S + (1 + r_t^{dS}) \tag{A.2.35}$$

and

$$\chi_{t,t+1}^S = \frac{q_{t+1}^k b_{t+1}^{E,S}(j)}{q_t^k b_t^{E,S}(j)} = \frac{\phi_{t+1}^S}{\phi_t^S} z_{t,t+1}^S. \tag{A.2.36}$$

As none of the components of ϕ_t^S depends on firm-specific factors, we can drop the subscript j by summing across individual shadow bankers to get for total shadow bank

[15]We assume that in the simulations, parameters are set such that the constraint always binds within a local region around steady state in equilibrium. Similarly to condition A.1.41 in appendix A.1, an equilibrium with a binding incentive constraint is characterized by $0 < \nu_t^S < \theta^S$, which can be shown with equation A.2.33.

lending:

$$q_t^k b_t^{E,S} = \phi_t^S k_t^S \tag{A.2.37}$$

with $b_t^{E,S}$ depicting aggregate lending/financial claims the shadow banking sector provides and k_t^S being the aggregate capital held by shadow banks in period t.

As we assume some shadow bankers to exit each period and new bankers to enter the market, we know that aggregate capital k_t^S is determined by capital of continuing shadow bankers, $k_t^{S,c}$, and capital of new bankers that enter, $k_t^{S,n}$:

$$k_t^S = k_t^{S,c} + k_t^{S,n}. \tag{A.2.38}$$

As a fraction σ^S of existing shadow bankers survives each period, we know that at period t, we have for $k_t^{S,c}$

$$k_t^{S,c} = \sigma^S[(r_{t-1}^{bS} - r_{t-1}^{dS})\phi_{t-1}^S + (1 + r_{t-1}^{dS})]k_{t-1}^S. \tag{A.2.39}$$

For new shadow bankers, we assume that they get some start-up capital from the household the shadow banker belongs to. This start-up value is assumed to be proportional to the amount of claims exiting shadow bankers had intermediated in their final period. With i.i.d. exit probability σ^S, total final period claims of exiting shadow bankers at t are given by $(1 - \sigma^S)q_t^k b_{t-1}^{E,S}$. We assume that each period the household transfers a fraction $\frac{\omega^S}{1-\sigma^S}$ of this value to entering bankers, such that in the aggregate, we get:

$$k_t^{S,n} = \omega^S q_t^k b_{t-1}^{E,S}. \tag{A.2.40}$$

Combining equations A.2.38, A.2.39 and A.2.40, we get the following law of motion for shadow bank capital:

$$k_t^S = \sigma^S[(r_{t-1}^{bS} - r_{t-1}^{dS})\phi_{t-1}^S + (1 + r_{t-1}^{dS})]k_{t-1}^S + \omega^S q_t^k b_{t-1}^{E,S}. \tag{A.2.41}$$

Finally, we assume a non-negative spread between the interest rates earned on shadow bank deposits, r_t^{dS}, and on the deposits households can place with commercial banks, r_t^{dC}, which is again determined by the parameter τ^S, with $0 \leq \tau^S \leq 1$. In appendix A.1, we provide a microfoundation for the existence of a positive spread, and use the results to incorporate a relationship between the two deposit rates similar to the relation stated in the two-period model:

$$1 + r_t^{dS} = \frac{1 + r_t^{dC}}{1 - \tau^S \varepsilon_t^\tau}. \tag{A.2.42}$$

As in the two-period version of the model, the parameter τ^S determines the spread between the gross rates on both deposit types and is implicitly related to the default probability of shadow banks. As a shortcut, we will calibrate τ^S and assume the existence of a spread shock ε_t^τ following an autoregressive process to motivate exogenous swings in the spread on interest rates earned on the two deposit types.

A.2.5 Capital Goods Producers and Retailers

Following Gerali et al. (2010), the first-order condition for capital goods producers is given by

$$1 = q_t^k\left[1-\frac{\kappa^i}{2}\left(\frac{I_t\varepsilon_t^{q^k}}{I_{t-1}}-1\right)^2-\kappa^i\left(\frac{I_t\varepsilon_t^{q^k}}{I_{t-1}}-1\right)\frac{I_t\varepsilon_t^{q^k}}{I_{t-1}}\right]+ \\ +\beta_E E_t\left[\frac{\lambda_{t+1}^E}{\lambda_t^E}q_{t+1}^k\kappa^i\left(\frac{I_{t+1}\varepsilon_{t+1}^{q^k}}{I_t}-1\right)\left(\frac{I_{t+1}\varepsilon_{t+1}^{q^k}}{I_t}\right)^2\varepsilon_{t+1}^{q^k}\right] \quad \text{(A.2.43)}$$

and capital accumulation is given by

$$K_t = (1-\delta^k)K_{t-1}+\left[1-\frac{\kappa^i}{2}\left(\frac{I_t\varepsilon_t^{q^k}}{I_{t-1}}\right)^2\right]. \quad \text{(A.2.44)}$$

We assume price stickiness à la Calvo (1983) in the retail sector.[16] Thus, only a share or retailers indicated by θ^p is able to adjust prices in a given period. Retailers' marginal costs are given by

$$mc_t^E = \frac{1}{x_t}. \quad \text{(A.2.45)}$$

A.2.6 Monetary Policy and Market Clearing

The central bank sets the policy rate according to a Taylor-type rule given by

$$(1+r_t) = (1+r)^{(1-\phi^r)}(1+r_{t-1})^{\phi^r}\left(\frac{\pi_t}{\pi}\right)^{\phi^\pi(1-\phi^r)}\left(\frac{y_t}{y_{t-1}}\right)^{\phi^y(1-\phi^r)}\varepsilon_t^r \quad \text{(A.2.46)}$$

[16] In the studies by Gerali et al. (2010) and Gambacorta and Signoretti (2014), price stickiness was modeled using Rotemberg (1982) pricing. However, we decided to use the more convenient Calvo pricing approach in the model.

where the weights on inflation and output growth are given by ϕ^π and ϕ^y, respectively. The market clearing condition is given by the aggregate resource constraint

$$Y_t = C_t + q_t^k(K_t - (1-\delta^k)K_{t-1}) + \frac{\delta^k K_{t-1}^b}{\pi_t} + AC_t \tag{A.2.47}$$

with AC_t determining the overall adjustment costs and composite consumption given by $C_t = c_t^P + c_t^E$.

A.2.7 Shock Processes

Deposit Spread Shock:

$$\varepsilon_t^\tau = (1-\rho^\tau)\varepsilon^\tau + \rho^\tau \varepsilon_{t-1}^\tau + \epsilon_t^\tau \tag{A.2.48}$$

Consumer Preference Shock:

$$\varepsilon_t^z = (1-\rho^z)\varepsilon^z + \rho^z \varepsilon_{t-1}^z + \epsilon_t^z \tag{A.2.49}$$

Productivity Shock:

$$a_t = (1-\rho^a)a + \rho^a a_{t-1} + \epsilon_t^a \tag{A.2.50}$$

Entrepreneur LTV Shock:

$$m_t^E = (1-\rho^{m^E})m^E + \rho^{m^E} m_{t-1}^E + \epsilon_t^{m^E} \tag{A.2.51}$$

Deposit Rate Markdown Shock:

$$\mu_t^d = (1-\rho^d)\mu^d + \rho^d \mu_{t-1}^d + \epsilon_t^{\mu^d} \tag{A.2.52}$$

Loan Rate Markup Shock:

$$\mu_t = (1-\rho^\mu)\mu + \rho^\mu \mu_{t-1} + \epsilon_t^\mu \tag{A.2.53}$$

Investment Efficiency Shock:

$$\varepsilon_t^{q^k} = (1-\rho^{qk})\varepsilon^{q^k} + \rho^{qk} \varepsilon_{t-1}^{q^k} + \epsilon_t^{q^k} \tag{A.2.54}$$

Price Markup Shock:

$$x_t^y = (1-\rho^y)x^y + \rho^y x_{t-1} + \epsilon_t^x \tag{A.2.55}$$

Wage Markup Shock:

$$x_t^l = (1-\rho^l)x^l + \rho^l x_{t-1}^l + \epsilon_t^l \tag{A.2.56}$$

Commercial Bank Capital Shock:

$$\varepsilon_t^{Kb} = (1-\rho^{Kb})\varepsilon_t^{Kb} + \rho^{Kb} \varepsilon_{t-1}^{Kb} + \epsilon_t^{Kb} \tag{A.2.57}$$

A.3 Appendix: Data and Estimation

We derive our data set from the European System of Accounts (ESA 2010) quarterly financial and non-financial sector accounts, provided by the ECB and Eurostat. Commercial bank balance sheet data is gathered from the data set on "Monetary Financial Institutions" (MFIs), whereas shadow bank data is based on statistics on "Other Financial Institutions" (OFIs) as well as on data on investment funds and money market funds (MMFs) provided by the ECB. Commercial bank interest rate data is combined from different sources, as indicated below. All variables except for interest rates are seasonally and working day adjusted and expressed in real terms. We furthermore detrend macroeconomic variables (real GDP, real consumption, real investment) and intermediary loans and deposits by applying log-differences. We then subtract the sample means from the data after log-differentiation to arrive at average growth rates of zero for these variables. Interest rates and price and wage inflation variables are also demeaned. A detailed description of each variable is given below, and the final time series used in the estimations are plotted in figure A.5.

A.3.1 Real Economic and Commercial Bank Data

For the real economy, we include information on real gross domestic product, real consumption, real investment, and consumer price as well as wage inflation. We furthermore use data on commercial bank deposits held by private households, commercial bank loans granted to the non-financial corporate sector, the short-term EONIA rate as a quarterly measure of the policy rate, and measures for interest rates on household deposits and firm loans. We detrend non-stationary seasonally adjusted data (real consumption, real investment, bank deposits and loans) by using demeaned log-differenced data and demean all interest and inflation rates.

Real GDP: Real gross domestic product, euro area 19 (fixed composition), deflated using the GDP deflator (index), calendar and seasonally adjusted data (national accounts, main aggregates (Eurostat ESA2010)).

Real consumption: Real consumption expenditure of households and non-profit institutions serving households (NPISH), euro area 19 (fixed composition), deflated using Consumption deflator (index), calendar and seasonally adjusted data (national accounts, main aggregates (Eurostat ESA2010)).

Real investment: Real gross fixed capital formation (GFCF), euro area 19 (fixed composition), deflated using GFCF deflator (index), calendar and seasonally adjusted data (national accounts, main aggregates (Eurostat ESA2010)).

Inflation: Harmonized index of consumer prices (HICP) index, quarterly changes, euro area (changing composition), net inflation rate, calendar and seasonally adjusted data.

Wage inflation: Labor cost index, OECD data, euro area 19 (fixed composition), wages and salaries, business economy, net wage inflation, calendar and seasonally adjusted data.

Nominal interest rate (policy rate): EONIA rate, ECB money market data.

Commercial bank loans: Real outstanding amounts of commercial bank (MFIs excluding ESCB) loans to non-financial corporations, euro area (changing composition), deflated using HICP, calendar and seasonally adjusted data.

Commercial bank deposits: Real deposits placed by euro area households (overnight deposits, with agreed maturity up to two years, redeemable with notice up to 3 months), outstanding amounts, euro area (changing composition), deflated using HICP, calendar and seasonally adjusted data.

Interest rate on commercial bank loans: Annualized agreed rate (AAR) on commercial bank loans to non-financial corporations with maturity over one year, euro area (changing composition), new business coverage. Before 2003: Retail interest Rates Statistics (RIR), not harmonized data. Starting 2003:Q1: MFI Interest Rate Statistics (MIR), harmonized data.

Interest rate on commercial bank deposits: Commercial bank interest rates on household deposits, weighted rate from rates on overnight deposits, with agreed maturity up to two years, redeemable at short notice (up to three months), euro area (changing composition), new business coverage. Before 2003: Retail interest Rates Statistics (RIR), not harmonized data. Starting 2003:Q1: MFI Interest Rate Statistics (MIR), harmonized data.

A.3.2 Shadow Bank Data

In addition to the variables on commercial bank and real activity, we include data on shadow banks in the euro area in our sample. In comparison to lending provided by commercial banks, we derive a time series on shadow bank lending to non-financial corporates. In doing so, we are able to include an empirical measure of shadow bank credit. Deriving information on the European shadow banking system is challenging since 1) a wide variety of shadow bank definitions are used among scholars and practitioners and 2) euro area data on financial institutions that could be classified as shadow banks is available at a much lower level of detail and in a less structured manner than information on commercial banks. Therefore, one has to compromise between the conceptional definition of shadow banks used and the empirical counterparts that can be analyzed with available data.

In practice, the shadow banking system consist of a multitude of financial institutions partly fulfilling highly specialized task in a prolonged chain of credit intermediation (Adrian, 2014; Adrian and Liang, 2014; Pozsar et al., 2010). Given the diverse nature of non-bank financial institutions, a variety of definitions of shadow banks have been proposed, covering either a particular set of institutions (institutional approach) or a range of activities different entities are jointly engaged in (activity approach). We base our empirical measures of shadow banks on the "broad" definition of the shadow banking system provided by the Financial Stability Board (FSB, 2017, 2011), which states that the shadow banking system is "the system of credit intermediation that involves entities and activities outside the regular banking system" (FSB, 2011, p.2) and that "...this implies focusing on credit intermediation that takes place in an environment where *prudential regulatory standards and supervisory oversight are either not applied or are applied to a materially lesser or different degree than is the case for regular banks engaged in similar activities*" (FSB, 2011, p.3).

More precisely, we follow the institutional approach employed by ECB staff to apply the FSB broad definition to available euro area data (Malatesta et al., 2016; Doyle et al., 2016; Bakk-Simon et al., 2012). The core of this approach depicts the use of the "Other Financial Intermediaries" (OFIs) aggregate in the Eurosystem's financial accounts data. Within the aggregate, all activities of financial intermediaries not classified as "Monetary Financial Institutions" (MFIs) are captured. Thus, the OFI aggregate depicts a residual component and not only includes institutions universally accepted as shadow banks.[17] For instance, the insurance corporations and pension funds sector (ICPFs) is mainly engaged in activities that are not related to shadow bank intermediation, and we therefore exclude balance sheet items of these institutions from our shadow bank aggregates. Furthermore, the OFI aggregate is lacking information on money market funds (MMFs), which are classified as MFIs. However, there is a broad consensus in the literature that MMFs engage in activities that could possibly be counted as shadow bank intermediation,[18] and we therefore include MMF information in the shadow bank aggregate. Our benchmark shadow bank definition (1) therefore closely resembles the broad shadow bank definition by the FSB and covers the whole range of OFIs except for ICPFs, plus MMFs (Scenario 1 in table A.2).[19]

The OFI sector, in line with the broad definition of shadow banks given by the FSB, covers non-MMF investment funds. Whereas some studies highlight the increasing role of direct investment fund lending to the non-financial private sector in the euro area since the recent global financial crisis (Doyle et al., 2016), other studies discuss the special role

[17] See Doyle et al. (2016).

[18] See for instance Adrian (2014), Adrian and Liang (2014), Pozsar et al. (2010), or FSB (2017, 2011).

[19] Detailed information on the the OFI sector composition has only recently been provided by the ECB. For instance, the collection of detailed balance sheet data on investment funds and financial vehicle corporations (FVCs) was initiated in 2008 and 2009, respectively. Harmonized data on MMFs is available from 2006 onward in the MFI statistics, but can be gathered from other sources for earlier years (see appendix A.3). Balance sheet information on these institutions accounts for approximately 50 percent of the total OFI sector, with the rest being characterized by smaller and more heterogeneous entities.

Table A.2: Different Definitions of Shadow Banks Based on the OFI Aggregate

Scenario	**Including Investment Funds**	**Including Money-Market Funds**	**Lending Counterparties**
1	X	X	NFCs
2		X	Total economy

investment funds play in the financial system and question the adequacy of considering these institutions as intermediaries between real economy borrowers and lenders. For instance, Bakk-Simon et al. (2012) argue that investment funds are indeed covered by regulation, even though substantially different than commercial banks. They therefore question whether the definition of shadow banks being intermediaries outside the regulatory system given by the FSB applies to investment funds. Consequently, we use as a robustness check an alternative measure of shadow bank loans that excludes investment funds (Scenario 2 in table A.2). However, we are not able to gather counterparty information for investment fund lending before 2008, and therefore use total lending of the OFI sector less investment fund lending in this second estimation, instead of lending to non-financial corporations only.

Shadow bank loans (including investment funds): Loans of other financial intermediaries (OFI) to non-financial corporations, excluding insurance corporations and pension funds, including investment funds, euro area 19 (fixed composition), deflated using HICP, calendar and seasonally adjusted data.

Shadow bank loans (excluding investment funds): Loans of other financial intermediaries (OFI) to total economy, excluding insurance corporations and pension funds, excluding investment fund assets (deposits, loans, and financial derivatives), euro area 19 (fixed composition), deflated using HICP, calendar and seasonally adjusted data.

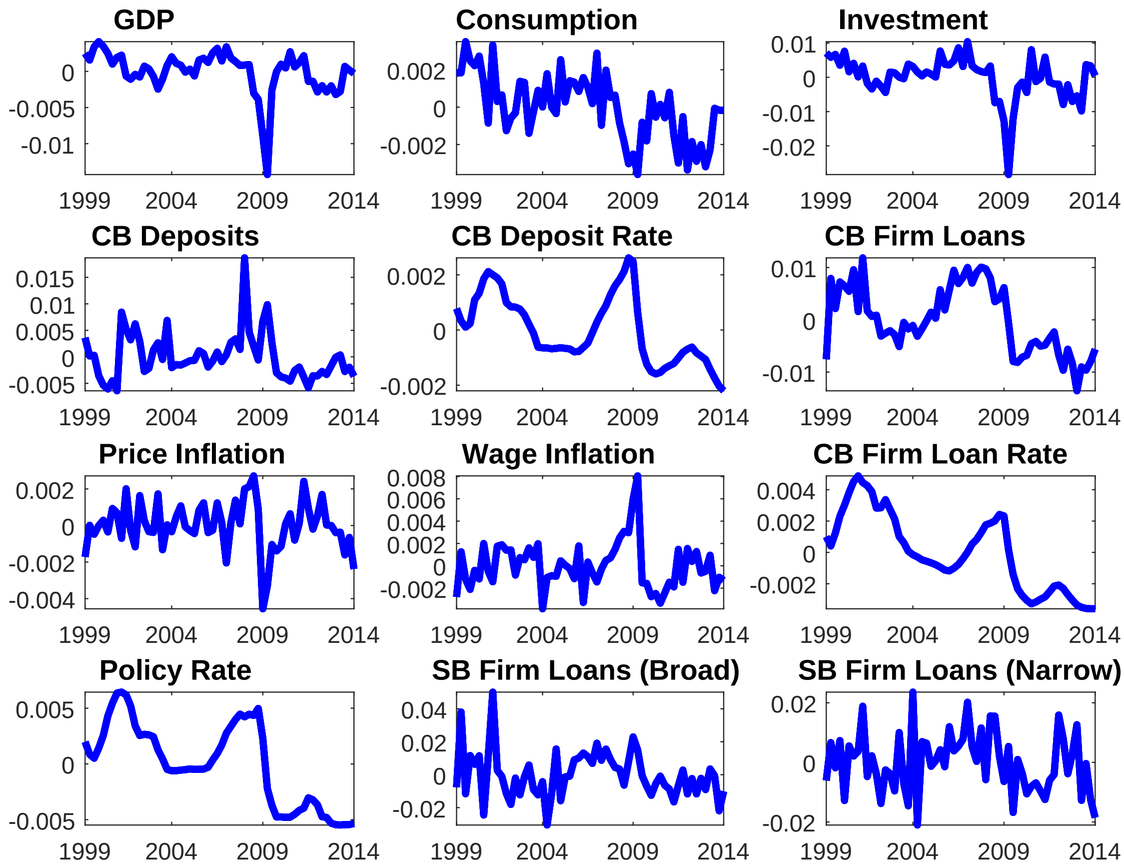
A.3.3 Prior and Posterior Distributions

Figure A.6 reports the prior and posterior distributions for the baseline estimation reported in table 4.2.

A.4 Appendix: Robustness Checks

In the following, we estimate our baseline model on two different specifications of the sample. First, to account for uncertainty around the exact date of the beginning of the effective lower bound (ELB) phase in the euro area, we provide parameter estimates when using an earlier end date as in the baseline specification. We are also aware of structural changes in the financial system after the 2007/2008 financial crisis and over the course of the subsequent European debt crisis which potentially altered the role and effectiveness of

Figure A.5: Euro Area Observable Time Series Used in Estimation



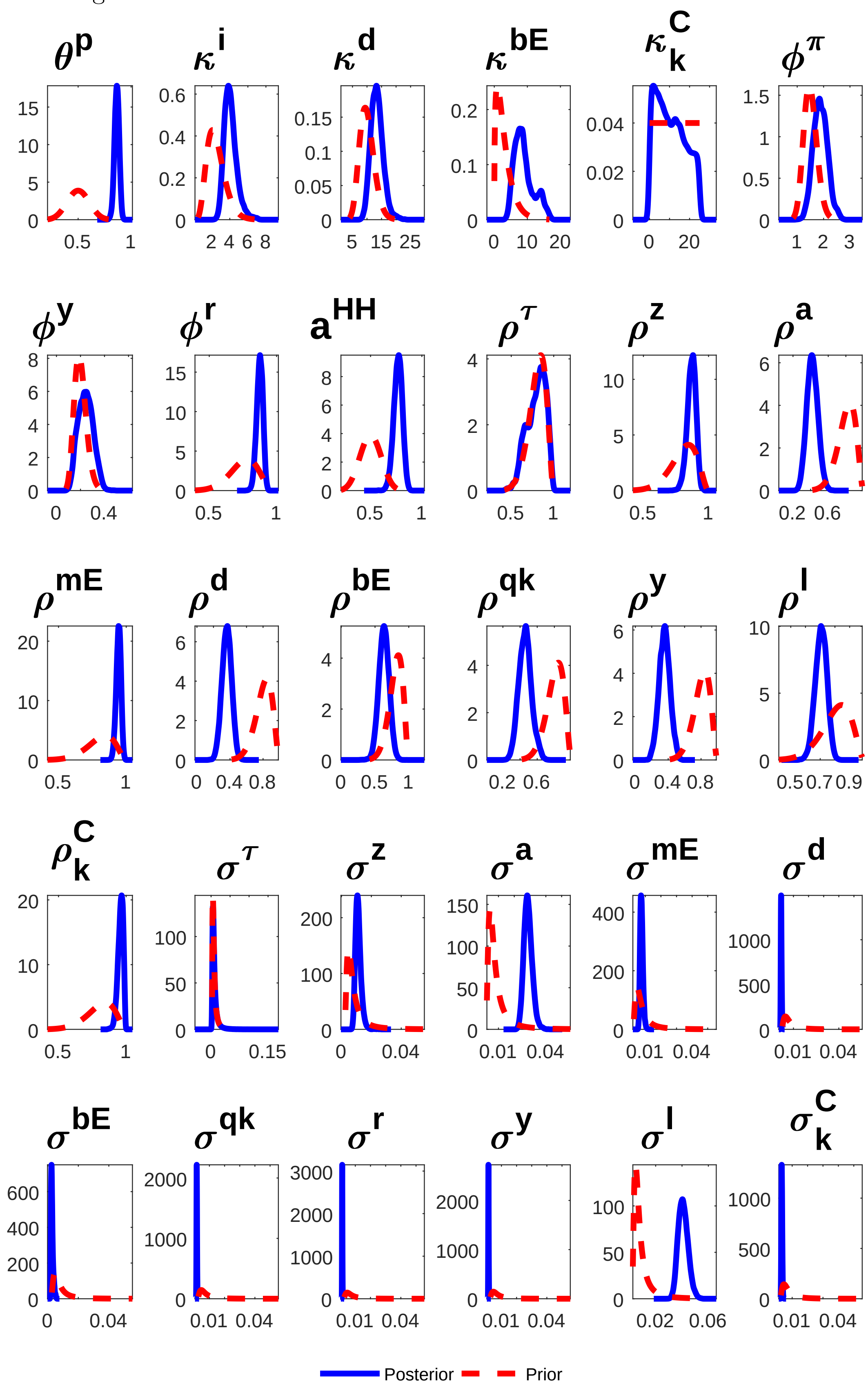
Note: Real stock and volume data (real GDP, real consumption, real investment, loans and deposits by commercial and shadow banks) are expressed as demeaned log-differences. Wage and price inflation and interest rates are quarterly net rates and expressed in absolute deviations from sample means.

shadow banking in the euro area. To take these considerations into account, we re-estimate our model for the period of 1999:Q1 to 2008:Q4, thereby excluding both the post-financial crisis and ELB period from the estimation. In addition, excluding the period after 2008 allows for a straightforward comparison of results to Gerali et al. (2010), who used the same period in the estimation. Estimation results are reported in columns 7 to 10 of table A.3. In addition, we restate our baseline estimation results for comparison in columns 3 to 6.

Whereas result from the pre-crisis period estimation are qualitatively comparable to the baseline estimates, some slight quantitative differences in parameter estimates can be observed. The mode estimates for the parameter governing investment adjustment costs turns out to be lower in the estimation using the pre-crisis sample. By including the years after 2008 - a period characterized by the aftermath of the global financial crisis and by the subsequent European sovereign debt crisis - the rise in investment adjustment costs could be driven by higher investment volatility - due to a significant fall in investment activity in the post-crisis years and the more moderate growth thereafter - in the post-2008 period. Furthermore, estimates for interest rate adjustment costs are higher in the pre-crisis sample compared to the full sample.

Second, we re-estimate our model by applying a different definition of shadow banks, i.e. by excluding investment funds from the shadow bank aggregate, as discussed in section 4.3 and appendix A.3 (Scenario 2 in table A.2). We report parameter estimates in columns 11 to 14 of table A.3. Our baseline results are not substantially affected when investment fund information is excluded. Commercial bank loan rate adjustment costs turn out to be slightly lower when investment fund information is excluded from the estimation, whereas other structural parameters - based on the comparison of posterior modes - do not differ from baseline results.

Figure A.6: Prior and Posterior Distributions: Baseline Estimation



Note: Prior and posterior distributions from the baseline estimation reported in table 4.2.

Table A.3: Posterior Distributions: Robustness and Evaluation

Parameter		Posterior Distribution				Pre-Crisis				Excluding Investment Funds			
		5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode
Structural Parameters													
θ^p	Calvo Parameter	0.83	0.87	0.90	0.86	0.76	0.81	0.86	0.81	0.83	0.86	0.90	0.86
κ^i	Investment Adjustment Cost	2.98	3.98	5.14	3.67	2.60	3.64	4.83	3.50	2.89	3.79	4.76	3.66
κ^d	Deposit Rate Adjustment Cost	10.00	13.26	16.72	12.62	11.37	15.06	18.99	14.74	9.89	12.94	16.25	12.62
κ^{bE}	Loan Rate Adjustment Cost	4.84	8.34	14.23	7.56	5.11	9.72	15.13	8.81	4.75	7.74	11.00	6.91
κ_k^C	CCR Deviation Cost	0.01	10.05	21.32	24.71	3.32	14.01	25.00	25.00	3.08	14.27	24.99	25.00
ϕ^π	TR Coefficient π	1.44	1.87	2.30	1.75	1.23	1.62	2.03	1.58	1.43	1.87	2.31	1.80
ϕ^y	TR Coefficient y	0.14	0.24	0.34	0.20	0.12	0.20	0.28	0.19	0.12	0.20	0.29	0.20
ϕ^r	Interest Rate Smoothing	0.84	0.88	0.91	0.88	0.79	0.86	0.91	0.86	0.84	0.88	0.91	0.88
a^{HH}	HH Habit Formation	0.70	0.77	0.84	0.77	0.53	0.66	0.78	0.64	0.71	0.78	0.85	0.77
Exogenous Processes (AR Coefficients)													
ρ^τ	Deposit Rate Spread	0.62	0.81	0.95	0.85	0.65	0.81	0.96	0.85	0.65	0.82	0.96	0.85
ρ^z	Consumer Preference	0.82	0.87	0.92	0.87	0.77	0.87	0.95	0.88	0.81	0.87	0.92	0.87
ρ^a	Technology	0.31	0.42	0.52	0.42	0.31	0.42	0.52	0.42	0.32	0.42	0.53	0.42
ρ^{mE}	Entrepreneur LTV	0.91	0.94	0.97	0.95	0.90	0.94	0.98	0.95	0.91	0.94	0.97	0.94
ρ^d	Deposit Rate Markdown	0.27	0.36	0.46	0.36	0.28	0.38	0.49	0.38	0.27	0.37	0.47	0.37
ρ^μ	Loan Rate Markup	0.51	0.63	0.75	0.64	0.52	0.67	0.82	0.67	0.50	0.63	0.76	0.64
ρ^{qk}	Investment Efficiency	0.33	0.46	0.58	0.49	0.27	0.40	0.54	0.41	0.34	0.46	0.58	0.47
ρ^y	Price Markup	0.25	0.36	0.47	0.37	0.25	0.38	0.51	0.36	0.24	0.35	0.46	0.34
ρ^l	Wage Markup	0.64	0.71	0.77	0.71	0.62	0.70	0.77	0.69	0.65	0.71	0.77	0.71
ρ^{Kb}	Commercial Bank Capital	0.93	0.96	0.99	0.97	0.86	0.92	0.97	0.93	0.93	0.96	0.99	0.96
Exogenous Processes (Standard Deviations)													
σ^τ	Deposit Rate Spread	0.002	0.007	0.016	0.005	0.002	0.007	0.018	0.005	0.002	0.007	0.023	0.005
σ^z	Consumer Preference	0.008	0.011	0.014	0.011	0.005	0.008	0.011	0.007	0.008	0.011	0.014	0.011
σ^a	Technology	0.025	0.029	0.033	0.028	0.021	0.025	0.030	0.025	0.024	0.028	0.033	0.028
σ^{mE}	Entrepreneur LTV	0.006	0.008	0.009	0.007	0.004	0.006	0.007	0.005	0.006	0.008	0.009	0.007
σ^d	Deposit Rate Markdown	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
σ^μ	Loan Rate Markup	0.002	0.002	0.003	0.002	0.002	0.003	0.004	0.003	0.002	0.003	0.003	0.002
σ^{qk}	Investment Efficiency	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002
σ^r	Monetary Policy	0.001	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.002	0.001
σ^y	Price Markup	0.001	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.001
σ^l	Wage Markup	0.035	0.041	0.047	0.040	0.029	0.035	0.042	0.035	0.035	0.041	0.047	0.040
σ^{Kb}	Commercial Bank Capital	0.003	0.003	0.004	0.003	0.003	0.003	0.004	0.003	0.003	0.003	0.004	0.003

Note: Results are based on 5 chains with 500,000 draws each based on the Metropolis-Hastings algorithm. Columns 3 to 6 report the posterior moments from the baseline estimation in table 4.2. Columns 7 to 10 report results from the estimation using the sample 1999:Q1 to 2008:Q4, and columns 11 to 14 report results from the estimation using shadow banking data excluding information on investment funds.

B Appendix Chapter 5

B.1 Appendix: The Full Non-Linear DSGE Model

B.1.1 Households

The representative patient household i maximizes the expected utility

$$\max_{C_t^P(i), L_t^P(i), D_t^{P,C}(i), D_t^{P,S}(i)} E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\tilde{u}^P(C_t^P; \varepsilon_t) - \int_0^1 \tilde{\nu}^P(L_t(j); \varepsilon_t) dj \right] \tag{B.1.1}$$

where

$$\tilde{u}^P(C_t^P; \varepsilon_t) \equiv \frac{C_t^{P\,1-\sigma}}{1-\sigma} = \ln(C_t^P) \text{ if } \sigma \to 1 \tag{B.1.2}$$

$$\tilde{\nu}^P(L_t^P; \varepsilon_t) \equiv \frac{L_t^{P\,1+\phi^P}}{1+\phi^P}. \tag{B.1.3}$$

Each household (i) consumes the composite consumption good C_t^P which is given by a Dixit-Stiglitz aggregate consumption good

$$C_t^P \equiv \left[\int_0^1 c_t^P(i)^{\frac{\theta^P - 1}{\theta^P}} di \right]^{\frac{\theta^P}{\theta^P - 1}} \tag{B.1.4}$$

with $\theta^P > 1$. Each type of the differentiated goods is supplied by one monopolistic competitive entrepreneur. Entrepreneurs in industry j use a differentiated type of labor specific to the respective industry, whereas prices for each class of differentiated goods produced in sector j are identically set across firms in that sector. I assume that each household supplies all types of labor and consumes all types of goods. The representative household maximizes utility subject to the budget constraint

$$C_t^P(i) + D_t^{P,C}(i) + D_t^{P,S}(i) \leq w_t L_t^P(i) + (1 + r_{t-1}^{dC}) D_{t-1}^{P,C}(i) + (1 + r_{t-1}^{dS}) D_{t-1}^{P,S}(i) + T_t^P(i) \tag{B.1.5}$$

where $C_t^P(i)$ depicts current total consumption. Total working hours (allotted to the different sectors j) are given by L_t^P and labor disutility is parameterized by ϕ^P. The flow of expenses includes current consumption and real deposits to be made to both commercial and shadow banks, $D_t^{P,C}(i)$ and $D_t^{P,S}(i)$. Resources consist of wage earnings $w_t^P L_t^P(i)$ (where w_t is the real wage rate for the labor input of each household), gross interest income on last period deposits $(1+r_{t-1}^{dC})D_{t-1}^{P,C}(i)$ and $(1+r_{t-1}^{dS})D_{t-1}^{P,S}(i)$, and lump-sum transfers T_t^P that include dividends from firms and banks (of which patient households are the ultimate owners).

First-order conditions of the household maximization problem yield the intertemporal Euler equation

$$\frac{1}{C_t^P} = \beta_P E_t\Big[\frac{1+r_t}{C_{t+1}^P}\Big] \tag{B.1.6}$$

and the labor supply condition

$$w_t = C_t^P L_t^{\phi^P}. \tag{B.1.7}$$

B.1.2 Entrepreneurs

Entrepreneurs engaged in a certain sector j use the respective labor type provided by households as well as capital to produce intermediate goods that retailers purchase in a competitive market. Each entrepreneur i derives utility from consumption $C_t^E(i)$, and finances consumption with production returns and with loans from financial intermediaries. They maximize expected utility

$$\max_{C_t^E(i),\, L_t^P(i),\, B_t^{E,C}(i),\, B_t^{E,S}(i)} \quad E_0 \sum_{t=0}^{\infty} \beta_E^t \frac{{C_t^E}^{1-\sigma}}{1-\sigma} \tag{B.1.8}$$

subject to the budget constraint

$$\begin{aligned} C_t^E(i) + w_t l_t^P(i) + (1+r_{t-1}^{bC})B_{t-1}^{E,C}(i) + (1+r_{t-1}^{bS})B_{t-1}^{E,S}(i) \\ \leq \frac{y_t^E(i)}{x_t} + B_t^{E,C}(i) + B_t^{E,S}(i) \end{aligned} \tag{B.1.9}$$

with x_t determining the price markup in the retail sector. I thus express output y_t^E produced by the entrepreneur in terms of the relative competitive price of the wholesale good, given by $\frac{1}{x_t}$. Output is produced according to the Cobb-Douglas technology

$$y_t^E(i) = a_t K^\alpha L_t(i)^{1-\alpha} \tag{B.1.10}$$

where the (stochastic) total factor productivity (TFP) is given by a_t. Entrepreneurs face a constraint on the amount they can borrow from commercial banks depending on the fixed stock of capital they hold as collateral. Whereas a regulatory loan-to-value (LTV) ratio m_t^E applies for funds borrowed from commercial banks, shadow bank funding is not prone to regulation. Due to a positive spread between interest rates charged for shadow bank and commercial bank loans, entrepreneurs have an incentive to borrow from commercial banks first and turn to shadow bank lending only whenever the possible amount of commercial bank funds, determined by $m_t^E K$, is reached. Further borrowing can be obtained from shadow banks by using capital holdings not reserved for commercial bank funds, $(1-m_t^E)K$. As physical capital is assumed to be fixed, the two respective borrowing constraints are given by

$$(1 + r_t^{bC})B_t^{E,C} \leq m_t^E K \tag{B.1.11}$$

$$(1 + r_t^{bS})B_t^{E,S} \leq (1 - m_t^E)K \tag{B.1.12}$$

where the LTV ratio for commercial banks m_t^E is set exogenously by the regulator and follows an exogenous AR(1) process with mean m^E.

As in Iacoviello (2005) the borrowing constraints is assumed to bind around the steady state such that uncertainty is absent in the model. Thus, in equilibrium, entrepreneurs face binding borrowing constraints, such that equations B.1.11 and B.1.12 hold with equality. Based on the maximization problem B.1.8, entrepreneurs' consumption Euler equation and labor demand are given by

$$\frac{1}{C_t^E} = \beta_E E_t \Big[\frac{1 + r^{bC}}{C_{t+1}^E} \Big] \tag{B.1.13}$$

$$w_t = \frac{(1-\alpha)y_t^E}{L_t x_t} \tag{B.1.14}$$

where x_t is the retail sector markup to which marginal costs are inversely related:

$$MC_t = \frac{1}{x_t}. \tag{B.1.15}$$

Entrepreneurs' leverage with respect to commercial and shadow banks, χ_t^C and χ_t^S is determined by the borrowing constraints the entrepreneur faces when acquiring funds from each intermediary:

$$\chi_t^C = \frac{m_t^E}{1 + r_t^{bC}} \tag{B.1.16}$$

$$\chi_t^S = \frac{1 - m_t^E}{1 + r_t^{bS}}. \tag{B.1.17}$$

As in Gambacorta and Signoretti (2014), entrepreneur consumption is linked to net worth

$$C_t^E = (1 - \beta_E) NW_t^E \tag{B.1.18}$$

which is given by

$$NW_t^E = \alpha \frac{y_t^E}{x_t} + K - (1 + r_{t-1}^{bC}) b_{t-1}^{E,C} - (1 + r_{t-1}^{bS}) b_{t-1}^{E,S} \tag{B.1.19}$$

or, expressed in terms of leverage, as

$$NW_t^E = \frac{K(1 - \chi_t^C - \chi_t^S)}{\beta_E}. \tag{B.1.20}$$

The aggregate production technology entrepreneurs employ is given by:

$$y_t^E = a_t K^\alpha L_t^{1-\alpha} \tag{B.1.21}$$

As physical capital, which entrepreneurs use as collateral for borrowing from both intermediaries, is fixed, loans from commercial and shadow banks are given by

$$B_t^{E,C} = K \chi_t^C \tag{B.1.22}$$

$$B_t^{E,S} = K \chi_t^S. \tag{B.1.23}$$

B.1.3 Financial Intermediaries

Commercial Banks

The commercial bank balance sheet is given by

$$B_t^{E,C} = K_t^C + D_t^{P,C} \tag{B.1.24}$$

where bank capital K_t^C is accumulated from bank profits J_t^C:

$$K_t^C = K_{t-1}^C(1-\delta^C) + J_t^C. \tag{B.1.25}$$

Aggregate bank profits are given by

$$J_t^C = r_t^{bC} B_t^{E,C} - r_t D_t^{P,C} - K_t^C \frac{\kappa_k^C}{2}\left(\frac{K_t^C}{B_t^{E,C}} - \nu_t\right)^2. \tag{B.1.26}$$

As described above, the retail loan rate is given by

$$r_t^{bC} = r_t - \kappa_k^C \left(\frac{K_t^C}{B_t^{E,C}} - \nu_t)(\frac{K_t^C}{B_t^{E,C}}\right)^2 + \mu_t. \tag{B.1.27}$$

Shadow Banks

The aggregate shadow bank balance sheet is given by

$$B_t^{E,S} = D_t^{P,S} + K_t^S. \tag{B.1.28}$$

Following derivations in section 5.2.3 and chapter 4, shadow bank capital is given by

$$K_t^S = \sigma^S[(r_{t-1}^{bS} - r_{t-1}^{dS})\phi_{t-1}^S + (1 + r_{t-1}^{dS})]K_{t-1}^S + \omega^S B_{t-1}^{E,S} \tag{B.1.29}$$

where, following Gertler and Karadi (2011), shadow bank loans are given by

$$B_t^{E,S} = \frac{\eta_t^S}{\theta^S - \nu_t^S} K_t^S \tag{B.1.30}$$

with

$$\eta_t^S = E_t\{(1-\sigma^S) + \beta_S \sigma^S \Psi_{t,t+1}^S \eta_{t,t+1}^S\}, \tag{B.1.31}$$

$$\nu_t^S = E_t\{(1-\sigma^S)\beta_S(r_t^{bS} - r_t) + \beta_S \sigma^S \Xi_{t,t+1}^S \nu_{t,t+1}^S\}, \tag{B.1.32}$$

$$\Psi_{t,t+1}^S = \frac{K_{t+1}^S}{K_t^S} = (r_{t+1}^{bS} - r_t)\phi_t^S + r_t, \tag{B.1.33}$$

$$\Xi_{t,t+1}^S = (\phi_{t+1}^S/\phi_t^S)\Psi_{t,t+1}^S, \tag{B.1.34}$$

and where shadow bank leverage ϕ_t^S is given by

$$\phi_t^S = \frac{B_t^{E,S}}{K_t^S}. \tag{B.1.35}$$

As in chapter 4, I assume a spread on commercial and shadow bank deposit rates:

$$1 + r_t^{dS} = \frac{1 + r_t^{dC}}{1 - \tau^s \varepsilon_t^\tau}. \tag{B.1.36}$$

B.1.4 Monetary Policy and Market Clearing

The central bank is assumed to follow a Taylor-type policy rule given by

$$1 + R_t = (1 + R)^{1-\phi^r} (1 + R_{t-1})^{\phi^r} \left[\pi_t^{\phi^\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi^y} \right]^{1-\phi^r} (1 + \epsilon_t^R) \tag{B.1.37}$$

where ϕ^r is equal to zero in the analytic derivations of in appendix B.4. The aggregate resource constraint is given by

$$Y_t = C_t + K + \frac{K_{t-1}^C \delta^C}{\pi_t}. \tag{B.1.38}$$

Market clearing implies

$$Y_t = \gamma_y y_t^E \tag{B.1.39}$$

$$C_t = C_t^P \gamma_p + C_t^E \gamma_e \tag{B.1.40}$$

$$B_t = B_t^{E,C} + B_t^{E,S}. \tag{B.1.41}$$

Shadow bank and commercial bank credit-to-GDP ratios are defined as:

$$Z_t = \frac{B_t^{E,C}}{Y_t} \tag{B.1.42}$$

$$Z_t^{SB} = \frac{B_t^{E,S}}{Y_t}. \tag{B.1.43}$$

Spreads on loan and deposit rates paid by commercial and shadow banks are given by

$$\Delta_t^{loan} = r_t^{bS} - r_t^{bC} \tag{B.1.44}$$

$$\Delta_t^{deposit} = r_t^{dS} - R_t, \tag{B.1.45}$$

and the spreads earned on intermediation by commercial and shadow banks by

$$\Delta_t^C = r_t^{bC} - R_t \tag{B.1.46}$$

$$\Delta_t^S = r_t^{bS} - r_t^{dS}. \tag{B.1.47}$$

B.1.5 Shock Processes

Deposit Spread Shock:

$$\varepsilon_t^\tau = 1 - \rho^\tau + \rho^\tau \varepsilon_{t-1}^\tau + \epsilon_t^\tau \tag{B.1.48}$$

Productivity Shock:

$$a_t = (1 - \rho^a)a + \rho^a a_{t-1} + \epsilon_t^a \tag{B.1.49}$$

Entrepreneur LTV Shock:

$$m_t^E = (1 - \rho^{m^E})m^E + \rho^{m^E} m_{t-1}^E + \epsilon_t^{m^E} \tag{B.1.50}$$

Loan Rate Markup Shock:

$$\mu_t = (1 - \rho^\mu)\mu + \rho^\mu \mu_{t-1} + \epsilon_t^\mu \tag{B.1.51}$$

B.2 Appendix: Estimation

In the analyses of chapter 5, I rely on the parameters estimated with the quantitative DSGE model of chapter 4 which features investment, household habit formation, and bank market power in deposit markets. I abstract from these characteristics in the model of chapter 5 for the sake of tractability of analytic derivations. In this section, I report estimation results for the modified model for comparability, and I again rely on the full-information Bayesian estimation approach described in chapter 4.3.[1] For estimation purposes, I incorporate all shock processes reported in section A.2.7 into the model of chapter 5, except for the deposit markdown shock μ_t^d (equation A.2.52), and the investment efficiency shock $\varepsilon_t^{q^k}$ (equation A.2.54). For remaining shock processes, I estimate standard deviations and autoregressive parameters relying on the same prior distributions as in section 4.3. I draw on the same data series as in chapter 4, but exclude data on investment and deposit rates. I estimate the same set of structural parameters, only excluding the parameters governing bank market power, κ^{bE} and κ^d, and investment adjustment costs, κ^i in chapter 4. I also exclude the parameter governing habit formation, a^P, as this feature is absent in the model of chapter 5. Table B.1 reports the posterior distribution for both the full model of chapter 4 and the modified model of chapter 5.

[1]However, in the Metropolis-Hastings algorithm, I conducted 5 chains with only 100,000 draws each, as convergence was reached already at that stage, while I relied on 500,000 draws per chain in the estimations of chapter 4.

Table B.1: Posterior Distributions: Full Model vs. Modified Model

		Full Model				Modified Model			
		5 Perc.	**Median**	**95 Perc.**	**Mode**	**5 Perc.**	**Median**	**95 Perc.**	**Mode**
Structural Parameters									
θ^p	Calvo Parameter	0.83	0.87	0.90	0.86	0.80	0.81	0.82	0.80
κ^i	Investment Adjustment Cost	2.98	3.98	5.14	3.67	-	-	-	-
κ^d	Deposit Rate Adjustment Cost	10.00	13.26	16.72	12.62	-	-	-	-
κ^{bE}	Loan Rate Adjustment Cost	4.84	8.34	14.23	7.56	-	-	-	-
κ_k^C	CCR Deviation Cost	0.01	10.05	21.32	24.71	0.03	12.49	22.37	9.25
ϕ^π	TR Coefficient π	1.44	1.87	2.30	1.75	2.29	2.73	3.14	2.71
ϕ^y	TR Coefficient y	0.14	0.24	0.34	0.20	0.10	0.15	0.21	0.15
ϕ^r	Interest Rate Smoothing	0.84	0.88	0.91	0.88	0.63	0.70	0.77	0.70
a^P, a^E	HH Habit Formation	0.70	0.77	0.84	0.77	-	-	-	-
Exogenous Processes (AR Coefficients)									
ρ^τ	Deposit Rate Spread	0.62	0.81	0.95	0.85	0.65	0.81	0.96	0.85
ρ^z	Consumer Preference	0.82	0.87	0.92	0.87	0.82	0.89	0.95	0.88
ρ^a	Technology	0.31	0.42	0.52	0.42	0.70	0.83	0.95	0.85
ρ^{mE}	Entrepreneur LTV	0.91	0.94	0.97	0.95	0.95	0.98	0.99	0.98
ρ^d	Deposit Rate Markdown	0.27	0.36	0.46	0.36	-	-	-	-
ρ^μ	Loan Rate Markup	0.51	0.63	0.75	0.64	0.66	0.82	0.96	0.85
ρ^{qk}	Investment Efficiency	0.33	0.46	0.58	0.49	-	-	-	-
ρ^y	Price Markup	0.25	0.36	0.47	0.37	0.28	0.40	0.52	0.41
ρ^l	Wage Markup	0.64	0.71	0.77	0.71	0.93	0.96	0.99	0.97
ρ^{Kb}	Commercial Bank Capital	0.93	0.96	0.99	0.97	0.95	0.97	0.99	0.98
Exogenous Processes (Standard Deviations)									
σ^τ	Deposit Rate Spread	0.002	0.007	0.016	0.005	0.002	0.007	0.017	0.005
σ^z	Consumer Preference	0.008	0.011	0.014	0.011	0.001	0.002	0.002	0.001
σ^a	Technology	0.025	0.029	0.033	0.028	0.002	0.003	0.004	0.003
σ^{mE}	Entrepreneur LTV	0.006	0.008	0.009	0.007	0.015	0.176	0.204	0.171
σ^d	Deposit Rate Markdown	0.002	0.002	0.002	0.002	-	-	-	-
σ^μ	Loan Rate Markup	0.002	0.002	0.003	0.002	0.000	0.001	0.001	0.001
σ^{qk}	Investment Efficiency	0.001	0.002	0.002	0.002	-	-	-	-
σ^r	Monetary Policy	0.001	0.001	0.002	0.001	0.001	0.002	0.002	0.002
σ^y	Price Markup	0.001	0.002	0.002	0.001	0.001	0.002	0.002	0.002
σ^l	Wage Markup	0.035	0.041	0.047	0.040	0.006	0.008	0.009	0.008
σ^{Kb}	Commercial Bank Capital	0.003	0.003	0.004	0.003	0.017	0.019	0.023	0.019

Note: Results are based on 5 chains with 100,000 draws each based on the Metropolis-Hastings algorithm. Columns 3 to 6 report the posterior moments from the baseline estimation in table 4.2. Columns 7 to 10 report results from the estimation of the modified model in chapter 5.

For comparison, I conduct the same analysis as in figures 5.4 and 5.5 with the estimated parameters and report impulse response functions to an unexpected monetary policy tightening and an expansionary technology shock in figures B.1 and B.2.[2] The impulse responses under optimal policy are qualitatively and quantitatively comparable for the monetary policy shock under both parameterizations (figures 5.4 and B.1). The drop in household consumption and output is less pronounced for the estimated model, and thus the decline in inflation is also more benign. For banking-related variables, differences between the calibrations are minor. For the productivity shock (figures 5.5 and B.2), dynamics are similar qualitatively under both parameterizations, but a few quantitative differences emerge. The expansion in the economy is larger, and thus lending dynamics are more pronounced in the estimated model. In return, interest rate spreads are higher, and swings in bank capital and profits are stronger.

B.3 Appendix: Efficient Steady State and Financial Sector Distortions

In this section, I derive zero-inflation ($\Pi = 1$) steady-state values starting from a perfectly competitive and frictionless financial sector. I then discuss how financial sector inefficiencies result in deviations of credit variables from efficient levels in the decentralized economy. Steady-state allocations are *efficient* whenever they are equal to the values determined in a *frictionless economy*, i.e. in a model with

- no price dispersion ($\Delta = 1$)
- no monopolistic competition in the firm sector ($x = 1$)
- no monopolistic competition in the commercial banking sector ($\mu = 0$)
- no moral hazard friction and risk in the shadow banking sector ($\theta^S = \tau^S = 0$)

I then discuss how different time-invariant macroprudential policies – capital requirements and LTV ratios – can be employed to obtain efficient steady-state allocations in the decentralized economy and in the presence of steady-state distortions.

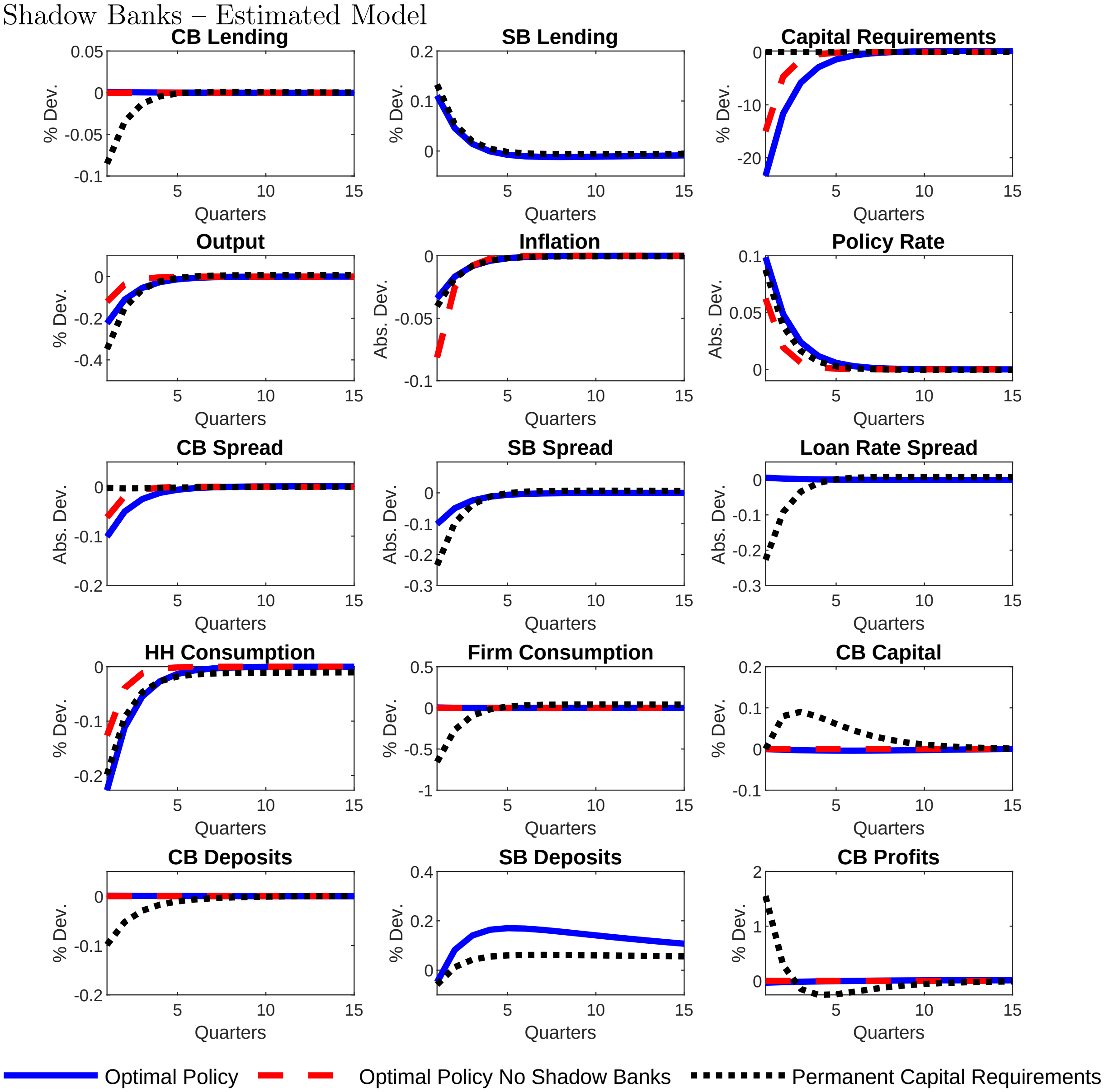
B.3.1 Social Planner Economy

As given by equation (5.33), the social planner maximizes a weighted average of patient household and impatient entrepreneur utility:

$$\mathbb{W} = (1 - \beta_P)U(C^P, L^P) + (1 - \beta_E)U(C^E) \tag{B.2.1}$$

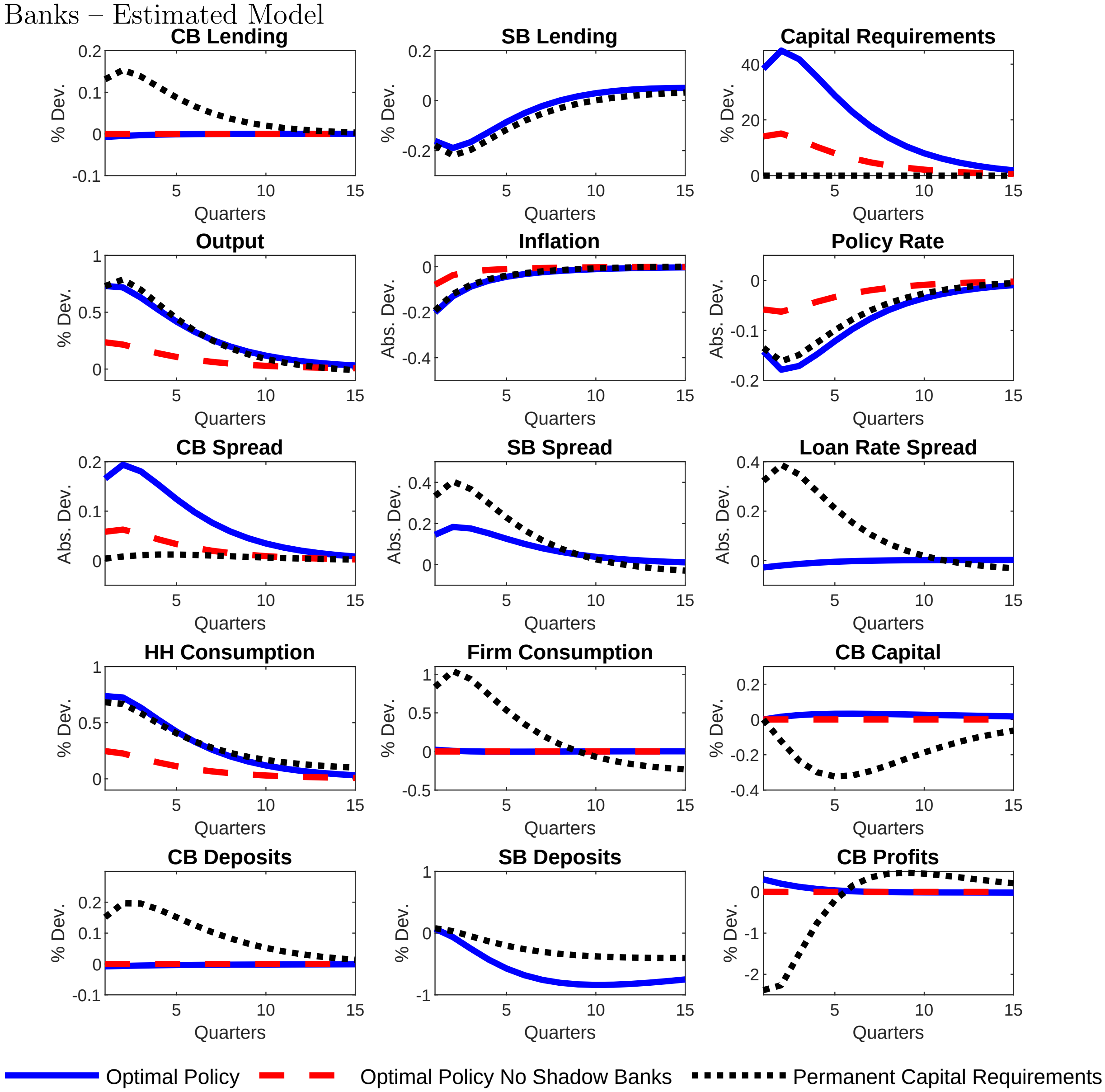
[2] For comparability of the dynamic responses, I set structural parameters to the estimated values, but employ the same shock processes as under the baseline calibration.

Figure B.1: Impulse Response Functions Monetary Policy Shock: With and Without Shadow Banks – Estimated Model



Note: Impulse responses to a one-standard-deviation monetary policy shock with welfare-optimal response by macroprudential regulator. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

Figure B.2: Impulse Response Functions Technology Shock: With and Without Shadow Banks – Estimated Model



Note: Impulse responses to a one-standard-deviation technology shock with welfare-optimal response by macroprudential regulator. Rates in absolute deviations from steady state, all other variables as percentage deviations from steady state.

where the Pareto weights are determined as in Lambertini et al. (2013) and Rubio (2011) and $U(\bullet)$ are the per-period utility functions. In choosing allocations, the social planner is constrained by the aggregate production function B.1.21 and the goods market clearing condition B.1.38. However, the social planner's problem is not subject to the borrowing constraints 5.8 and 5.9.

Combining the aggregate production function and the goods market clearing condition yields

$$K^{\alpha}L^{1-\alpha} = \gamma_P C^P + \gamma_E C^E. \tag{B.2.2}$$

Letting λ depict the Lagrange multiplier on constraint B.2.2, the first-order conditions yield

$$(1-\beta_P)U'_{C^P} = -\lambda\gamma_P \tag{B.2.3}$$

$$(1-\beta_E)U'_{C^E} = -\lambda\gamma_E \tag{B.2.4}$$

$$(1-\beta_P)U'_{L^P} = \lambda(1-\alpha)\frac{Y}{L^P} \tag{B.2.5}$$

Assuming unity in consumption weights ($\gamma_P = \gamma_E = 1$), the efficient steady state implies that the patient household's marginal rate of substitution between consumption and labor equals the economy's marginal rate of transformation between output and labor:

$$-\frac{U'_{L^P}}{U'_{C^P}} = (1-\alpha)\frac{Y}{L^P}. \tag{B.2.6}$$

Using the explicit utility functions given by equations 5.1 and 5.6 in the first-order conditions, the relation between marginal utilities of borrowers and savers is given by

$$(1-\beta_P)C^{P^{-\sigma}} = (1-\beta_E)C^{E^{-\sigma}}. \tag{B.2.7}$$

Solving for C^E and using in the aggregate consumption identity $C = C^P + C^E$ yields

$$C^P = \left[1 + \left(\frac{1-\beta_E}{1-\beta_P}\right)^{\frac{1}{\sigma}}\right]^{-1} C. \tag{B.2.8}$$

Assuming a subsidy set to remove distortions from monopolistic competition in the firm sector such that $x = 1$, the efficient steady state labor market equilibrium is determined by equations B.1.7 and B.1.14

$$C^P L^{\phi^P} = (1-\alpha)\frac{Y}{L}. \tag{B.2.9}$$

Plugging in the expression for C^P derived above, and substituting the aggregate production function and the social planner constraint B.2.2, one can derive

$$L = \left[(1-\alpha)\left\{1 + \left(\frac{1-\beta_E}{1-\beta_P}\right)^{\frac{1}{\sigma}}\right\}\right]^{\frac{1}{\alpha(1-\alpha)\phi^L}}. \quad \text{(B.2.10)}$$

Finally, using the efficient steady state level of labor input in the production function determines steady-state output, which is independent of the distribution of debt and credit intermediated in the economy:

$$Y^* = K^\alpha \left[(1-\alpha)\left\{1 + \left(\frac{1-\beta_E}{1-\beta_P}\right)^{\frac{1}{\sigma}}\right\}\right]^{\frac{1}{\alpha\phi^L}}. \quad \text{(B.2.11)}$$

Proposition 8 (Efficient level of output)**.** *In the frictionless economy, the efficient level of output is not affected by the distribution of debt and the relative credit shares from intermediaries.*

In the frictionless planner economy, credit supply by commercial banks is only limited due to regulation and given by

$$B^{E,C} = \frac{K^C}{\nu}. \quad \text{(B.2.12)}$$

Furthermore, one can show that given perfect intermediation by both types of intermediaries, borrowers and savers are indifferent between channeling funds through commercial or shadow banks, as the two intermediaries are identical.[3] Formally, I assume that in the frictionless economy, shadow banks are not able to divert funds ($\theta^S = 0$) and are riskless intermediaries ($\tau^S = 0$), such that they are structurally identical to commercial banks. In fact, one can show that steady-state leverage of shadow banks is given by

$$\phi^S = \frac{-b - \sqrt{b^2 - 4ac}}{2a} \quad \text{(B.2.13)}$$

where
$a = \theta^S \beta_S \sigma^S \Delta^S$
$b = -(1-\sigma^S)(\theta^S - \beta_S \Delta^S)$
$c = 1 - \sigma^S$.

One can straightforwardly see that $\phi^S = 0$ whenever $\theta^S = 0$ and $\Delta^S = 0$, as is the case in the frictionless economy. Therefore, steady-state shadow bank lending in the planner economy which is given by

$$B^{E,S} = \phi^S K^S \quad \text{(B.2.14)}$$

[3]See benchmark case in appendix A.1.

is equal to zero and shadow banks are nonexistent in the planner economy.

Proposition 9 (Shadow and commercial bank credit in the planner economy)**.** *In the frictionless economy, the efficient level of shadow bank credit is equal to zero, such that shadow banks are nonexistent, as shadow banks and commercial banks are effectively identical institutions. Absent borrowing constraints, credit intermediation is determined by credit supply, which depends on capital regulation.*

B.3.2 Decentralized Economy

As shown above, the frictionless planner economy does not provide scope for shadow banking, such that the efficient level of shadow bank credit is equal to zero. However, whenever borrowers face constraints with respect to lending from commercial banks, as in the decentralized economy studied in the following, the potential for shadow banking increases as borrowers will try to circumvent credit constraints by turning to shadow banks which determine an additional source of funding. I will discuss how the fact that borrowers face credit constraints in the decentralized economy provides scope for non-zero shadow bank activity, even in the absence of bank market power and moral hazard or default risk in the shadow banking sector. In the decentralized economy, the real interest rate is determined by the patient household's discount rate such that

$$1 + r = \frac{1}{\beta_P}. \tag{B.2.15}$$

For now, all intermediaries efficiently intermediate funds between borrowers and savers and earn zero profits. Therefore, the interest rate spreads are zero in the decentralized economy's steady state such that

$$r^{bC*} = r^{bS*} = r^{dC*} = r^{dS*} = r. \tag{B.2.16}$$

Furthermore, borrowing constraints 5.8 and 5.9 the entrepreneur faces bind. As financial firms intermediate funds efficiently, equilibrium credit from both intermediaries is determined not only by credit supply but also by credit demand in steady state, which is determined by the borrowing constraints

$$B^{E,C*} = \frac{m^E K}{1 + r^{bC*}} = \beta_P m^E K \Leftrightarrow \chi^{C*} = \beta_P m^E, \tag{B.2.17}$$

$$B^{E,S*} = \frac{(1 - m^E)K}{1 + r^{bS*}} = \beta_P (1 - m^E) K \Leftrightarrow \chi^{S*} = \beta_P (1 - m^E). \tag{B.2.18}$$

Solving for m^E and combining yields

$$B^{E,S*} = \beta_P K - B^{E,C*}. \tag{B.2.19}$$

In the frictionless planner economy's steady state discussed in the previous section, macroprudential regulation determined *total* credit supply and intermediation. In the decentralized and in the distorted steady states discussed below, credit demand constraints in combination with financial market distortions furthermore affect the *relative* provision of credit by shadow and commercial banks.

Proposition 10 (Credit leakage in decentralized economy)**.** *Due to credit leakage as in chapter 4, higher levels of credit provided by commercial banks lower credit demanded from shadow banks and vice versa in the decentralized steady state. Due to borrower constraints on commercial bank credit, scope for shadow bank intermediation is present in the decentralized economy.*

B.3.3 Friction 1: Commercial Bank Market Power

In the following, I introduce financial market frictions and allow for market power in the commercial banking sector. In chapter 4, these frictions were microfounded via monopolistic competition in commercial bank credit markets. In this chapter, I economize on the analytic derivations by assuming a permanent additive markup $\mu > 0$ that commercial banks charge over the deposit rate they pay to households. While I assume steady-state distortions due to monopolistic competition in the firm sector to be removed by a subsidy such that $x = 1$, I allow distortions stemming from financial sector inefficiencies such as bank market power to affect steady-state levels of credit. Thus, whenever I refer to the *distorted steady state* in this chapter, I assume distortions in the real economy to be compensated with adequate (fiscal) policies, while distortions related to financial markets affect credit aggregates and are not yet compensated.

Due to the markup charged, the commercial bank loan rate is now given by

$$1 + r^{bC} = 1 + r + \mu = \frac{1}{\beta_P} + \mu = \frac{1 + \beta_P \mu}{\beta_P} \tag{B.2.20}$$

such that $r^{bC} > r^{bC*}$ for $\mu > 0$. Using the steady-state bank loan rates in the steady-state loan demand condition yields

$$B^{E,C} = \frac{m^E K}{1 + r^{bC}} = \frac{\beta_P}{1 + \beta_P \mu} m^E K \tag{B.2.21}$$

in the inefficient economy such that $B^{E,C} < B^{E,C*}$. The difference between the level of commercial bank credit in the efficient and the distorted steady state is given by

$$\widehat{B}^{E,C} = B^{E,C} - B^{E,C*} = \left(\frac{\beta_P}{1+\beta_P\mu} - \beta_P\right) m^E K. \tag{B.2.22}$$

As perfectly competitive and for now risk-free shadow banks provide the same credit good to borrowers, the introduction of a loan markup in the commercial banking sector, ceteris paribus, increases the demand for shadow bank credit by entrepreneurs. Conversely, market power in the commercial bank credit market induces that borrowers demand less credit from commercial banks than determined by a binding borrowing constraint 5.8. Therefore, a negative value of $\widehat{B}^{E,C}$ implies that the borrowing constraint for commercial bank credit is not binding. As laid out in detail in appendix A.1, the borrowing constraint on shadow bank credit 5.9 should not be interpreted as a regulatory constraint. Instead, it is determined by the share of physical capital K pledged by borrowers to receive commercial bank lending. In fact, borrowers use the share of their capital endowment not reserved as collateral for commercial bank credit and pledge it against shadow bank borrowing. Thus, $m^{E,S}$ is affected by both the regulatory LTV ratio for commercial banks (if borrowers are able to borrow from these institutions until constraint 5.8 binds), and by the deviation of commercial bank credit from the efficient level, which is depicted by the level of commercial bank credit when 5.8 binds:

$$m^{E,S} = 1 - m^E - (1 + r^{bC})\frac{\widehat{B}^{E,C}}{m^E K}. \tag{B.2.23}$$

The last term depicts the additional amount of shadow bank credit that can be received by pledging collateral not used for commercial bank credit whenever commercial bank borrowing deviates from the efficient credit level of the decentralized economy. It is determined by the gross lending that could have been received from commercial banks without credit rationing due to bank market power, relative to the potential level of commercial bank borrowing. With bank market power, shadow bank credit is therefore given by

$$B^{E,S} = \frac{m^{E,S} K}{1 + r^{bS}}. \tag{B.2.24}$$

Using $m^{E,S}$ in this condition and simplifying yields

$$B^{E,S} = \beta_P\left(1 - \frac{1}{1+\beta_P\mu} m^E\right) K \tag{B.2.25}$$

implying $B^{E,S} > B^{E,S^*}$. Equation B.2.25 takes account of the fact that higher demand for shadow bank credit also affects the relative cost of funding from these institutions. Assuming entrepreneurs to accommodate their frictionless steady-state level of total credit demand $B = B^{E,C} + B^{E,S}$, the shift towards shadow banks raises returns of these institutions. Due to arbitrage, the loan rate efficient shadow banks earn will finally converge towards the commercial bank loan rate, such that $r^{bS} \to r^{bC}$ in the limit. As a consequence, steady-state net worth of entrepreneurs, given by

$$NW^E = \alpha Y + K - (1 + r^{bC})B^{E,C} + (1 + r^{bS})B^{E,S} \tag{B.2.26}$$

or

$$NW^E = \alpha Y + K - (1 + r^{bC})(B^{E,C} + B^{E,S}) \tag{B.2.27}$$

will be lower than the efficient level NW^{E^*} as credit costs are larger due to commercial bank market power.

Importantly, the deviation of commercial bank credit leaves the efficient level of output from proposition 8 unaffected. One can therefore express the deviation in credit in the form of steady-state credit-to-GDP ratio

$$\widehat{Z} = Z - Z^* \tag{B.2.28}$$

$$\widehat{Z}^{SB} = Z^{SB} - Z^{SB*} \tag{B.2.29}$$

where $Z = \frac{B^{E,C}}{Y^*}$, $Z^* = \frac{B^{E,C*}}{Y^*}$, $Z^{SB} = \frac{B^{E,S}}{Y^*}$, $Z^{SB^*} = \frac{B^{E,S*}}{Y^*}$ and therefore $Z < Z^*$ and $Z^{SB} > Z^{SB^*}$. In equations 5.39 and 5.40, it will exactly be due to this distortion that permanent gaps between the observed and the efficient levels of commercial and shadow bank credit-to-GDP ratios open up.

Proposition 11 (Credit distortions due to CB market power)**.** *Market power in the commercial banking sector induces steady-state distortions that result in deviations of commercial and shadow bank credit from efficient levels in the decentralized economy, as commercial (shadow) bank credit is lower (higher) compared to the level obtained in the frictionless economy. Due to market power, commercial banks provide less credit than in the efficient economy, and borrowers will demand credit from shadow banks to keep total credit received at the efficient level. Higher credit costs due to bank market power increases funding costs from both types of intermediaries for borrowing entrepreneurs. Thus, their net worth is lower than in the frictionless economy.*

B.3.4 Friction 2: Moral Hazard in the Shadow Banking Sector

Introducing monopolistic competition in the commercial banking sector already provided a rationale for permanent deviations of commercial and shadow bank credit from efficient levels. In the following, I furthermore discuss how introducing moral hazard and risk in the shadow banking sector affects the above results and induces an additional trade-off for time-invariant macroprudential policies.

First, I allow shadow banks to secretly divert a share of deposits which opens up the common moral hazard problem developed in Gertler and Karadi (2011) underlying the microfoundations of the shadow banking sector, implying steady-state shadow bank leverage $\theta^S > 0$. Second, due to absence of regulation, shadow banks are risky, such that depositors demand a risk premium on the funds provided. According to equation 5.21, the steady-state deposit rate spread therefore becomes

$$1 + r^{dS} = \frac{1 + r^{dC}}{1 - \tau^S}. \tag{B.2.30}$$

As shadow banks act under perfect competition, they pass higher funding costs to customers such that

$$1 + r^{bS} = \frac{1 + r^{bC}}{1 - \tau^S}. \tag{B.2.31}$$

Furthermore, as discussed in Gertler and Karadi (2011), due to the introduction of market imperfections in the form of moral hazard, the risk-adjusted premium on credit intermediation becomes positive, as banks' ability to obtain funds is limited. As in the original study, the calibration induces that the steady-state spread shadow banks earn on intermediation $\Delta^S > 0$ whenever moral hazard is present in the model. In this case, the incentive constraint that limits shadow bank leverage endogenously binds in steady state, as shadow banks would otherwise indefinitely expand their lending. Therefore, in the distorted steady state with moral hazard and risk in the shadow banking sector, shadow bank leverage given by equation B.2.13 will be greater than zero and shadow bank credit will be above the efficient level. Furthermore, due to the riskiness of shadow banks, shadow bank credit in the distorted steady state becomes

$$B^{E,S} = \frac{1 - \tau^S}{1 + r^{bC}} m^{E,S} K = \frac{1 - \tau^S}{1 + r + \mu} m^{E,S} K \tag{B.2.32}$$

or

$$B^{E,S} = (1 - \tau^S)\beta_P \left(1 - \frac{1}{1 + \beta_P \mu} m^E\right) K. \tag{B.2.33}$$

Finally, one can express the difference between shadow bank credit in the distorted and the efficient steady state as

$$\begin{aligned}\widehat{B}^{E,S} = B^{E,S} - B^{E,S*} &= (1-\tau^S)\beta_P\left(1 - \frac{1}{1+\beta_P\mu}m^E\right)K - \beta_P(1-m^E)K \\ &= \left[\left(1 - \frac{1-\tau^S}{1+\beta_P\mu}\right)m^E - \tau^S\right]K\beta_P \end{aligned} \quad \text{(B.2.34)}$$

implying $B^{E,S} > B^{E,S*}$ under the baseline calibration. However, high values of τ^S and low values of μ potentially result in a negative value of $\widehat{B}^{E,S}$ as both higher risk in the shadow banking sector and low market power of commercial banks can induce a reverse shift of credit towards commercial banks.

Proposition 12 (Moral hazard and shadow bank risk)**.** *Due to moral hazard in the shadow bank sector, shadow bank leverage is greater than zero which potentially magnifies the deviation of steady-state shadow bank credit in the decentralized economy from its efficient level. However, high levels of shadow bank risk can mitigate the effect, as the risk premium on shadow bank funds depositors demand decreases shadow bank credit demand compared to the case without shadow bank risk ($\tau^S = 0$).*

B.3.5 Implications for Permanent Macroprudential Policy

Market-Clearing Levels of Macroprudential Policies

As shown in section B.3.1, the first-best allocation in a frictionless economy features zero intermediation by shadow banks. Given that both bank types intermediate funds in an identical and perfectly competitive manner in this economy, welfare-costless commercial bank intermediation induces that it is optimal to reduce regulatory constraints to zero, such that $\nu = 0$ is optimal in this environment.

However, bank market power and inefficiencies in the shadow banking sector as introduced in sections B.3.3 and B.3.4 induce a policy trade-off that affects the optimal level of time-invariant capital requirements and LTV ratios. In the decentralized economy absent financial frictions of section B.3.2, the commercial bank credit market equilibrium is given by

$$\underbrace{\frac{K^C}{\nu^*}}_{\text{Credit supply}} = \underbrace{\beta_P m^E K.}_{\text{Credit demand}} \quad \text{(B.2.35)}$$

Solving for the efficient level of capital requirements yields

$$\nu^* = \frac{K^C}{\beta_P m^E K}. \tag{B.2.36}$$

However, in the distorted steady state of the economy featuring financial frictions, the commercial bank credit market equilibrium reads

$$\underbrace{\frac{K^C}{\nu^C}}_{\text{Credit supply}} = \underbrace{\frac{\beta_P}{1+\beta_P\mu} m^E K}_{\text{Credit demand}} \tag{B.2.37}$$

such that

$$\nu^C = \frac{K^C(1+\beta_P\mu)}{\beta_P m^E K} \tag{B.2.38}$$

implying

$$\begin{aligned} \nu^C &> \nu^* \text{ if } \mu > 0 \\ \nu^C &= \nu^* \text{ if } \mu = 0 \end{aligned} \tag{B.2.39}$$

where ν^C refers to the market-clearing level of capital requirements in the commercial bank credit market. Market power in the commercial banking sector therefore provides a rationale for regulators to raise capital requirements above the efficient level. Intuitively, the social cost induced from bank market power ceteris paribus provides an incentive to shift more intermediation towards the perfectly competitive shadow banking sector. As higher capital charges on commercial banks induce credit leakage, raising regulatory costs for commercial banks increases the share of credit intermediation provided by shadow banks.

If shadow banks are assumed to be risk-free intermediaries, it would ultimately be welfare-improving to shift intermediation completely to these perfectly competitive intermediaries to minimize the welfare loss stemming from bank market power. However, as shadow banks are risky lenders (captured by the spread parameter τ^S), increasing the share of credit intermediated increases potential costs from shadow bank default. The shadow bank credit market equilibrium in the steady state of the decentralized economy without frictions is given by

$$\underbrace{\beta_P K - B^{E,C*}}_{\text{Credit supply}} = \underbrace{\beta_P(1 - m^E)K}_{\text{Credit demand}} \tag{B.2.40}$$

$$\beta_P K - \frac{K^C}{\nu^*} = \beta_P(1 - m^E)K. \tag{B.2.41}$$

Solving for ν^*, the steady-state level of commercial bank capital requirements that results in the clearing of the shadow bank credit market, again implies

$$\nu^* = \frac{K^C}{\beta_P m^E K}. \tag{B.2.42}$$

In the distorted steady state of the financial friction economy, the shadow bank credit market equilibrium is given by

$$\underbrace{\beta_P K - \frac{K^C}{\nu^S}}_{\text{Credit supply}} = \underbrace{(1 - \tau^S)\beta_P\left(1 - \frac{1}{1 + \beta_P \mu} m^E\right)K.}_{\text{Credit demand}} \tag{B.2.43}$$

Solving for ν^S yields

$$\nu^S = K^C\left[\beta_P K - (1 - \tau^S)\beta_P\left(1 - \frac{1}{1 + \beta_P \mu} m^E\right)K\right]^{-1} \tag{B.2.44}$$

implying

$$\begin{aligned}
\nu^S &> \nu^* \text{ if } \mu > 0, \tau^S = 0,\\
\nu^S &< \nu^* \text{ if } \mu = 0, \tau^S > 0,\\
\nu^S &= \nu^* \text{ if } \mu = 0, \tau^S = 0,\\
\nu^S &< \nu^* \text{ if } \mu > 0, \tau^S > 0.
\end{aligned} \tag{B.2.45}$$

Comparing across markets in the distorted steady state, we observe from conditions B.2.39 and B.2.45 that

$$\nu^C > \nu^* > \nu^S \text{ if } \mu > 0, \tau^S > 0. \tag{B.2.46}$$

Proposition 13 (Implications on capital requirements)**.** *In the economy featuring financial frictions, the distorted steady state implies that the market-clearing level of commercial bank capital requirements is larger than zero. In the frictionless decentralized economy, there is a unique market-clearing level of capital requirements. In the economy featuring financial frictions, no single market-clearing level of commercial bank capital requirement can be determined. Time-invariant macroprudential policy faces a trade-off, as the level of requirements*

- *increases when the commercial bank loan markup increases*
- *decreases when shadow bank risk premia increase*

Welfare-Optimal Levels of Macroprudential Regulation

Having established how market-clearing levels of steady-state capital requirements depend on the distortion parameters μ and τ^S, I discuss how time-invariant macroprudential policies can be employed to bring credit aggregates to efficient levels such that permanent steady-state distortions due to financial market inefficiencies disappear. In the analysis, I assume that regulators first set borrower-side LTV ratios such that the efficiency gap in the shadow bank sector is closed and then, conditional on the resulting level of LTV ratios, the optimal level of steady-state capital requirements that additionally closes the efficiency gap in the commercial bank credit market.

Shadow bank credit Regulators set the borrower-oriented permanent LTV ratio such that shadow bank credit is at its efficient level. To do so, one must find the optimal level of the steady-state LTV ratio $\widehat{m}^E$ that results in $\widehat{B}^{E,S} = B^{E,S} - B^{E,S*} = 0$. Letting $\widehat{m}^E$ determine the optimal LTV ratio closing the credit gap, we get from equation B.2.34

$$
\begin{aligned}
0 &= \left[\left(1 - \frac{1-\tau^S}{1+\beta_P\mu}\right)\widehat{m}^E - \tau^S\right]K\beta_P \\
\Leftrightarrow \widehat{m}^E &= \tau^S \frac{1+\beta_P\mu}{\tau^S+\beta_P\mu}
\end{aligned}
\tag{B.2.47}
$$

which implies

$$
\begin{aligned}
\widehat{m}^E &= 0 \text{ if } \mu > 0, \tau^S = 0 \\
\widehat{m}^E &= 1 \text{ if } \mu = 0, \tau^S > 0.
\end{aligned}
\tag{B.2.48}
$$

Proposition 14 (Optimal level of LTV ratio)**.** *The optimal level of the LTV ratio, i.e. the level that brings steady-state shadow bank credit to its efficient level in the distorted economy,*

- *is equal to zero whenever shadow bank risk is zero and implies a complete shift of intermediation from welfare-costly commercial to welfare-costless shadow banks in this case.*

- *is equal to one whenever commercial banks are perfectly competitive and shadow banks are risky, and implies a complete shift of intermediation from welfare-costly shadow to welfare-costless commercial banks in this case.*

Furthermore, the optimal level of the LTV ratio

- *decreases when the commercial bank loan markup increases*

- *increases when shadow bank risk premia increase*

Commercial bank credit From the analysis in section B.3.5, we know that due to market power in the commercial banking sector, $\nu^C > \nu^*$ if $\mu > 0$ and that $B^{E,C} = B^{E,C^*}$ whenever $\nu^C = \frac{K^C(1+\beta_P\mu)}{\beta_P m^E K}$. We can now derive the efficient level of steady-state capital requirements $\widehat{\nu}$ that closes the commercial bank credit gap B.2.22 taking into account the efficient level of the LTV ratio $\widehat{m}^E$ that closes the shadow bank credit gap B.2.34 which is given by

$$\begin{aligned} \widehat{\nu} &= \frac{K^C(1+\beta_P\mu)}{\beta_P\widehat{m}^E K} \\ \Leftrightarrow \widehat{\nu} &= \frac{K^C(1+\beta_P\mu)}{\beta_P K}\frac{\tau^S+\beta_P\mu}{\tau^S(1+\beta_P\mu)} \\ \Leftrightarrow \widehat{\nu} &= \frac{K^C(\tau^S+\beta_P\mu)}{\beta_P\tau^S K}. \end{aligned} \tag{B.2.49}$$

The efficient capital requirements ν^* is now given by

$$\begin{aligned} \nu^* &= \frac{K^C}{\beta_P\widehat{m}^E K} \\ \Leftrightarrow \nu^* &= \frac{K^C}{\beta_P K}\frac{\tau^S+\beta_P\mu}{\tau^S(1+\beta_P\mu)} \end{aligned} \tag{B.2.50}$$

such that

$$
\begin{aligned}
&\widehat{\nu} > \nu^* \text{ if } \mu > 0, \tau^S \to 0,\\
&\widehat{\nu} = \nu^* \text{ if } \mu = 0, \tau^S > 0,\\
&\widehat{\nu} = \nu^* \text{ if } \mu = 0, \tau^S \to 0,\\
&\widehat{\nu} > \nu^* \text{ if } \mu > 0, \tau^S > 0.
\end{aligned} \tag{B.2.51}
$$

Proposition 15 (Optimal level of capital requirements)**.** *The conditional optimal level of the commercial bank capital requirement, i.e. the level that brings steady-state commercial bank credit to its efficient level in the distorted economy taking the level of the LTV ratio that closes the shadow bank credit gap into account,*

- *is larger than the level obtained in the decentralized economy without financial frictions whenever commercial banks act under monopolistic competition and shadow bank credit is at the efficient level. In this case, ceteris paribus, welfare increases with the share of intermediation conducted by perfectly competitive shadow banks.*
- *is equal to the level obtained in the decentralized economy without financial frictions whenever commercial banks act under perfect competition and shadow bank credit is at the efficient level. In this case, the efficient level of commercial bank credit of the decentralized economy absent financial frictions is reached whenever $\widehat{\nu} = \nu^*$, see section B.3.5.*

B.4 Appendix: Utility-Based Welfare Functions

B.4.1 No Shadow Banking

The welfare function is derived following Benigno and Woodford (2012) from a second-order approximation of aggregate utility. Following Lambertini et al. (2013) and Rubio (2011), the social welfare measure is given by a weighted average of patient households' and impatient firms' welfare functions:

$$W_{t_0} = (1 - \beta_P)W^P_{t_0} + (1 - \beta_E)W^E_{t_0}. \tag{B.3.1}$$

For patient household and firms, the respective welfare function is given by the conditional expectation of lifetime utility at date t_0,

$$W^P_{t_0} \approx E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0}[U(C^P_t, L^P_t)] \tag{B.3.2}$$

and

$$W_{t_0}^E \approx E_{t_0} \sum_{t=t_0}^{\infty} \beta_E^{t-t_0} [U(C_t^E)]. \tag{B.3.3}$$

Patient Household Welfare

As in Benigno and Woodford (2005), I assume patient households to derive utility from consuming a Dixit-Stiglitz aggregate consumption good given by

$$C_t^P \equiv \left[\int_0^1 c_t^P(i)^{\frac{\theta^P - 1}{\theta^P}} di \right]^{\frac{\theta^P}{\theta^P - 1}} \tag{B.3.4}$$

with $\theta^P > 1$. Each type of the differentiated goods is supplied by one monopolistic competitive entrepreneur. Entrepreneurs in industry j use a differentiated type of labor specific to the respective industry, whereas prices for each class of differentiated goods produced in sector j are identically set across firms in that sector. I assume that each household supplies all types of labor and consumes all types of goods. Therefore, the representative household's period utility is of the form

$$U_t^P(C_t^P, L_t^P) = \tilde{u}^P(C_t^P; \varepsilon_t) - \int_0^1 \tilde{\nu}^P(L_t(j); \varepsilon_t) dj \tag{B.3.5}$$

where

$$\tilde{u}^P(C_t^P; \varepsilon_t) \equiv \frac{C_t^{P\,1-\sigma}}{1-\sigma} \tag{B.3.6}$$

$$\tilde{\nu}^P(L_t^P; \varepsilon_t) \equiv \frac{L^{P\,1+\phi^P}}{1+\phi^P}. \tag{B.3.7}$$

Employment

The production technology is identical across sectors, even though each firm uses the industry-specific labor type as input:

$$y_t^E(i) = a_t K^\alpha L_t(i)^{1-\alpha}. \tag{B.3.8}$$

By inverting the production function, one can express the second term in equation (B.3.5) as a function of equilibrium production. Furthermore, as in Benigno and Woodford (2005), the relative quantities of the differentiated goods demanded can be expressed as a function of the relative prices for these goods. We can thus express

$$\int_0^1 \tilde{\nu}^P(y_t(i);\varepsilon_t)dj = \frac{1}{1+\phi^P}\frac{Y_t^{1+\omega}}{a_t^{1+\omega}L_t^{\phi^P}}\Delta_t \equiv \nu^P(Y_t;\varepsilon_t)\Delta_t \equiv \mathbb{V} \tag{B.3.9}$$

with $\omega \equiv \frac{1}{1-\alpha}(1+\phi^P)-1$ and where Δ_t depicts the price dispersion term stemming from the use of the Calvo (1983) pricing framework.[4] The law of motion for price dispersion is given by

$$\Delta_t = h(\Delta_{t-1},\pi_t) \tag{B.3.10}$$

where

$$h(\Delta_t,\pi_t) = \theta^\pi \Delta \pi^{\theta^P(1+\omega)} + (1-\theta^\pi)\Big(\frac{1-\theta^\pi\pi^{\theta^P-1}}{1-\theta^\pi}\Big)^{\frac{\theta^P(1+\omega)}{\theta^P-1}} \tag{B.3.11}$$

The Calvo parameter θ^π measures the fraction of prices that remain unchanged by entrepreneurs in a certain period. The gross inflation rate is given by $\pi_t = P_t/P_{t-1}$ where P_t depicts the overall price level in period t.

Plugging in the respective expressions in equation B.3.5, period utility is thus given by

$$U_t^P(C_t^P,L_t^P) = \frac{C_t^{P\,1-\sigma}}{1-\sigma} - \mathbb{V}. \tag{B.3.12}$$

Following again Benigno and Woodford (2005), one can derive a second-order approximation of $\mathbb{V}$ that yields

$$\widehat{\mathbb{V}} = (1-\Phi)YU^P_{C^P}\Big\{\frac{1}{2}\frac{\theta^\pi}{(1-\theta^\pi)(1-\theta^\pi\beta^P)}\theta^P(1+\omega\theta^P)\widehat{\pi}_t^2 + \widehat{Y}_t + \frac{1}{2}(1+\omega)\widehat{Y}_t^2 - \omega\widehat{Y}_t q_t\Big\} + \\ + t.i.p. + O^3 \tag{B.3.13}$$

where
$\Phi \equiv 1 - \left(\frac{\theta^P-1}{\theta^P}\right)\frac{1}{\mu}$
$q_t \equiv \frac{\phi^P L^P + \frac{1}{1-\alpha}(1+\phi^P)\widehat{a}_t}{\omega}$

and where a Taylor approximation of equation (B.3.10) has been used[5] and bars indicate steady-state values and hats log-deviations from steady-state.

The second-order approximation of equation (B.3.12) around the steady state therefore yields

[4]See Benigno and Woodford (2005, 2012) for a detailed derivation.
[5]See again appendix B.3 of Benigno and Woodford (2005) for details.

$$U_t^P - U^P = U^P_{C^P} C^P (\frac{C_t^P - C^P}{C^P}) + \frac{1}{2}\Big[U^P_{C^P C^P} C^{P2} (\frac{C_t^P - C^P}{C^P})^2\Big] -$$
$$-(1-\Phi) Y U^P_{C^P} \Big\{ \frac{1}{2} \frac{\theta^\pi}{(1-\theta^\pi)(1-\theta^\pi \beta^P)} \theta^P (1+\omega\theta^P) \widehat{\pi}_t^2 + \widehat{Y}_t + \frac{1}{2}(1+\omega)\widehat{Y}_t^2 - \omega \widehat{Y}_t q_t \Big\} + t.i.p. + O^3 \tag{B.3.14}$$

or in terms of log-deviations

$$U_t^P - U^P = U^P_{C^P} C^P \Big[\widehat{C}_t^P + \frac{1}{2}(1-\psi)(\widehat{C}_t^P)^2\Big] -$$
$$-(1-\Phi) Y U^P_{C^P} \Big\{ \frac{1}{2} \frac{\theta^\pi}{(1-\theta^\pi)(1-\theta^\pi \beta^P)} \theta^P (1+\omega\theta^P) \widehat{\pi}_t^2 + \widehat{Y}_t + \frac{1}{2}(1+\omega)\widehat{Y}_t^2 - \omega \widehat{Y}_t q_t \Big\} + t.i.p. + O^3 \tag{B.3.15}$$

where $\psi \equiv -\frac{U^P_{C^P C^P}}{U^P_{C^P}} C^P$. Following Benigno and Woodford (2012), $t.i.p.$ refers to terms independent of policy and O^3 captures terms of higher-order terms.

Defining $\widehat{W}_t^P \equiv \frac{U_t^P - U^P}{U^P_{C^P} C^P}$ and plugging in expressions for the derivative terms delivers

$$\widehat{W}_t^P = \widehat{C}_t^P + (1-\sigma)\frac{1}{2}(\widehat{C}_t^P)^2 - (1-\Phi)\frac{Y}{C^P}\Big\{ \frac{1}{2} \frac{\theta^\pi}{(1-\theta^\pi)(1-\theta^\pi \beta^P)} \theta^P (1+\omega\theta^P) \widehat{\pi}_t^2 +$$
$$+ \widehat{Y}_t + \frac{1}{2}(1+\omega)\widehat{Y}_t^2 - \omega \widehat{Y}_t q_t \Big\} + t.i.p. + O^3. \tag{B.3.16}$$

Collecting terms yields

$$\widehat{W}_t^P = \widehat{C}_t^P + (1-\sigma)\frac{1}{2}(\widehat{C}_t^P)^2 - \frac{1}{2}\psi^{\pi^2}_{(0)} \widehat{\pi}_t^2 - \psi^{Y}_{(0)} \widehat{Y}_t - \frac{1}{2}\psi^{Y^2}_{(0)} \widehat{Y}_t^2 + \psi^{YA} \widehat{a}_t \widehat{Y}_t + t.i.p. + O^3 \tag{B.3.17}$$

with

$\psi^{\pi^2}_{(0)} \equiv (1-\Phi)\frac{Y}{C^P}\frac{\theta^\pi}{(1-\theta^\pi)(1-\theta^\pi\beta^P)}\theta^P(1+\omega\theta^P)$
$\psi^{Y}_{(0)} = (1-\Phi)\frac{Y}{C^P}$
$\psi^{Y^2}_{(0)} = (1-\Phi)\frac{Y}{C^P}(1+\omega)$
$\psi^{YA} = (1-\Phi)\frac{Y}{C^P}(\phi^P L^P + \frac{1}{1-\alpha}(1+\phi^P))$.

Consumption

From the aggregate consumption condition B.1.40, we know that $\widehat{C}_t^P$ is given by

$$\widehat{C}_t^P = \frac{C}{C^P}\widehat{C}_t - \frac{C^E}{C^P}\widehat{C}_t^E. \tag{B.3.18}$$

Plugging in $\widehat{W}_t^P$ and rewriting yields

$$\widehat{W}_t^P = \frac{C}{C^P}\Big(\widehat{C}_t + (1-\sigma)\frac{1}{2}\frac{C}{C^P}\widehat{C}_t^2\Big) - \frac{C^E}{C^P}\widehat{C_t^E} - (1-\sigma)\frac{CC^E}{C^{P2}}\widehat{C}_t\widehat{C}_t^E + (1-\sigma)\Big(\frac{C^E}{C^P}\Big)^2\frac{1}{2}(\widehat{C}_t^E)^2 - \\ - \frac{1}{2}\psi_{(0)}^{\pi^2}\widehat{\pi}_t^2 - \psi_{(0)}^{Y}\widehat{Y}_t - \frac{1}{2}\psi_{(0)}^{Y^2}\widehat{Y}_t^2 + \psi^{YA}\widehat{a}_t\widehat{Y}_t + t.i.p. + O^3. \tag{B.3.19}$$

We now derive an expression for $\mathbb{C} \equiv \widehat{C}_t + (1-\sigma)\frac{1}{2}\frac{C}{C^P}\widehat{C}_t^2$. Using the second-order approximation of the aggregate resource constraint (equation B.1.38) we can get the expression

$$\mathbb{C} = \Big[\frac{1}{2}\frac{Y}{C} - \sigma'\frac{1}{2}\big(\frac{Y}{C}\big)^2\Big]\widehat{Y}_t^2 - \Big[\frac{1}{2}\frac{\delta^C K^C}{\pi C} + \sigma'\frac{1}{2}\big(\frac{\delta^C K^C}{\pi C}\big)^2\Big]\big((\widehat{K}_{t-1}^C)^2 + \widehat{\pi}_t^2\big) + \\ + \frac{Y}{C}\widehat{Y}_t - \frac{\delta^C K^C}{\pi C}\big(\widehat{K}_{t-1}^C - \widehat{\pi}_t\big) + \\ + covars + t.i.p. + O^3 \tag{B.3.20}$$

where $covars$[6] contains covariance terms between the endogenous variables $\widehat{Y}_t$, $\widehat{K}_{t-1}^C$, and $\widehat{\pi}_t$, and $\sigma' = 1 - (1-\sigma)\frac{C}{C^P}$.

We can now replace the log-deviations of lagged commercial bank capital from steady state with the second-order approximation of the law of motion of bank capital (equation B.1.25) to get:

$$\mathbb{C} = \frac{1}{2}\frac{Y}{C}\Big[1 - \sigma'\frac{Y}{C}\Big]\widehat{Y}_t^2 + \frac{1}{2}\Big[\frac{\sigma'(\psi^{K^C})^2}{(1-\delta^C)^2} - \frac{1}{1-\delta^C}\psi^{K^C}\Big](\widehat{K}_t^C)^2 + \\ + \frac{1}{2}\Big[\frac{J}{(1-\delta^C)K^C}\psi^{K^C} + \sigma'(\psi^{K^C})^2\Big]\widehat{J}_t^2 - \frac{1}{2}\psi^{K^C}(1+\psi^{K^C})\widehat{\pi}_t^2 + \\ + \frac{Y}{C}\widehat{Y}_t - \frac{1}{1-\delta^C}\psi^{K^C}\widehat{K}_t^C + \frac{J}{(1-\delta^C)K^C}\psi^{K^C}\widehat{J}_t + \psi^{K^C}\widehat{\pi}_t + \\ + covars + t.i.p. + O^3 \tag{B.3.21}$$

[6] In the following derivations, the term *covars* will be extended by the covariance terms of all the endogenous and exogenous variables introduced each step. Due to space limitations, not all these terms will be written out until the end of the derivations.

where $\psi^{K^C} \equiv \frac{\delta^C K^C}{\pi C}$.

Using the second-order approximation of the commercial bank profit function (equation B.1.26), we can substitute out $\widehat{J}_t$ and $\widehat{J}_t^2$ to get

$$\begin{aligned}\mathbb{C} = &\tfrac{1}{2}\psi^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi^{K^{C^2}}(\widehat{K}_t^C)^2 - \tfrac{1}{2}\psi^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi^{r^{bC^2}}(\widehat{r}_t^{bC})^2 + \tfrac{1}{2}\psi^{B^2}\widehat{B}_t^2 + \tfrac{1}{2}\psi^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi^{D^2}\widehat{D}_t^2 - \tfrac{1}{2}\psi^{\nu^2}\widehat{\nu}_t^2 + \\ &+ \psi^Y\widehat{Y}_t - \psi^{K^C}\widehat{K}_t^C + \psi^{\pi}\widehat{\pi}_t + \psi^{r^{bC}}\widehat{r}_t^{bC} + \psi^B\widehat{B}_t - \psi^r\widehat{r}_t - \psi^D\widehat{D}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.22}$$

with

$$\begin{aligned}
&\psi^{Y^2} \equiv \tfrac{Y}{C}\left(1 - \sigma'\tfrac{Y}{C}\right) && \psi^Y \equiv \tfrac{Y}{C}\\
&\psi^{K^{C^2}} \equiv \tfrac{\psi^{K^C}}{1-\delta^C}\left(\tfrac{\sigma'\psi^{K^C}}{1-\delta^C} - 1\right) - \tfrac{\theta\nu^2}{1-\delta^C}\psi^{K^C} && \psi^{K^C} \equiv \tfrac{1}{1-\delta^C}\psi^{K^C}\\
&\psi^{\pi^2} \equiv \psi^{K^C}\left(1 + \psi^{K^C}\right) && \psi^{\pi} \equiv \psi^{K^C}\\
&\psi^{r^{bC^2}} \equiv \sigma'\psi^{K^C}\left(\tfrac{r^{bC}B^C}{J^C}\right)^2 + \tfrac{r^{bC}B^C}{(1-\delta^C)K^C}\psi^{K^C} && \psi^{r^{bC}} \equiv \tfrac{r^{bC}B^C}{(1-\delta^C)K^C}\psi^{K^C}\\
&\psi^{B^2} \equiv \psi^{r^{bC^2}} - \tfrac{\theta\nu^2}{1-\delta^C} && \psi^B \equiv \tfrac{r^{bC}B^C}{(1-\delta^C)K^C}\\
&\psi^{r^2} \equiv \sigma'\psi^{K^C}\left(\tfrac{rD^C}{J^C}\right)^2 - \tfrac{\theta\nu^2}{(1-\delta^C)K^C}\psi^{K^C} && \psi^r \equiv \tfrac{rD^C}{(1-\delta^C)K^C}\\
&\psi^{D^2} \equiv \sigma'\psi^{K^C}\left(\tfrac{rD^C}{J^C}\right)^2 - \tfrac{rD^C}{(1-\delta^C)K^C}\psi^{K^C} && \psi^D \equiv \tfrac{rD^C}{(1-\delta^C)K^C}\psi^{K^C}\\
&\psi^{\nu^2} \equiv \tfrac{\theta\nu^2}{1-\delta^C}\psi^{K^C}
\end{aligned}$$

Next, we can eliminate second-order terms related to $\widehat{D}_t$ in $\mathbb{C}$ by using the commercial bank balance sheet (equation B.1.28) which yields:

$$\begin{aligned}\mathbb{C} = &\tfrac{1}{2}\psi^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(2)}^{K^{C^2}}(\widehat{K}_t^C)^2 - \tfrac{1}{2}\psi^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi^{r^{bC^2}}(\widehat{r}_t^{bC})^2 + \tfrac{1}{2}\psi_{(2)}^{B^2}\widehat{B}_t^2 + \tfrac{1}{2}\psi^{r^2}\widehat{r}_t^2 - \tfrac{1}{2}\psi^{\nu^2}\widehat{\nu}_t^2 + \\ &+ \psi^Y\widehat{Y}_t - \psi_{(2)}^{K^C}\widehat{K}_t^C + \psi^{\pi}\widehat{\pi}_t + \psi^{r^{bC}}\widehat{r}_t^{bC} + \psi_{(2)}^B\widehat{B}_t - \psi^r\widehat{r}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.23}$$

with

$$\begin{aligned}
&\psi_{(2)}^{K^{C^2}} \equiv \psi^{K^{C^2}} + \psi^D\tfrac{K^C}{D} - 2\psi^{K^CD}\tfrac{D}{K^C} + 2\psi^{D^2}\left(\tfrac{K^C}{D}\right)^2\\
&\psi_{(2)}^{B^2} \equiv \psi^{B^2} - \psi^D\tfrac{B^C}{D} - 2\psi^{B^CD}\tfrac{B^C}{K^C} + 2\psi^{D^2}\left(\tfrac{B^C}{D}\right)^2\\
&\psi_{(2)}^{K^C} \equiv \psi^D\tfrac{K^C}{D} - \psi^{K^CB^C}\\
&\psi_{(2)}^B \equiv \psi^B - \psi^D\tfrac{B^C}{D}\\
&\psi^{K^CD} \equiv \psi^{K^{C^2}}\tfrac{\sigma' rD}{J}\\
&\psi^{BD} \equiv \sigma'\tfrac{r^{bC}B^CrD}{J^2}\\
&\psi^{K^CB} \equiv \tfrac{\theta\nu^2}{1-\delta^C} - \psi^{K^{C^2}}\sigma'\tfrac{r^{bC}B^C}{J}
\end{aligned}$$

I employ the bank profit equation B.1.26 to replace commercial bank capital:

$$\begin{aligned}\mathbb{C} = &\tfrac{1}{2}\psi^{Y^2}\widehat{Y}_t^2 - \tfrac{1}{2}\psi^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi_{(2)}^{r^{bC^2}}(\widehat{r}_t^{bC})^2 + \tfrac{1}{2}\psi_{(3)}^{B^2}\widehat{B}_t^2 + \tfrac{1}{2}\psi_{(2)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(2)}^{\nu^2}\widehat{\nu}_t^2 + \\ &+ \psi^{Y}\widehat{Y}_t + \psi^{\pi}\widehat{\pi}_t + \psi_{(2)}^{r^{bC}}\widehat{r}_t^{bC} + \psi_{(3)}^{B}\widehat{B}_t + \psi_{(2)}^{r}\widehat{r}_t + \psi_{(2)}^{K^C}\widehat{\nu}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.24}$$

with

$\psi_{(2)}^{r^{bC^2}} \equiv \psi^{r^{bC^2}} - \frac{r^{bC}}{\theta\nu^3}\psi_{(2)}^{K^C}(1 + 4\frac{r^{bC}}{\theta\nu^3})$

$\psi_{(3)}^{B^2} \equiv \psi_{(2)}^{B^2} + \psi_{(2)}^{K^C B} + \psi_{(2)}^{K^{C^2}} - 5\psi_{(2)}^{K^C}$

$\psi_{(2)}^{r^2} \equiv \psi^{r^2} + \frac{r}{\theta\nu^3}(\psi_{(2)}^{K^C} + \psi_{(2)}^{K^C r}) + (\frac{r}{\theta\nu^3})^2(\psi_{(2)}^{K^{C^2}} - 5\psi_{(2)}^{K^C})$

$\psi_{(2)}^{\nu^2} \equiv \psi_{(2)}^{K^{C^2}} - 8\psi_{(2)}^{K^C} - \psi^{\nu^2} - \psi^{K^C\nu}$

$\psi_{(2)}^{r^{bC}} \equiv \psi^{r^{bC}} - \frac{r^{bC}}{\theta\nu^3}\psi_{(2)}^{K^C}$

$\psi_{(3)}^{B} \equiv \psi_{(2)}^{B} + \psi_{(2)}^{K^C}$

$\psi_{(2)}^{r} \equiv \frac{r}{\theta\nu^3}\psi_{(2)}^{K^C} - \psi^{r}$

$\psi_{(2)}^{K^C B} \equiv \psi^{K^C B} + \frac{B^C}{D}\psi^{K^C D} + \frac{K^C}{D}\psi^{BD} - 2\frac{B^C K^C}{D^2}\psi^{D^2}$

$\psi_{(2)}^{K^C r} \equiv \psi^{K^C r} - \frac{K^C}{D}\psi^{Dr}$

$\psi^{K^C\nu} \equiv \frac{\theta\nu^2}{1-\delta^C}$

$\psi^{K^C r} \equiv \psi^{K^{C^2}}\frac{\sigma' r D}{J}$

$\psi^{Dr} \equiv \left(\sigma'(\frac{rD}{J})^2 - \frac{rD}{(1-\delta^C)K^C}\right)\psi^{K^C}$

Using entrepreneur borrowing and leverage from equations B.1.16 and B.1.22, $\widehat{r}_t^{bC}$ can be replaced:

$$\begin{aligned}\mathbb{C} = &\tfrac{1}{2}\psi^{Y^2}\widehat{Y}_t^2 - \tfrac{1}{2}\psi^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi_{(4)}^{B^2}\widehat{B}_t^2 + \tfrac{1}{2}\psi_{(2)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(2)}^{\nu^2}\widehat{\nu}_t^2 + \\ &+ \psi^{Y}\widehat{Y}_t + \psi^{\pi}\widehat{\pi}_t + \psi_{(4)}^{B}\widehat{B}_t + \psi_{(2)}^{r}\widehat{r}_t + \psi_{(2)}^{K^C}\widehat{\nu}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.25}$$

with

$\psi_{(4)}^{B^2} \equiv \psi_{(3)}^{B^2} + \psi_{(2)}^{r^{bC^2}} + \psi_{(3)}^{r^{bC}B}$

$\psi_{(4)}^{B} \equiv \psi_{(3)}^{B} + \psi_{(2)}^{r^{bC}}$

$\psi_{(3)}^{r^{bC}B} \equiv$

$\psi_{(2)}^{r^{bC}B} + \psi_{(2)}^{K^C r^{bC}} - (\psi_{(2)}^{K^{C^2}} - 5\psi_{(2)}^{K^C})\frac{r^{bC}r}{(\theta\nu^3)^2}$

$\psi_{(2)}^{r^{bC}B} \equiv \psi^{r^{bC}B} - \frac{B^C}{D}\psi^{r^{bC}D}$

$\psi_{(2)}^{K^C r^{bC}} \equiv \frac{K^C}{D}\psi^{r^{bC}D} - \psi^{K^C r^{bC}}$

$\psi^{r^{bC}B} \equiv \left(\frac{r^{bC}B^C}{(1-\delta^C)K^C} + \sigma'(\frac{r^{bC}B^C}{J})^2\right)\psi^{K^C}$

$\psi^{r^{bC}D} \equiv \sigma'\frac{r^{bC}B^C rD}{J^2}\psi^{K^C}$

$\psi^{K^C r^{bC}} \equiv \frac{\sigma' r^{bC}B^C}{J}\psi^{K^{C^2}}$

We can then use the definition of the commercial bank credit-to-GDP ratio Z_t (equation B.1.42) to express lending in relation to GDP:

$$\begin{aligned}\mathbb{C} = & \tfrac{1}{2}\psi^{Y^2}_{(2)}\widehat{Y}_t^2 - \tfrac{1}{2}\psi^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi^{r^2}_{(2)}\widehat{r}_t^2 + \tfrac{1}{2}\psi^{\nu^2}_{(2)}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi^{z,cb^2}\widehat{Z}_t^2 + \\ & + \psi^{Y}_{(2)}\widehat{Y}_t + \psi^{\pi}\widehat{\pi}_t + \psi^{r}_{(2)}\widehat{r}_t + \psi^{K^C}_{(2)}\widehat{\nu}_t + \psi^{B}_{(4)}\widehat{Z}_t + \\ & + covars + t.i.p. + O^3\end{aligned} \tag{B.3.26}$$

with

$$\psi^{Y^2}_{(2)} \equiv 1 + \psi^{Y^2} + \psi^{YB}_{(4)} + \psi^{B^2}_{(4)}$$
$$\psi^{z,cb^2} \equiv \psi^{B^2}_{(4)} + \psi^{B}_{(4)}$$
$$\psi^{Y}_{(2)} \equiv \psi^{Y} + \psi^{B}_{(4)}$$
$$\psi^{YB}_{(4)} \equiv \psi^{YB}_{(3)} - \psi^{Yr^{bC}}$$
$$\psi^{YB}_{(3)} \equiv \psi^{YB}_{(2)} - \psi^{YK^C}$$
$$\psi^{Yr^{bC}} \equiv \frac{\sigma' Y r^{bC} B^C}{(1-\delta^C)K^C C}\psi^{K^C}$$
$$\psi^{YB}_{(2)} \equiv \frac{B}{D}\psi^{YD} - \psi^{YB}$$
$$\psi^{YB} \equiv \frac{\sigma' Y r^{bC} B^C}{(1-\delta^C)K^C C}\psi^{K^C}$$
$$\psi^{YD} \equiv \frac{\sigma' Y r D}{(1-\delta^C)K^C C}\psi^{K^C}$$
$$\psi^{YK^C}_{(2)} \equiv \psi^{YK^C} + \frac{K^C}{D}\psi^{YD}$$
$$\psi^{YK^C} \equiv \frac{\sigma' Y}{(1-\delta^C)C}\psi^{K^C}$$

Finally, I use the first-order approximation of the monetary policy rule B.1.37 to replace $\widehat{r}_t$[7]

$$\begin{aligned}\mathbb{C} = & \tfrac{1}{2}\psi^{Y^2}_{(3)}\widehat{Y}_t^2 + \tfrac{1}{2}\psi^{\pi^2}_{(2)}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi^{r^2}_{(2)}\widehat{r}_t^2 + \tfrac{1}{2}\psi^{\nu^2}_{(2)}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi^{z,cb^2}\widehat{Z}_t^2 + \\ & + \psi^{Y}_{(3)}\widehat{Y}_t + \psi^{\pi}_{(2)}\widehat{\pi}_t + \psi^{K^C}_{(2)}\widehat{\nu}_t + \psi^{B}_{(4)}\widehat{Z}_t + \\ & + covars + t.i.p. + O^3\end{aligned} \tag{B.3.27}$$

with

$$\psi^{Y^2}_{(3)} \equiv \psi^{Y^2}_{(2)} + 2\frac{\phi^y}{1+r}\psi^{Yr}_{(3)}$$
$$\psi^{\pi^2}_{(2)} \equiv 2\frac{\phi^\pi \pi}{1+r}\psi^{\pi r}_{(2)} - \psi^{\pi}$$
$$\psi^{Y}_{(3)} \equiv \psi^{Y}_{(2)} + \frac{\phi^y}{1+r}\psi^{r}_{(2)}$$
$$\psi^{\pi}_{(2)} \equiv \psi^{\pi} + \frac{\phi^\pi \pi}{1+r}\psi^{r}_{(2)}$$
$$\psi^{Yr}_{(3)} \equiv \psi^{Yr}_{(2)} + \psi^{Br}_{(3)}$$
$$\psi^{Yr}_{(2)} \equiv \psi^{Yr} - \frac{r}{\theta\nu^3}\psi^{YK^C}_{(2)}$$
$$\psi^{Br}_{(3)} \equiv \psi^{Br}_{(2)} + \frac{r}{\theta\nu^3}\left(\psi^{K^C B}_{(2)} + 5\psi^{K^{C^2}}_{(2)}\right) + \psi^{K^C r}_{(2)}$$
$$\psi^{Yr} \equiv \psi^{YD}$$
$$\psi^{Br}_{(2)} \equiv \frac{B}{D}\psi^{Dr} - \psi^{Br}$$
$$\psi^{Br} \equiv \psi^{r^{bC}D}$$

[7] I use the first-order instead of second-order approximation of the monetary policy rule, as I assume the central bank not to evaluate the second moments of Y_t and π_t in its decision making.

In the next step, I substitute $\mathbb{C}$ in $\widehat{W}_t^P$. Rearranging terms yields:

$$\begin{aligned}\widehat{W}_t^P = & \tfrac{1}{2}\psi_{(4)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi_{(3)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(2)}^{z,cb^2}\widehat{Z}_t^2 + \tfrac{1}{2}\psi^{ce^2}(\widehat{C}_t^E)^2 + \\ & + \psi_{(4)}^{Y}\widehat{Y}_t + \psi_{(3)}^{\pi}\widehat{\pi}_t + \psi^{\nu}\widehat{\nu}_t + \psi^{z,cb}\widehat{Z}_t - \psi^{ce}\widehat{C}_t^E + \\ & + covars + t.i.p. + O^3\end{aligned} \tag{B.3.28}$$

with

$\psi_{(4)}^{Y^2} \equiv \frac{C}{C^P}\psi_{(3)}^{Y^2} - \psi_{(0)}^{Y^2}$
$\psi_{(3)}^{\pi^2} \equiv \frac{C}{C^P}\psi_{(2)}^{\pi^2} - \psi_{(0)}^{\pi^2}$
$\psi_{(3)}^{r^2} \equiv \frac{C}{C^P}\psi_{(2)}^{r^2}$
$\psi_{(3)}^{\nu^2} \equiv \frac{C}{C^P}\psi_{(2)}^{\nu^2}$
$\psi_{(2)}^{z,cb^2} \equiv \frac{C}{C^P}\psi^{z,cb^2}$
$\psi^{ce^2} \equiv \frac{C}{C^P}(1-\sigma')$
$\psi_{(4)}^{Y} \equiv \frac{C}{C^P}\psi_{(3)}^{Y} - \psi_{(0)}^{Y}$
$\psi_{(3)}^{\pi} \equiv \frac{C}{C^P}\psi_{(2)}^{\pi}$
$\psi^{\nu} \equiv \frac{C}{C^P}\psi_{(2)}^{K^C}$
$\psi^{z,cb} \equiv \frac{C}{C^P}\psi_{(4)}^{B}$
$\psi^{ce} \equiv \frac{C}{C^P}$

Entrepreneur consumption can then be substituted by combining equations B.1.16, B.1.18, and B.1.20:

$$\begin{aligned}\widehat{W}_t^P = & \tfrac{1}{2}\psi_{(6)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi_{(3)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(4)}^{z,cb^2}\widehat{Z}_t^2 + \\ & + \psi_{(5)}^{Y}\widehat{Y}_t + \psi_{(3)}^{\pi}\widehat{\pi}_t + \psi^{\nu}\widehat{\nu}_t + \psi_{(2)}^{z,cb}\widehat{Z}_t + \\ & + covars + t.i.p. + O^3\end{aligned} \tag{B.3.29}$$

with

$\psi_{(6)}^{Y^2} \equiv \psi_{(5)}^{Y^2} + \left(\frac{K\chi}{\beta_E NW^E}\right)^2\psi_{(2)}^{ce^2}$
$\psi_{(5)}^{Y^2} \equiv \psi_{(4)}^{Y^2} + 2\psi^{Yce}\frac{K\chi}{\beta_E NW^E}$
$\psi_{(2)}^{ce^2} \equiv \psi^{ce^2} + \psi^{ce}$
$\psi_{(4)}^{z,cb^2} \equiv \psi_{(3)}^{z,cb^2} + \left(\frac{K\chi}{\beta_E NW^E}\right)^2\psi_{(2)}^{ce^2}$
$\psi_{(3)}^{z,cb^2} \equiv \psi_{(2)}^{z,cb^2} + \frac{K\chi}{\beta_E NW^E}\psi^{ce} + 2\frac{K\chi}{\beta_E NW^E}\psi^{zce}$
$\psi_{(5)}^{Y} \equiv \psi_{(4)}^{Y} + \frac{K\chi}{\beta_E NW^E}\psi^{ce}$
$\psi_{(2)}^{z,cb} \equiv \psi^{z,cb} + \frac{K\chi}{\beta_E NW^E}\psi^{ce}$
$\psi^{Yce} \equiv (1-\sigma')\frac{CC^E}{C^P}\psi_{(3)}^{Y}$
$\psi^{zce} \equiv (1-\sigma')\frac{CC^E}{C^P}\psi_{(4)}^{B}$

Again using the first-order approximation of policy rule B.1.37, one can replace the inflation variance term $\widehat{\pi}_t^2$ and furthermore get:

$$\begin{aligned}\widehat{W}_t^P &= \tfrac{1}{2}\psi_{(8)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(4)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(4)}^{z,cb^2}\widehat{Z}_t^2 + \\ &+ \psi_{(7)}^{Y}\widehat{Y}_t + \psi_{(4)}^{\pi}\widehat{\pi}_t + \psi^{\nu}\widehat{\nu}_t + \psi_{(2)}^{z,cb}\widehat{Z}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.30}$$

with

$$\psi_{(8)}^{Y^2} \equiv \psi_{(7)}^{Y^2} - \tfrac{\phi^y}{1+r}\psi_{(4)}^{Yr}$$
$$\psi_{(7)}^{Y^2} \equiv \psi_{(6)}^{Y^2} + \left(\tfrac{\phi^y}{\phi^\pi\pi}\right)^2\psi_{(3)}^{\pi^2}$$
$$\psi_{(4)}^{r^2} \equiv \psi_{(3)}^{r^2} + \left(\tfrac{1+r}{\phi^\pi\pi}\right)^2\psi_{(3)}^{\pi^2}$$
$$\psi_{(7)}^{Y} \equiv \psi_{(6)}^{Y} + \tfrac{\phi^y}{1+r}\psi_{(3)}^{r}$$
$$\psi_{(6)}^{Y} \equiv \psi_{(5)}^{Y} - \tfrac{(1+r)\phi^y}{(\phi^\pi\pi)^2}\psi_{(3)}^{\pi^2}$$
$$\psi_{(4)}^{\pi} \equiv \psi_{(3)}^{\pi} + \tfrac{\phi^\pi\pi}{1+r}\psi_{(3)}^{r}$$
$$\psi_{(3)}^{r} \equiv \left(\tfrac{1+r}{\phi^\pi\pi}\right)^2\psi_{(3)}^{\pi^2}$$
$$\psi_{(4)}^{Yr} \equiv \tfrac{(1+r)\phi^y}{(\phi^\pi\pi)^2}\psi_{(3)}^{\pi^2}$$

Impatient Entrepreneur Welfare

For the impatient firm, period utility is given by

$$U_t^E(C_t^E) = \frac{C_t^{E\,1-\sigma}}{1-\sigma}. \tag{B.3.31}$$

We can thus derive a similar expression for period welfare as for households:

$$\widehat{W}_t^E = \widehat{C}_t^E + (1-\sigma)\frac{1}{2}(\widehat{C}_t^E)^2. \tag{B.3.32}$$

As above, we can combine equations B.1.16, B.1.18, and B.1.20 to get:

$$\widehat{C}_t^E = -\frac{K\chi}{\beta_E NW^E}(\widehat{Z}_t + \frac{1}{2}\widehat{Z}_t^2) - \frac{K\chi}{\beta_E NW^E}\widehat{Y}_t - \frac{K\chi}{\beta_E NW^E}\widehat{Y}_t\widehat{Z}_t - \frac{1}{2}(\widehat{C}_t^E)^2. \tag{B.3.33}$$

Plugging in $\widehat{W}_t^E$ yields

$$\begin{aligned}\widehat{W}_t^E &= -\frac{1}{2}\sigma\Big(\frac{K\chi}{\beta_E NW^E}\Big)^2\widehat{Y}_t^2 - \frac{1}{2}\Big[\frac{K\chi}{\beta_E NW^E} + \sigma\Big(\frac{K\chi}{\beta_E NW^E}\Big)^2\Big]\widehat{Z}_t^2 - \\ &- \frac{K\chi}{\beta_E NW^E}(\widehat{Y}_t + \widehat{Z}_t) - \Big[\frac{K\chi}{\beta_E NW^E} + \sigma\Big(\frac{K\chi}{\beta_E NW^E}\Big)^2\Big]\widehat{Y}_t\widehat{Z}_t.\end{aligned} \tag{B.3.34}$$

Joint Welfare

We can now derive period welfare along the lines of equation B.3.1. Period joint welfare is given by

$$W_t = (1-\beta_P)W_t^P + (1-\beta_E)W_t^E. \tag{B.3.35}$$

Approximating yields:

$$\widehat{W}_t = (1-\beta_P)\frac{W^P}{W}\widehat{W}_t^P + (1-\beta_E)\frac{W^E}{W}\widehat{W}_t^E. \tag{B.3.36}$$

We can now plug in expressions $\widehat{W}_t^P$ and $\widehat{W}_t^E$ to get

$$\begin{aligned}\widehat{W}_t = &\tfrac{1}{2}\psi_{(9)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(5)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(4)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(5)}^{z,cb^2}\widehat{Z}_t^2 + \\ &+ \psi_{(8)}^{Y}\widehat{Y}_t + \psi_{(5)}^{\pi}\widehat{\pi}_t + \psi_{(2)}^{\nu}\widehat{\nu}_t + \psi_{(3)}^{z,cb}\widehat{Z}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.37}$$

with

$\psi_{(9)}^{Y^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(8)}^{Y^2} - (1-\beta_E)\frac{W^E}{W}\sigma'\big(\frac{K\chi}{\beta_E N W^E}\big)^2$

$\psi_{(5)}^{r^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(4)}^{r^2}$

$\psi_{(4)}^{\nu^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(3)}^{\nu^2}$

$\psi_{(5)}^{z,cb^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(4)}^{z,cb^2} - (1-\beta_E)\frac{W^E}{W}\Big[\frac{K\chi}{\beta_E N W^E} + \sigma'\big(\frac{K\chi}{\beta_E N W^E}\big)^2\Big]$

$\psi_{(8)}^{Y} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(7)}^{Y} - (1-\beta_E)\frac{W^E}{W}\frac{K\chi}{\beta_E N W^E}$

$\psi_{(5)}^{\pi} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(4)}^{\pi}$

$\psi_{(2)}^{\nu} \equiv (1-\beta_P)\frac{W^P}{W}\psi^{\nu}$

$\psi_{(3)}^{z,cb} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(2)}^{z,cb} - (1-\beta_E)\frac{W^E}{W}\frac{K\chi}{\beta_E N W^E}$

We can remove the linear term $\widehat{\nu}_t$ by combining the first-order approximation of the credit supply condition B.1.27 with the first-order approximations of the commercial bank balance sheet condition (equation B.1.24), bank profits (equation B.1.26), the law of motion for bank capital (equation B.1.25), and the aggregate resource constraint (equation B.1.38) to express $\widehat{\nu}_t$ only in linear terms of $\widehat{Z}_t$, $\widehat{Y}_t$, and $\widehat{\pi}_t$ such that

$$\begin{aligned}\widehat{W}_t = &\tfrac{1}{2}\psi_{(10)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(5)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(4)}^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi_{(4)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(6)}^{z,cb^2}\widehat{Z}_t^2 + \\ &+ \psi_{(9)}^{Y}\widehat{Y}_t + \psi_{(6)}^{\pi}\widehat{\pi}_t + \psi_{(4)}^{z,cb}\widehat{Z}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.38}$$

with

$$\psi^{Y^2}_{(10)} \equiv \psi^{Y^2}_{(9)} + \psi^{Y\nu}_{(5)}\Omega^{y}_{(5)} \qquad \psi^{Y}_{(9)} \equiv \psi^{Y}_{(8)} - \psi^{\nu}_{(2)}\Omega^{y}_{(5)}$$
$$\psi^{\pi^2}_{(4)} \equiv 2\psi^{\pi\nu}_{(3)}\Omega^{\pi}_{(4)} \qquad \psi^{\pi}_{(6)} \equiv \psi^{\pi}_{(5)} - \psi^{\nu}_{(2)}\Omega^{\pi}_{(4)}$$
$$\psi^{z,cb^2}_{(6)} \equiv \psi^{z,cb^2}_{(5)} - \psi^{\nu z}_{(3)}\Omega^{B}_{(4)} \qquad \psi^{z,cb}_{(4)} \equiv \psi^{z,cb}_{(4)} - \psi^{\nu}_{(2)}\Omega^{B}_{(4)}$$

where the auxiliary parameters $\Omega^{y}_{(5)}$, $\Omega^{\pi}_{(4)}$, and $\Omega^{B}_{(4)}$ were derived during the side step of replacing $\widehat{\nu}_t$. Using the approximation of the Taylor rule to replace $\widehat{\pi}^2_t$ yields

$$\begin{aligned}\widehat{W}_t = &\tfrac{1}{2}\psi^{Y^2}_{(11)}\widehat{Y}^2_t + \tfrac{1}{2}\psi^{r^2}_{(6)}\widehat{r}^2_t + \tfrac{1}{2}\psi^{\nu^2}_{(4)}\widehat{\nu}^2_t + \tfrac{1}{2}\psi^{z,cb^2}_{(6)}\widehat{Z}^2_t + \\ &+ \psi^{Y}_{(9)}\widehat{Y}_t + \psi^{\pi}_{(7)}\widehat{\pi}_t + \psi^{z,cb}_{(4)}\widehat{Z}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.39}$$

with
$\psi^{Y^2}_{(11)} \equiv \psi^{Y^2}_{(10)} - \left(\frac{\phi^y}{\phi^\pi\pi}\right)^2\psi^{\pi^2}_{(4)}$
$\psi^{r^2}_{(6)} \equiv \psi^{r^2}_{(5)} + \left(\frac{1+r}{\phi^\pi\pi}\right)^2\psi^{\pi^2}_{(4)}$
$\psi^{\pi}_{(7)} \equiv \psi^{\pi}_{(6)} + \frac{1+r}{\phi^\pi\pi}\psi^{\pi^2}_{(4)}$.

Finally, I follow the same strategy as in Benigno and Woodford (2005) and use an iterated expression of the second-order approximation of the aggregate-supply relationship to replace the linear output term $\widehat{Y}_t$ in the lifetime welfare criterion

$$\begin{aligned}\widehat{W}_{t_0} = E_{t_0}\sum_{t=t_0}^{\infty}\beta_P^{t-t_0}[&\tfrac{1}{2}\psi^{Y^2}_{(11)}\widehat{Y}^2_t + \tfrac{1}{2}\psi^{r^2}_{(6)}\widehat{r}^2_t + \tfrac{1}{2}\psi^{\nu^2}_{(4)}\widehat{\nu}^2_t + \tfrac{1}{2}\psi^{z,cb^2}_{(6)}\widehat{Z}^2_t + \\ &+ \psi^{Y}_{(9)}\widehat{Y}_t + \psi^{\pi}_{(7)}\widehat{\pi}_t + \psi^{z,cb}_{(4)}\widehat{Z}_t] + t.i.p. + O^3.\end{aligned} \tag{B.3.40}$$

In the process, I replace the linear inflation term $\widehat{\pi}_t$ in the infinite sum by iterating forward the first-order approximation of the New-Keynesian Phillips curve and collect the covariances of $\widehat{Y}_t$, $\widehat{r}_t$, and $\widehat{Z}_t$ by defining efficiency gaps for these variables in a similar fashion as in Benigno and Woodford (2005). Following these steps, one can express discounted lifetime welfare as

$$\widehat{W}_{t_0} = E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0} [\tfrac{1}{2}\psi_{(12)}^{Y^2}(\widehat{Y}_t - \widehat{Y}_t^*)^2 + \tfrac{1}{2}\psi_{(7)}^{r^2}(\widehat{r}_t - \widehat{r}_t^*)^2 + \tfrac{1}{2}\psi_{(5)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(7)}^{z,cb^2}(\widehat{Z}_t - \widehat{Z}_t^*)^2 + \\ + \psi_{(5)}^{z,cb}\widehat{Z}_t] + t.i.p. + O^3 + T_0 \quad \text{(B.3.41)}$$

where T_0 depicts a transitory component similar to the expression derived in Benigno and Woodford (2005). The coefficients can then directly be mapped in the parameters of the period loss function given by equation 5.39.

B.4.2 Shadow Banking

Patient Household Welfare

In the model, the introduction of shadow banks affects both the saving decision of patient households and the borrowing decision of impatient entrepreneurs as both agents can intermediate funds now with both financial institutions. The introduction of shadow banking alters the above derivation of the welfare loss function via the entrepreneur problem, as entrepreneur net worth now depends on borrowing from both commercial and shadow banks (equation B.1.19)[8]. As indicated by equation B.1.18, net worth in turn affects entrepreneur consumption, and therefore steady state levels NW^E and C^E are affected by the introduction of shadow banking. Adding shadow banks to the model does therefore not affect the above derivation until equation B.3.28, but only enters in the following step when steady-state entrepreneur consumption C^E is replaced.

Following the subsequent derivations analogously, the term

$$\widehat{W}_t^P = \tfrac{1}{2}\psi_{(6)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\pi^2}\widehat{\pi}_t^2 + \tfrac{1}{2}\psi_{(3)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(3)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(4)}^{z,cb^2}\widehat{Z}_t^2 + + \tfrac{1}{2}\psi_{(2)}^{z,sb^2}(\widehat{Z}_t^{SB})^2 + \\ + \psi_{(5)}^{Y}\widehat{Y}_t + \psi_{(3)}^{\pi}\widehat{\pi}_t + \psi^{\nu}\widehat{\nu}_t + \psi_{(2)}^{z,cb}\widehat{Z}_t + + \psi^{z,sb}\widehat{Z}_t^{SB} + \\ + covars + t.i.p. + O^3 \quad \text{(B.3.42)}$$

[8] In the model without shadow banks, equation B.1.19 would be identical except for the last term related to shadow banking not being in place.

with

$$\psi^{Y^2}_{(6)} \equiv \psi^{Y^2}_{(5)} + \left(\tfrac{K(\chi^C+\chi^S)}{\beta_E NW^E}\right)^2 \psi^{ce^2}_{(2)}$$
$$\psi^{Y^2}_{(5)} \equiv \psi^{Y^2}_{(4)} + 2\psi^{Yce}\tfrac{K(\chi^C+\chi^S)}{\beta_E NW^E}$$
$$\psi^{ce^2}_{(2)} \equiv \psi^{ce^2} + \psi^{ce}$$
$$\psi^{z,cb^2}_{(4)} \equiv \psi^{z,cb^2}_{(3)} + \left(\tfrac{K\chi^C}{\beta_E NW^E}\right)^2 \psi^{ce^2}_{(2)}$$
$$\psi^{z,cb^2}_{(3)} \equiv \psi^{z,cb^2}_{(2)} + \tfrac{K\chi^C}{\beta_E NW^E}\psi^{ce} + 2\tfrac{K\chi^C}{\beta_E NW^E}\psi^{zce}$$
$$\psi^{z,sb^2}_{(2)} \equiv \psi^{z,sb^2} + \left(\tfrac{K\chi^S}{\beta_E NW^E}\right)^2 \psi^{ce^2}_{(2)}$$
$$\psi^{z,sb^2} \equiv \tfrac{K\chi^S}{\beta_E NW^E}\psi^{ce}$$

$$\psi^{Y}_{(5)} \equiv \psi^{Y}_{(4)} + \tfrac{K(\chi^C+\chi^S)}{\beta_E NW^E}\psi^{ce}$$
$$\psi^{z,cb}_{(2)} \equiv \psi^{z,cb} + \tfrac{K\chi^C}{\beta_E NW^E}\psi^{ce}$$
$$\psi^{z,sb} \equiv \tfrac{K\chi^S}{\beta_E NW^E}\psi^{ce}$$
$$\psi^{Yce} \equiv (1-\sigma')\tfrac{CC^E}{C^P}\psi^{Y}_{(3)}$$
$$\psi^{zce} \equiv (1-\sigma')\tfrac{CC^E}{C^P}\psi^{B}_{(4)}$$

As above, the first-order approximation of the Taylor-type policy rule B.1.37 can be used to replace the inflation variance term $\widehat{\pi}_t^2$ to get

$$\begin{aligned}\widehat{W}_t^P &= \tfrac{1}{2}\psi^{Y^2}_{(8)}\widehat{Y}_t^2 + \tfrac{1}{2}\psi^{r^2}_{(4)}\widehat{r}_t^2 + \tfrac{1}{2}\psi^{\nu^2}_{(3)}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi^{z,cb^2}_{(4)}\widehat{Z}_t^2 + +\tfrac{1}{2}\psi^{z,sb^2}_{(2)}(\widehat{Z}_t^{SB})^2 + \\ &+ \psi^{Y}_{(7)}\widehat{Y}_t + \psi^{\pi}_{(4)}\widehat{\pi}_t + \psi^{\nu}\widehat{\nu}_t + \psi^{z,cb}_{(2)}\widehat{Z}_t + +\psi^{z,sb}\widehat{Z}_t^{SB} + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.43}$$

where the updated parameters on output and the interest rate are identical to the values derived for equation B.3.30.

Impatient Entrepreneur Welfare

The entrepreneur's period utility is again given by

$$U_t^E(C_t^E) = \frac{C_t^{E\,1-\sigma}}{1-\sigma} \tag{B.3.44}$$

such that

$$\widehat{W}_t^E = \widehat{C}_t^E + (1-\sigma)\frac{1}{2}(\widehat{C}_t^E)^2 \tag{B.3.45}$$

follows. Combining equations B.1.16, B.1.18, and B.1.20 now yields:

$$\begin{aligned}\widehat{C}_t^E = &-\frac{K\chi^C}{\beta_E NW^E}(\widehat{Z}_t + \frac{1}{2}\widehat{Z}_t^2) - \frac{K(\chi^C+\chi^S)}{\beta_E NW^E}\widehat{Y}_t - \frac{K\chi^C}{\beta_E NW^E}\widehat{Y}_t\widehat{Z}_t - \\ &- \frac{K\chi^S}{\beta_E NW^E}(\widehat{Z}_t^{SB} + \frac{1}{2}(\widehat{Z}_t^{SB})^2) - \frac{K\chi^S}{\beta_E NW^E}\widehat{Y}_t\widehat{Z}_t^{SB} - \frac{1}{2}(\widehat{C}_t^E)^2.\end{aligned} \tag{B.3.46}$$

Plugging in $\widehat{W}_t^E$ now yields

$$\widehat{W}_t^E = -\frac{1}{2}\sigma\Big(\frac{K(\chi^C+\chi^S)}{\beta_E NW^E}\Big)^2\widehat{Y}_t^2 - \frac{1}{2}\Big[\frac{K\chi^C}{\beta_E NW^E} + \sigma\Big(\frac{K\chi^C}{\beta_E NW^E}\Big)^2\Big]\widehat{Z}_t^2 - \\ -\frac{1}{2}\Big[\frac{K\chi^S}{\beta_E NW^E} + \sigma\Big(\frac{K\chi^S}{\beta_E NW^E}\Big)^2\Big](\widehat{Z}_t^{SB})^2 - \frac{K(\chi^C+\chi^S)}{\beta_E NW^E}\widehat{Y}_t - \\ -\frac{K\chi^C}{\beta_E NW^E}\widehat{Z}_t - \frac{K\chi^S}{\beta_E NW^E}\widehat{Z}_t^{SB} - \Big[\frac{K\chi^C}{\beta_E NW^E} + \sigma\frac{K^2\chi^C(\chi^C+\chi^S)}{(\beta_E NW^E)^2}\Big]\widehat{Y}_t\widehat{Z}_t - \\ -\Big[\frac{K\chi^S}{\beta_E NW^E} + \sigma\frac{K^2\chi^S(\chi^C+\chi^S)}{(\beta_E NW^E)^2}\Big]\widehat{Y}_t\widehat{Z}_t^{SB} - \sigma\frac{K^2\chi^C\chi^S}{(\beta_E NW^E)^2}\widehat{Z}_t\widehat{Z}_t^{SB} \quad \text{(B.3.47)}$$

as $\widehat{Z}_t^{SB}$ enters the derivations.

Joint Welfare

Again, following B.3.1, period joint welfare is given by

$$W_t = (1-\beta_P)W_t^P + (1-\beta_E)W_t^E \quad \text{(B.3.48)}$$

with the same approximating as before where expressions $\widehat{W}_t^P$ and $\widehat{W}_t^E$ are again substituted to get

$$\widehat{W}_t = \tfrac{1}{2}\psi_{(9)}^{Y^2}\widehat{Y}_t^2 + \tfrac{1}{2}\psi_{(5)}^{r^2}\widehat{r}_t^2 + \tfrac{1}{2}\psi_{(4)}^{\nu^2}\widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(5)}^{z,cb^2}\widehat{Z}_t^2 + +\tfrac{1}{2}\psi_{(3)}^{z,sb^2}(\widehat{Z}_t^{SB})^2 + \\ +\psi_{(8)}^{Y}\widehat{Y}_t + \psi_{(5)}^{\pi}\widehat{\pi}_t + \psi_{(2)}^{\nu}\widehat{\nu}_t + \psi_{(3)}^{z,cb}\widehat{Z}_t + +\psi_{(2)}^{z,sb}\widehat{Z}_t^{SB} + \\ + covars + t.i.p. + O^3 \quad \text{(B.3.49)}$$

with

$\psi_{(9)}^{Y^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(8)}^{Y^2} - (1-\beta_E)\frac{W^E}{W}\sigma'\big(\frac{K(\chi^C+\chi^S)}{\beta_E NW^E}\big)^2$

$\psi_{(5)}^{r^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(4)}^{r^2}$

$\psi_{(4)}^{\nu^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(3)}^{\nu^2}$

$\psi_{(5)}^{z,cb^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(4)}^{z,cb^2} - (1-\beta_E)\frac{W^E}{W}\Big[\frac{K\chi^C}{\beta_E NW^E} + \sigma'\big(\frac{K\chi^C}{\beta_E NW^E}\big)^2\Big]$

$\psi_{(3)}^{z,sb^2} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(2)}^{z,sb^2} - (1-\beta_E)\frac{W^E}{W}\Big[\frac{K\chi^S}{\beta_E NW^E} + \sigma'\big(\frac{K\chi^S}{\beta_E NW^E}\big)^2\Big]$

$\psi_{(8)}^{Y} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(7)}^{Y} - (1-\beta_E)\frac{W^E}{W}\frac{K(\chi^C+\chi^S)}{\beta_E NW^E}$

$\psi_{(5)}^{\pi} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(4)}^{\pi}$

$\psi_{(2)}^{\nu} \equiv (1-\beta_P)\frac{W^P}{W}\psi^{\nu}$

$\psi_{(3)}^{z,cb} \equiv (1-\beta_P)\frac{W^P}{W}\psi_{(2)}^{z,cb} - (1-\beta_E)\frac{W^E}{W}\frac{K\chi^C}{\beta_E NW^E}$

$\psi_{(2)}^{z,sb} \equiv (1-\beta_P)\frac{W^P}{W}\psi^{z,sb} - (1-\beta_E)\frac{W^E}{W}\frac{K\chi^S}{\beta_E NW^E}$

The linear term $\widehat{\nu}_t$ can be removed as stated above. As $\widehat{\nu}_t$ can be replaced with variables related to commercial bank credit only, the side steps outlined above are identical to the case without shadow banks and do not affect the parameters on shadow bank credit-to-GDP. Thus, we get

$$\begin{aligned}\widehat{W}_t = &\tfrac{1}{2}\psi^{Y^2}_{(10)}\widehat{Y}^2_t + \tfrac{1}{2}\psi^{r^2}_{(5)}\widehat{r}^2_t + \tfrac{1}{2}\psi^{\pi^2}_{(4)}\widehat{\pi}^2_t + \tfrac{1}{2}\psi^{\nu^2}_{(4)}\widehat{\nu}^2_t + \tfrac{1}{2}\psi^{z,cb^2}_{(6)}\widehat{Z}^2_t + +\tfrac{1}{2}\psi^{z,sb^2}_{(3)}(\widehat{Z}^{SB}_t)^2 + \\ &+ \psi^{Y}_{(9)}\widehat{Y}_t + \psi^{\pi}_{(6)}\widehat{\pi}_t + \psi^{z,cb}_{(4)}\widehat{Z}_t + +\psi^{z,sb}_{(2)}\widehat{Z}^{SB}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.50}$$

with the same parameter values (except for terms including $\widehat{Z}^{SB}_t$) as derived for equation B.3.38. Again using the monetary policy rule approximation to replace $\widehat{\pi}^2_t$ yields

$$\begin{aligned}\widehat{W}_t = &\tfrac{1}{2}\psi^{Y^2}_{(11)}\widehat{Y}^2_t + \tfrac{1}{2}\psi^{r^2}_{(6)}\widehat{r}^2_t + \tfrac{1}{2}\psi^{\nu^2}_{(4)}\widehat{\nu}^2_t + \tfrac{1}{2}\psi^{z,cb^2}_{(6)}\widehat{Z}^2_t + +\tfrac{1}{2}\psi^{z,sb^2}_{(3)}(\widehat{Z}^{SB}_t)^2 + \\ &+ \psi^{Y}_{(9)}\widehat{Y}_t + \psi^{\pi}_{(7)}\widehat{\pi}_t + \psi^{z,cb}_{(4)}\widehat{Z}_t + +\psi^{z,sb}_{(2)}\widehat{Z}^{SB}_t + \\ &+ covars + t.i.p. + O^3\end{aligned} \tag{B.3.51}$$

and updated parameter values are identical to the ones derived for equation B.3.39, as none of the added shadow bank parameters is affected by the Taylor rule substitution.

Following Benigno and Woodford (2005) again by using an iterated expression of the second-order approximation of the aggregate-supply relationship to replace the linear output term $\widehat{Y}_t$ in the lifetime welfare criterion yields

$$\begin{aligned}\widehat{W}_{t_0} = E_{t_0}\sum_{t=t_0}^{\infty}\beta_P^{t-t_0}[&\tfrac{1}{2}\psi^{Y^2}_{(11)}\widehat{Y}^2_t + \tfrac{1}{2}\psi^{r^2}_{(6)}\widehat{r}^2_t + \tfrac{1}{2}\psi^{\nu^2}_{(4)}\widehat{\nu}^2_t + \tfrac{1}{2}\psi^{z,cb^2}_{(6)}\widehat{Z}^2_t + +\tfrac{1}{2}\psi^{z,sb^2}_{(3)}(\widehat{Z}^{SB}_t)^2 \\ &+ \psi^{Y}_{(9)}\widehat{Y}_t + \psi^{\pi}_{(7)}\widehat{\pi}_t + \psi^{z,cb}_{(4)}\widehat{Z}_t + \psi^{z,sb}_{(2)}\widehat{Z}^{SB}_t] + t.i.p. + O^3.\end{aligned} \tag{B.3.52}$$

Again, I replace the linear inflation term $\widehat{\pi}_t$ in the infinite sum by iterating forward the first-order approximation of the New-Keynesian Phillips curve and collect the covariances of $\widehat{Y}_t$, $\widehat{r}_t$, $\widehat{Z}_t$,and $\widehat{Z}^{SB}_t$ by defining efficiency gaps for these variables as in Benigno and Woodford (2005). Discounted lifetime welfare with shadow banks is thus given by

$$\widehat{W}_{t_0} = E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0} [\tfrac{1}{2}\psi_{(12)}^{Y^2} \widetilde{Y}_t^2 + \tfrac{1}{2}\psi_{(7)}^{r^2} \widetilde{r}_t^2 + \tfrac{1}{2}\psi_{(5)}^{\nu^2} \widehat{\nu}_t^2 + \tfrac{1}{2}\psi_{(7)}^{z,cb^2} \widetilde{Z}_t^2 + \tfrac{1}{2}\psi_{(4)}^{z,sb^2} (\widetilde{Z}_t^{SB})^2$$
$$+ \psi_{(5)}^{z,cb} \widehat{Z}_t + \psi_{(3)}^{z,sb} \widehat{Z}_t^{SB}] + t.i.p. + O^3 + T_0 \quad \text{(B.3.53)}$$

where $\widetilde{Z}_t^{SB} = \widehat{Z}_t^{SB} - \widehat{Z}_t^{SB*}$ and coefficients can again directly be mapped in the parameters of the period loss function given by equation 5.40.

B.5 Appendix: Conditional Welfare Costs in Consumption Equivalents

In this section, I derive the consumption equivalence expression of welfare applied in section 5.5. Assuming $\sigma \to 1$, lifetime welfare given by equation 5.33 is

$$W_{t_0}^* = (1-\beta_P)E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0} \left\{ \ln[C_t^{P*}] - \frac{L_t^{P*1+\phi^P}}{1+\phi^P} \right\} + (1-\beta_E)E_{t_0} \sum_{t=t_0}^{\infty} \beta_E^{t-t_0} \ln[C_t^{E*}] \quad \text{(B.4.1)}$$

under the Ramsey policy in the decentralized economy of section B.3.2 absent nominal rigidities as well as real and financial frictions. Lifetime welfare in the economy with nominal rigidities, as well as real and financial frictions is given by equation 5.33:

$$W_{t_0} = (1-\beta_P)E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0} \left\{ \ln[C_t^{P}] - \frac{L_t^{P1+\phi^P}}{1+\phi^P} \right\} + (1-\beta_E)E_{t_0} \sum_{t=t_0}^{\infty} \beta_E^{t-t_0} \ln[C_t^{E}]. \quad \text{(B.4.2)}$$

Let ξ^P and ξ^E determine the welfare costs for patient households and impatient entrepreneurs, respectively. Thus, in the economy with frictions, the welfare costs in terms of consumption relative to the levels in the frictionless economy can be expressed as

$$W_{t_0} = (1-\beta_P)E_{t_0} \sum_{t=t_0}^{\infty} \beta_P^{t-t_0} \left\{ \ln[(1-\xi^P)^{\frac{1}{1-\beta_P}} C_t^{P*}] - \frac{L_t^{P*1+\phi^P}}{1+\phi^P} \right\} +$$
$$+ (1-\beta_E)E_{t_0} \sum_{t=t_0}^{\infty} \beta_E^{t-t_0} \ln[(1-\xi^E)^{\frac{1}{1-\beta_E}} C_t^{E*}] \quad \text{(B.4.3)}$$

where the welfare cost of each agent is assumed to be proportional to the welfare share in equation 5.33. Rewriting yields

$$W_{t_0} = (1-\beta_P)E_{t_0}\sum_{t=t_0}^{\infty}\beta_P^{t-t_0}\ln[(1-\xi^P)^{\frac{1}{1-\beta_P}}] + (1-\beta_P)E_{t_0}\sum_{t=t_0}^{\infty}\beta_P^{t-t_0}\left\{\ln[C_t^{P*}] - \frac{L_t^{P*1+\phi^P}}{1+\phi^P}\right\} +$$
$$(1-\beta_E)E_{t_0}\sum_{t=t_0}^{\infty}\beta_E^{t-t_0}\ln[(1-\xi^E)^{\frac{1}{1-\beta_E}}] + (1-\beta_E)E_{t_0}\sum_{t=t_0}^{\infty}\beta_E^{t-t_0}\ln[C_t^{E*}] \quad \text{(B.4.4)}$$

which yields

$$W_{t_0} = \frac{1}{1-\beta_P}\ln(1-\xi^P) + \frac{1}{1-\beta_E}\ln(1-\xi^E) + W_{t_0}^*. \quad \text{(B.4.5)}$$

Rearranging yields

$$\frac{1}{1-\beta_P}\ln(1-\xi^P) + \frac{1}{1-\beta_E}\ln(1-\xi^E) = W_{t_0} - W_{t_0}^* \quad \text{(B.4.6)}$$
$$\ln(1-\xi^P) + \frac{1-\beta_P}{1-\beta_E}\ln(1-\xi^E) = (W_{t_0} - W_{t_0}^*)(1-\beta_P) \quad \text{(B.4.7)}$$
$$(1-\xi^P)(1-\xi^E)^{\frac{1-\beta_P}{1-\beta_E}} = \exp[(W_{t_0} - W_{t_0}^*)(1-\beta_P)] \quad \text{(B.4.8)}$$
$$1-\xi \equiv (1-\xi^P)^{1-\beta_E}(1-\xi^E)^{1-\beta_P} = \exp[(W_{t_0} - W_{t_0}^*)(1-\beta_P)]^{1-\beta_E}. \quad \text{(B.4.9)}$$

B.6 Appendix: Optimal Policy Rule with Shadow Banks

Minimizing the loss function

$$\widehat{L}_t' = \tfrac{1}{2}\lambda^{y^{2'}}\widetilde{Y}_t^2 + \tfrac{1}{2}\lambda^{r^{2'}}\widetilde{r}_t^2 + \tfrac{1}{2}\lambda^{z,cb^{2'}}\widetilde{Z}_t^2 + \tfrac{1}{2}\lambda^{z,sb^{2'}}(\widetilde{Z}_t^{SB})^2 + \tfrac{1}{2}\lambda^{\nu^{2'}}\widehat{\nu}_t^2 \quad \text{(B.5.1)}$$

subject to the linearized structural equations given in appendix B.1 yields the following set of first-order conditions

$$0 = \Xi_{1t} + \Xi_{17t} \tag{B.5.2}$$

$$0 = \Xi_{1t} + \Xi_{3t} \tag{B.5.3}$$

$$0 = \Xi_{3t} - \theta^{p}\Xi_{19t} \tag{B.5.4}$$

$$0 = \Xi_{4t} - \varphi_1\Xi_{24t} \tag{B.5.5}$$

$$0 = \Xi_{8t} - \Xi_{4t} \tag{B.5.6}$$

$$0 = \Xi_{5t} - \varphi_2\Xi_{10t} - \varphi_3\Xi_{9t} \tag{B.5.7}$$

$$0 = \Xi_{11t} + \varphi_4\Xi_{6t} \tag{B.5.8}$$

$$0 = \Xi_{9t} - \Xi_{25t} - \varphi_5\Xi_{13t} \tag{B.5.9}$$

$$0 = \Xi_{15t} - \varphi_6\Xi_{13t} - \varphi_7\Xi_{11t} \tag{B.5.10}$$

$$0 = \Xi_{25t} + \Xi_{12t} - \Xi_{49t} - \Xi_{15t} \tag{B.5.11}$$

$$0 = \Xi_{50t} + \Xi_{49t} - \phi^{y}\Xi_{28t} + \Xi_{22t} + \Xi_{18t} - \Xi_{1t} - \Xi_{30t} \tag{B.5.12}$$

$$0 = \Xi_{1t} - \phi^{P}\Xi_{17t} - \varphi_8\Xi_{18t} \tag{B.5.13}$$

$$0 = \Xi_{20t} - \alpha\beta_P\Xi_{18t+1} \tag{B.5.14}$$

$$0 = \Xi_{12t} - \varphi_9\Xi_{13t} \tag{B.5.15}$$

$$0 = \Xi_{15t} + \Xi_{14t} - \varphi_{10}\Xi_{14t+1} - \varphi_{11}\Xi_{22t+1} - \nu\Xi_{12t} \tag{B.5.16}$$

$$0 = \Xi_{13t} - \varphi_{12}\Xi_{14t+1} \tag{B.5.17}$$

$$0 = \varphi_{13}(\Xi_{41t} - \Xi_{42t}) - \varphi_{14}\Xi_{36t} - \Xi_{32t} + \Xi_{28t} + \Xi_{16t} - \varphi_{15}\Xi_{13t} - \Xi_{11t} + \varphi_{16}\Xi_{44t+1} \tag{B.5.18}$$

$$0 = \Xi_{24t} - \varphi_{17}\Xi_{22t} \tag{B.5.19}$$

$$0 = \Xi_{19t} - \phi^{\pi}\Xi_{28t} - \varphi_{18}(\Xi_{16t-1} + \beta_P\Xi_{19t-1}) + \frac{\varphi_{11}}{\beta_P}\Xi_{22t} \tag{B.5.20}$$

$$0 = \Xi_{16t} - \varphi_{19}\Xi_{24t} - \Xi_{17t} - \varphi_{18}\Xi_{16t-1} \tag{B.5.21}$$

$$0 = 2\lambda^{\nu^{2\prime}}\widehat{\nu}_t - \Xi_{15t} \tag{B.5.22}$$

$$0 = \Xi_{40t} + \Xi_{10t} - \Xi_{26t} \tag{B.5.23}$$

$$0 = \varphi_{20}\Xi_{44t} - \varphi_{21}\Xi_{7t} + \varphi_{22}\Xi_{41t} + \varphi_{23}\Xi_{38t+1} \tag{B.5.24}$$

$$0 = \varphi_{24}\Xi_{36t} - \varphi_{25}\Xi_{38t+1} \tag{B.5.25}$$

$$0 = \Xi_{50t} - \Xi_{26t} + \Xi_{39t} + \varphi_{26}\Xi_{38t+1} \tag{B.5.26}$$

$$0 = \varphi_{27}\Xi_{38t+1} - \Xi_{39t} - \Xi_{38t} \tag{B.5.27}$$

$$0 = \varphi_2\Xi_{10t} - \Xi_{7t} - \varphi_{28}\Xi_{8t} \tag{B.5.28}$$

$$0 = \Xi_{6t} + \varphi_{28}\Xi_{8t} - \varphi_3\Xi_{9t} \tag{B.5.29}$$

$$0 = \Xi_{50t} - \Xi_{35t} \tag{B.5.30}$$

$$0 = \Xi_{49t} - \Xi_{34t} \tag{B.5.31}$$

$$0 = \eta^S \, \Xi_{42t} - \Xi_{40t} - \varphi_{29}\Xi_{42t-1} \tag{B.5.32}$$

$$0 = \nu^S \, \Xi_{41t} + \varphi_{30}\Xi_{40t} - \varphi_{31}\Xi_{41t-1} \tag{B.5.33}$$

$$0 = \Xi_{39t} - \Xi_{43t} + \beta_P \, \Xi_{43t+1} - \varphi_{32}\Xi_{44t+1} \tag{B.5.34}$$

$$0 = \Xi_{43t} - \varphi_{37}\Xi_{41t-1} \tag{B.5.35}$$

$$0 = \Psi^S \, \Xi_{44t} - \Xi_{43t} - \beta_P{}^{(-1)}\eta^S \, \theta^S \, \beta_S \, \Psi^S\Xi_{42t-1} \tag{B.5.36}$$

$$0 = 2\lambda^{y^{2\prime}}\widetilde{Y}_t + \Xi_{30t} \tag{B.5.37}$$

$$0 = \Xi_{30t} + \Xi_{29t} \tag{B.5.38}$$

$$0 = \Xi_{32t} + \Xi_{31t} \tag{B.5.39}$$

$$0 = 2\lambda^{r^{2\prime}}\widetilde{r}_t + \Xi_{32t} \tag{B.5.40}$$

$$0 = \Xi_{34t} + \Xi_{33t} \tag{B.5.41}$$

$$0 = 2\lambda^{z,cb^{2\prime}}\widetilde{Z}_t + \Xi_{34t} \tag{B.5.42}$$

$$0 = 2\lambda^{z,sb^{2\prime}}\widetilde{Z}_t^{SB} + \Xi_{35t} \tag{B.5.43}$$

where the Lagrange multipliers are given by $\Xi_{m,t+n}, m \in \{1, \ldots, 50\}; n \in \{-1, 0, 1\}$. The vector of initial conditions is given by

$$\Upsilon = \begin{bmatrix} \Xi_{16-1} \\ \Xi_{19-1} \\ \Xi_{41-1} \\ \Xi_{42-1} \end{bmatrix} \tag{B.5.44}$$

and the auxiliary parameters are composites of deep parameters and steady-state relations:

$\varphi_1 = \frac{C^E}{C}$
$\varphi_2 = \frac{\chi^S\,K}{B^{E,S}}$
$\varphi_3 = \frac{\chi^C\,K}{B^{E,C}}$
$\varphi_4 = \frac{1}{1+r^{bc}}$
$\varphi_5 = \frac{R+\Delta^C}{\Delta^C+R\,\nu}$
$\varphi_6 = \frac{\theta\,\nu^4}{\Delta^C+\nu\,R}$
$\varphi_7 = \theta\,\nu^3$
$\varphi_8 = 1-\alpha$
$\varphi_9 = \frac{R}{\Delta^C+\nu\,R}$
$\varphi_{10} = \beta_P(1-\delta^C)$
$\varphi_{11} = \beta_P\frac{\delta^C\,Kb}{Y}$
$\varphi_{12} = \beta_P\delta^C$
$\varphi_{13} = R(1-\theta^S)\beta_S$
$\varphi_{14} = \frac{1}{1+R}$
$\varphi_{15} = \frac{\nu}{\Delta^C+\nu\,R}$
$\varphi_{16} = \beta_P\,R(\phi^S-1)$
$\varphi_{17} = \frac{C}{Y}$
$\varphi_{18} = \beta_P{}^{(-1)}$
$\varphi_{19} = \frac{C^P}{C}$
$\varphi_{20} = r^{bS}\,\phi^S$
$\varphi_{21} = \frac{1}{1+r^{bS}}$
$\varphi_{22} = r^{bS}\,\left(1-\theta^S\right)\,\beta_S$
$\varphi_{23} = \beta_P\frac{q\,B^{E,S}}{K^S}\,\sigma^S$
$\varphi_{24} = \frac{1}{1+r^{dS}}$
$\varphi_{25} = \beta_P\sigma^S\,\left(1-\frac{q\,B^{E,S}}{K^S}\right)$
$\varphi_{26} =$
$\beta_P\frac{q\,B^{E,S}}{K^S}\,\left(\sigma^S\Delta_t^S+\omega^S\right)$
$\varphi_{27} = \beta_P\,\left(1+r^{dS}\right)\,\sigma^S$
$\varphi_{28} = \frac{\frac{K}{\beta_E}\,\chi^S}{NW}$
$\varphi_{29} = \beta_P{}^{(-1)}\eta^S\,\theta^S\,\beta_S\,\Psi^S$
$\varphi_{30} = \frac{\nu^S}{\theta^S-\nu^S}$
$\varphi_{31} = \beta_P{}^{(-1)}\nu^S\,\theta^S\,\beta_S\,\Xi^S$
$\varphi_{32} = \beta_P\phi^S\,\left(r^{bS}-R\right)$
$\varphi_{33} = (1+\phi^P)\theta^p$
$\varphi_{34} = \alpha\beta_P$
$\varphi_{35} = \frac{\Psi^S}{\varphi_{32}}$
$\varphi_{36} = \frac{\varphi_{29}}{\eta^S}$
$\varphi_{37} = \beta_P{}^{(-1)}\nu^S\,\theta^S\,\beta_S\,\Xi^S$

Treating initial conditions Υ as parameters, the system given by equations B.5.2 to B.5.43 can be simplified such that

$$0 = \varphi_{38}\Xi_{15t} - \varphi_{39} - \varphi_{40}\Xi_{22t} - \varphi_{41}\Xi_{38t} - \varphi_{42}\Xi_{38t+1} + \varphi_{43}\widetilde{Y}_t - \varphi_{44}\widetilde{Z}_t - \varphi_{45}\widetilde{Z}_t^{SB} - 2\varphi_7\lambda^{r^2}\widetilde{r}_t \tag{B.5.45}$$

$$0 = \Xi_{14t} + \varphi_{46}\Xi_{15t} - \varphi_{10}\Xi_{14t+1} - \varphi_{11}\Xi_{22t+1} - \varphi_{47} - \varphi_{48}\Xi_{22t} - \varphi_{49}\Xi_{38t} - \varphi_{50}\Xi_{38t+1} - \varphi_{51}\widetilde{Z}_t - \varphi_{52}\widetilde{Z}_t^{SB} \tag{B.5.46}$$

$$0 = \varphi_{53} + \varphi_{54}\Xi_{15t} + \varphi_{55}\Xi_{22t} + \varphi_{56}\Xi_{38t} + \varphi_{57}\Xi_{38t+1} + \varphi_{58}\widetilde{Z}_t + \varphi_{59}\widetilde{Z}_t^{SB} - \varphi_{12}\Xi_{14t+1} \tag{B.5.47}$$

$$0 = \varphi_{60}\Xi_{22t} + \varphi_{61}\Xi_{38t} + \varphi_{62}\Xi_{38t+1} + \varphi_{63}\widetilde{Z}_t^{SB} - \varphi_{64} \tag{B.5.48}$$

$$0 = 2\lambda^{\nu^{2\prime}}\widehat{\nu}_t - \Xi_{15t} \tag{B.5.49}$$

where φ_{38} to φ_{64} depict auxiliary parameters defined for simplification. Treating the period-t values of Lagrange multipliers Ξ_{14t}, Ξ_{15t}, Ξ_{22t}, and Ξ_{38t} as endogenous variables, one can solve the system defined by equations B.5.45 to B.5.48. Combining the solution for Ξ_{15t} with equation B.5.49, one can derive

$$2\lambda^{\nu^{2\prime}}\widehat{\nu}_t = \varphi_{65} + \varphi_{66}\Xi_{14t+1} + \varphi_{67}\Xi_{38t+1} + \varphi_{68}\widetilde{r}_t + \varphi_{69}\widetilde{Y}_t + \varphi_{70}\widetilde{Z}_t + \varphi_{71}\widetilde{Z}_t^{SB} \tag{B.5.50}$$

with φ_{65} to φ_{71} again depicting auxiliary parameters. In addition to the capital requirement $\widehat{\nu}_t$ and potential target variables $\widetilde{r}_t$, $\widetilde{Y}_t$, $\widetilde{Z}_t$, and $\widetilde{Z}_t^{SB}$, equation B.5.50 contains expected values of Lagrange multipliers, $E_t\{\Xi_{14t+1}, \Xi_{38t+1}\}$. To derive a direct rule in the definition of Giannoni and Woodford (2003a,b), we need to express these multipliers in terms of policy and target variables only. By extending the system of equations, one can iteratively include the expected values of the Lagrange multipliers as endogenous variables and find explicit solutions. Starting by lagging equation B.5.50 by one period, we can extend the system of equations B.5.45 to B.5.49 to get

$$
\begin{aligned}
0 &= \varphi_{38}\Xi_{15t} - \varphi_{39} - \varphi_{40}\Xi_{22t} - \varphi_{41}\Xi_{38t} - \varphi_{42}\Xi_{38t+1} + \varphi_{43}\widetilde{Y}_t - \varphi_{44}\widetilde{Z}_t \\
&\quad - \varphi_{45}\widetilde{Z}_t^{SB} - 2\varphi_7\lambda^{r^2}\widetilde{r}_t && \text{(B.5.51)}\\
0 &= \Xi_{14t} + \varphi_{46}\Xi_{15t} - \varphi_{10}\Xi_{14t+1} - \varphi_{11}\Xi_{22t+1} - \varphi_{47} - \varphi_{48}\Xi_{22t} - \varphi_{49}\Xi_{38t} \\
&\quad - \varphi_{50}\Xi_{38t+1} - \varphi_{51}\widetilde{Z}_t - \varphi_{52}\widetilde{Z}_t^{SB} && \text{(B.5.52)}\\
0 &= \varphi_{53} + \varphi_{54}\Xi_{15t} + \varphi_{55}\Xi_{22t} + \varphi_{56}\Xi_{38t} + \varphi_{57}\Xi_{38t+1} + \varphi_{58}\widetilde{Z}_t + \varphi_{59}\widetilde{Z}_t^{SB} \\
&\quad - \varphi_{12}\Xi_{14t+1} && \text{(B.5.53)}\\
0 &= \varphi_{60}\Xi_{22t} + \varphi_{61}\Xi_{38t} + \varphi_{62}\Xi_{38t+1} + \varphi_{63}\widetilde{Z}_t^{SB} - \varphi_{64} && \text{(B.5.54)}\\
0 &= 2\lambda^{\nu^{2\prime}}\widehat{\nu}_{t-1} - \varphi_{65} - \varphi_{66}\Xi_{14t} - \varphi_{67}\Xi_{38t} - \varphi_{68}\widetilde{r}_{t-1} - \varphi_{69}\widetilde{Y}_{t-1} - \varphi_{70}\widetilde{Z}_{t-1} \\
&\quad - \varphi_{71}\widetilde{Z}_{t-1}^{SB} && \text{(B.5.55)}\\
0 &= 2\lambda^{\nu^{2\prime}}\widehat{\nu}_t - \Xi_{15t}. && \text{(B.5.56)}
\end{aligned}
$$

By solving the system of equations B.5.51 to B.5.55, one can derive a solution for Lagrange multipliers Ξ_{14t}, Ξ_{15t}, Ξ_{22t}, and Ξ_{38t} as well as for $E_t\{\Xi_{38t+1}\}$. The solution for the latter is given by

$$
\begin{aligned}
E_t\{\Xi_{38t+1}\} = \varphi_{72}E_t\{\Xi_{14t+1}\} + \varphi_{73}E_t\{\Xi_{22t+1}\} + \varphi_{74}\widetilde{r}_t + \varphi_{75}\widetilde{r}_{t-1} + \varphi_{76}\widetilde{Y}_t + \varphi_{77}\widetilde{Y}_{t-1} + \\
+ \varphi_{78}\widetilde{Z}_t + \varphi_{79}\widetilde{Z}_{t-1} + \varphi_{80}\widetilde{Z}_t^{SB} + \varphi_{81}\widetilde{Z}_{t-1}^{SB} + \varphi_{82} + \varphi_{83}\widehat{\nu}_{t-1} \quad \text{(B.5.57)}
\end{aligned}
$$

with auxiliary parameters φ_{72} to φ_{83}. As the solution not only depends on contemporaneous and lagged values of the policy tool $\widehat{\nu}_t$ and the potential target variables, but also on $E_t\{\Xi_{14t+1}\}$ and $E_t\{\Xi_{22t+1}\}$, we need to further extend the system and find explicit solutions for the latter expressions. Adding the lag of equation B.5.57 to system B.5.51 to B.5.56 in the second step, one gets

$$0 = \varphi_{38}\Xi_{15t} - \varphi_{39} - \varphi_{40}\Xi_{22t} - \varphi_{41}\Xi_{38t} - \varphi_{42}\Xi_{38t+1} + \varphi_{43}\widetilde{Y}_t - \varphi_{44}\widetilde{Z}_t - \varphi_{45}\widetilde{Z}_t^{SB} - 2\varphi_7\lambda^{r^2}\widetilde{r}_t \tag{B.5.58}$$

$$0 = \Xi_{14t} + \varphi_{46}\Xi_{15t} - \varphi_{10}\Xi_{14t+1} - \varphi_{11}\Xi_{22t+1} - \varphi_{47} - \varphi_{48}\Xi_{22t} - \varphi_{49}\Xi_{38t} - \varphi_{50}\Xi_{38t+1} - \varphi_{51}\widetilde{Z}_t - \varphi_{52}\widetilde{Z}_t^{SB} \tag{B.5.59}$$

$$0 = \varphi_{53} + \varphi_{54}\Xi_{15t} + \varphi_{55}\Xi_{22t} + \varphi_{56}\Xi_{38t} + \varphi_{57}\Xi_{38t+1} + \varphi_{58}\widetilde{Z}_t + \varphi_{59}\widetilde{Z}_t^{SB} - \varphi_{12}\Xi_{14t+1} \tag{B.5.60}$$

$$0 = \varphi_{60}\Xi_{22t} + \varphi_{61}\Xi_{38t} + \varphi_{62}\Xi_{38t+1} + \varphi_{63}\widetilde{Z}_t^{SB} - \varphi_{64} \tag{B.5.61}$$

$$0 = 2\lambda^{\nu^{2\prime}}\widehat{\nu}_{t-1} - \varphi_{65} - \varphi_{66}\Xi_{14t} - \varphi_{67}\Xi_{38t} - \varphi_{68}\widetilde{r}_{t-1} - \varphi_{69}\widetilde{Y}_{t-1} - \varphi_{70}\widetilde{Z}_{t-1} - \varphi_{71}\widetilde{Z}_{t-1}^{SB} \tag{B.5.62}$$

$$0 = \Xi_{38t} - \varphi_{72}\Xi_{14t} - \varphi_{73}\Xi_{22t} - \varphi_{74}\widetilde{r}_{t-1} - \varphi_{75}\widetilde{r}_{t-2} - \varphi_{76}\widetilde{Y}_{t-1} - \varphi_{77}\widetilde{Y}_{t-2} - \varphi_{78}\widetilde{Z}_{t-1} - \varphi_{79}\widetilde{Z}_{t-2} - \varphi_{80}\widetilde{Z}_{t-1}^{SB} - \varphi_{81}\widetilde{Z}_{t-2}^{SB} - \varphi_{82} - \varphi_{83}\widehat{\nu}_{t-2} \tag{B.5.63}$$

$$0 = 2\lambda^{\nu^{2\prime}}\widehat{\nu}_t - \Xi_{15t}. \tag{B.5.64}$$

Solving the system given by equations B.5.58 to B.5.63 again for Lagrange multipliers Ξ_{14t}, Ξ_{15t}, Ξ_{22t}, and Ξ_{38t}, $E_t\{\Xi_{38t+1}\}$ and additionally for $E_t\{\Xi_{22t+1}\}$, one can derive a solution for Ξ_{15t} which only depends on contemporaneous and lagged values of the policy tool and potential target variables, but still includes $E_t\{\Xi_{14t+1}\}$:

$$\begin{aligned}\Xi_{15t} = {} & \varphi_{84} + \varphi_{85}E_t\{\Xi_{14t+1}\}+ \\ & + \varphi_{86}\widetilde{r}_t + \varphi_{87}\widetilde{r}_{t-1} + \varphi_{88}\widetilde{r}_{t-2}+ \\ & + \varphi_{89}\widetilde{Y}_t + \varphi_{90}\widetilde{Y}_{t-1} + \varphi_{91}\widetilde{Y}_{t-2}+ \\ & + \varphi_{92}\widetilde{Z}_t + \varphi_{93}\widetilde{Z}_{t-1} + \varphi_{94}\widetilde{Z}_{t-2}+ \\ & + \varphi_{95}\widetilde{Z}_t^{SB} + \varphi_{96}\widetilde{Z}_{t-1}^{SB} + \varphi_{97}\widetilde{Z}_{t-2}^{SB}+ \\ & + \varphi_{98}\widehat{\nu}_{t-1} + \varphi_{99}\widehat{\nu}_{t-2}\end{aligned} \tag{B.5.65}$$

with auxiliary parameters φ_{84} to φ_{99}. Finally, lagging equation B.5.65 by one period and adding to system B.5.58 to B.5.64, one can derive the system

$$0 = \varphi_{38}\Xi_{15t} - \varphi_{39} - \varphi_{40}\Xi_{22t} - \varphi_{41}\Xi_{38t} - \varphi_{42}\Xi_{38t+1} + \varphi_{43}\widetilde{Y}_t - \varphi_{44}\widetilde{Z}_t - \varphi_{45}\widetilde{Z}_t^{SB} - 2\varphi_7\lambda^{r^2}\widetilde{r}_t \tag{B.5.66}$$

$$0 = \Xi_{14t} + \varphi_{46}\Xi_{15t} - \varphi_{10}\Xi_{14t+1} - \varphi_{11}\Xi_{22t+1} - \varphi_{47} - \varphi_{48}\Xi_{22t} - \varphi_{49}\Xi_{38t} - \varphi_{50}\Xi_{38t+1} - \varphi_{51}\widetilde{Z}_t - \varphi_{52}\widetilde{Z}_t^{SB} \tag{B.5.67}$$

$$0 = \varphi_{53} + \varphi_{54}\Xi_{15t} + \varphi_{55}\Xi_{22t} + \varphi_{56}\Xi_{38t} + \varphi_{57}\Xi_{38t+1} + \varphi_{58}\widetilde{Z}_t + \varphi_{59}\widetilde{Z}_t^{SB} - \varphi_{12}\Xi_{14t+1} \tag{B.5.68}$$

$$0 = \varphi_{60}\Xi_{22t} + \varphi_{61}\Xi_{38t} + \varphi_{62}\Xi_{38t+1} + \varphi_{63}\widetilde{Z}_t^{SB} - \varphi_{64} \tag{B.5.69}$$

$$0 = 2\lambda^{\nu^{2\prime}}\widehat{\nu}_{t-1} - \varphi_{65} - \varphi_{66}\Xi_{14t} - \varphi_{67}\Xi_{38t} - \varphi_{68}\widetilde{r}_{t-1} - \varphi_{69}\widetilde{Y}_{t-1} - \varphi_{70}\widetilde{Z}_{t-1} - \varphi_{71}\widetilde{Z}_{t-1}^{SB} \tag{B.5.70}$$

$$0 = \Xi_{38t} - \varphi_{72}\Xi_{14t} - \varphi_{73}\Xi_{22t} - \varphi_{74}\widetilde{r}_{t-1} - \varphi_{75}\widetilde{r}_{t-2} - \varphi_{76}\widetilde{Y}_{t-1} - \varphi_{77}\widetilde{Y}_{t-2} - \varphi_{78}\widetilde{Z}_{t-1} - \varphi_{79}\widetilde{Z}_{t-2} - \varphi_{80}\widetilde{Z}_{t-1}^{SB} - \varphi_{81}\widetilde{Z}_{t-2}^{SB} - \varphi_{82} - \varphi_{83}\widehat{\nu}_{t-2} \tag{B.5.71}$$

$$0 = \Xi_{15t-1} - \varphi_{84} - \varphi_{85}\Xi_{14t} - \varphi_{98}\widehat{\nu}_{t-2} - \varphi_{99}\widehat{\nu}_{t-3} - \varphi_{86}\widetilde{r}_{t-1} - \varphi_{87}\widetilde{r}_{t-2} - \varphi_{88}\widetilde{r}_{t-3} - \varphi_{89}\widetilde{Y}_{t-1} - \varphi_{90}\widetilde{Y}_{t-2} - \varphi_{91}\widetilde{Y}_{t-3} - \varphi_{92}\widetilde{Z}_{t-1} - \varphi_{93}\widetilde{Z}_{t-2} - \varphi_{94}\widetilde{Z}_{t-3} - \varphi_{95}\widetilde{Z}_{t-1}^{SB} - \varphi_{96}\widetilde{Z}_{t-2}^{SB} - \varphi_{97}\widetilde{Z}_{t-3}^{SB} \tag{B.5.72}$$

$$0 = 2\lambda^{\nu^{2\prime}}\widehat{\nu}_t - \Xi_{15t}. \tag{B.5.73}$$

Solving equations B.5.66 to B.5.72 for Lagrange multipliers Ξ_{14t}, Ξ_{15t}, Ξ_{22t}, Ξ_{38t}, $E_t\{\Xi_{38t+1}\}$, $E_t\{\Xi_{22t+1}\}$, and $E_t\{\Xi_{14t+1}\}$, the solution for Ξ_{15t} is now given by

$$\begin{aligned}\Xi_{15t} = \varphi_{100} + \varphi_{101}\widehat{\nu}_{t-1} + \varphi_{102}\widehat{\nu}_{t-2} + \varphi_{103}\widehat{\nu}_{t-3} + \\ + \varphi_{104}\widetilde{r}_t + \varphi_{105}\widetilde{r}_{t-1} + \varphi_{106}\widetilde{r}_{t-2} + \varphi_{107}\widetilde{r}_{t-3} + \\ + \varphi_{108}\widetilde{Y}_t + \varphi_{109}\widetilde{Y}_{t-1} + \varphi_{110}\widetilde{Y}_{t-2} + \varphi_{111}\widetilde{Y}_{t-3} + \\ + \varphi_{112}\widetilde{Z}_t + \varphi_{113}\widetilde{Z}_{t-1} + \varphi_{114}\widetilde{Z}_{t-2} + \varphi_{115}\widetilde{Z}_{t-3} + \\ + \varphi_{116}\widetilde{Z}_t^{SB} + \varphi_{117}\widetilde{Z}_{t-1}^{SB} + \varphi_{118}\widetilde{Z}_{t-2}^{SB} + \varphi_{119}\widetilde{Z}_{t-3}^{SB}\end{aligned} \tag{B.5.74}$$

with auxiliary parameters φ_{100} to φ_{119}. Combining equations B.5.49 and B.5.74, one can derive a solution for $\widehat{\nu}_t$ which only depends on lagged values of the policy tools and target variables:

$$
\begin{aligned}
\widehat{\nu}_t = {} & \rho^{\nu} + \rho_1^{\nu}\widehat{\nu}_{t-1} + \rho_2^{\nu}\widehat{\nu}_{t-2} + \rho_3^{\nu}\widehat{\nu}_{t-3} + \\
& + \phi_1^{r}\widetilde{r}_t + \phi_2^{r}\widetilde{r}_{t-1} + \phi_3^{r}\widetilde{r}_{t-2} + \phi_4^{r}\widetilde{r}_{t-3} + \\
& + \phi_1^{y}\widetilde{Y}_t + \phi_2^{y}\widetilde{Y}_{t-1} + \phi_3^{y}\widetilde{Y}_{t-2} + \phi_4^{y}\widetilde{Y}_{t-3} + \\
& + \phi_1^{z,cb}\widetilde{Z}_t + \phi_2^{z,cb}\widetilde{Z}_{t-1} + \phi_3^{z,cb}\widetilde{Z}_{t-2} + \phi_4^{z,cb}\widetilde{Z}_{t-3} + \\
& + \phi_1^{z,sb}\widetilde{Z}_t^{SB} + \phi_2^{z,sb}\widetilde{Z}_{t-1}^{SB} + \phi_3^{z,sb}\widetilde{Z}_{t-2}^{SB} + \phi_4^{z,sb}\widetilde{Z}_{t-3}^{SB}
\end{aligned} \tag{B.5.75}
$$

which depicts the capital requirement rule 5.49 stated in section 5.6.1.

C Appendix Chapter 6

C.1 Appendix: The Non-Linear Open Economy Model

C.1.1 Households

The representative patient household i in each country $c \in \{h, f\}$ maximizes expected utility

$$\max_{c_t^{P,c}(i),\, l_t^c(i),\, d_t^c(i)} E_0 \sum_{t=0}^{\infty} (\beta_P^c)^t \left[z_t^{c,c} \log[c_t^{P,c}(i) - a_P^c c_{t-1}^{P,c}(i)] - \frac{\varphi_P^c}{1+\phi_P^c} l_t^c(i)^{1+\phi_P^c} \right] \quad \text{(C.1.1)}$$

subject to the nominal budget constraint

$$P_t^c c_t^{P,c}(i) + D_t^c(i) \leq W_t^c l_t^c(i) + \tilde{R}_{t-1}^{d,c,nom} D_{t-1}^c(i) + \Pi_t^{cp,c,nom}(i) + \Pi_t^{bank,c,nom}(i) - \tau_t^{c,nom}(i).$$

We obtain the real budget constraint of households after dividing by the consumer price level P_t^c:

$$c_t^{P,c}(i) + d_t^c(i) \leq w_t^c l_t^c(i) + \tilde{R}_t^{d,c} d_{t-1}^c(i) + \Pi_t^{cp,c}(i) + \Pi_t^{bank,c}(i) - \tau_t^c(i), \quad \text{(C.1.2)}$$

with $d_t^c(i)$, w_t^c, $\Pi_t^{cp,c}(i)$, $\Pi_t^{bank,c}(i)$, $\tau_t^c(i)$ and $\tilde{R}_t^{d,c}$ all denoting real variables, and $\Pi_t = \frac{P_t^c}{P_{t-1}^c}$ defining consumer price inflation. Current consumption $c_t^{P,c}(i)$ is prone to habit formation governed by a_P^c, and $z_t^{c,c}$ depicts a consumption preference shock described by an AR(1) process. Working hours are given by l_t^c and labor disutility is parameterized by ϕ_P^c. The flow of expenses includes current consumption, and real deposits to be made to domestic banks $d_t^c(i)$. Resources consist of wage earnings $w_t^c l_t^c(i)$ (where w_t^c is the real wage rate for the labor input paid in the country the respective household resides) and gross interest income on last period deposits placed in domestic banks, $\tilde{R}_t^{d,c}$. The fiscal authority charges lump-sum taxes $\tau_t^c(i)$ in real terms to finance government debt. The household receives real profits $\Pi_t^{bank,c}(i)$ from exiting bankers, and $\Pi_t^{cp,c}(i)$ from capital producers. Transferred bank profits are given by

$$\Pi_t^{bank,c}(i) = (1-\theta_b^c)[\rho_t^c n_t^{c,c} + \rho_t^{\neg c} n_t^{c,\neg c} - \chi_t^{b,c}]$$

and the Lagrange function for the patient household is therefore given by:

$$\mathcal{L}^{P,c} = E_0 \sum_{t=0}^{\infty} (\beta_P^c)^t \Bigg[z_t^{c,c} \log[c_t^{P,c}(i) - a_P^c c_{t-1}^{P,c}(i)] - \frac{\varphi_P^c}{1+\phi_P^c} l_t^{P,c}(i)^{1+\phi_P^c}$$
$$- \lambda_t^{P,c} \Big[c_t^{P,c}(i) + d_t^c(i) - w_t^c l_t^{P,c}(i) - \tilde{R}_{t-1}^{d,c} d_{t-1}^c(i) - \Pi_t^{cp,c}(i) - \Pi_t^{bank,c}(i) + \tau_t^c(i) \Big] \Bigg]. \quad \text{(C.1.3)}$$

Following Mendicino et al. (2018), bank debt is partially insured by a fraction κ_t^c. Insured bank debt always pays back the promised rate $R_t^{d,c}$. Uninsured deposits pay back the promised rate $R_t^{d,c}$ if the bank is solvent and a fraction $(1-\kappa_t^c)$ of the net recovery value of bank assets in case of default. The return of households on a unit of bank debt is then given by

$$\tilde{R}_t^{d,c} = R_t^{d,c} - (1-\kappa_t^c)\frac{\Omega_{t+1}^c}{d_t^c}, \quad \text{(C.1.4)}$$

where $\frac{\Omega_{t+1}^c}{d_t^c}$ is the average default loss per unit of bank debt. The share of insured deposits, κ_t^c is time-varying and depends on available funds in the deposit insurance.

The first-order conditions are given by:

1. Consumption:

$$\frac{z_t^{c,c}}{c_t^{P,c}(i) - a_P^c c_{t-1}^{P,c}(i)} - a_P^c \beta_P^c E_t \left\{ \frac{1}{c_{t+1}^{P,c}(i) - a_P^c c_t^{P,c}(i)} \right\} = \lambda_t^{P,c}$$

2. Labor:

$$\varphi_P^c [l_t^{P,c}(i)]^{\phi_P^c} = \lambda_t^{P,c} w_t^c$$

3. Deposit:

$$\beta_P^c E_t \{ \lambda_{t+1}^{P,c} \tilde{R}_t^{d,c} \} = \lambda_t^{P,c}$$

C.1.2 Entrepreneurs

Entrepreneurs engaged in a certain sector j in country c use the respective labor type provided by households as well as capital to produce intermediate goods that retailers purchase in a competitive market. Each entrepreneur i derives utility from consumption $c_t^{E,c}(i)$ and maximizes expected utility

$$\max_{c_t^{E,c}(i),l_t^{P,c}(i),k_t^{E,c}(i)} E_0 \sum_{t=0}^{\infty} (\beta_P^c)^t \log c_t^{E,c}(i) \tag{C.1.5}$$

subject to the nominal budget constraint

$$P_t^c c_t^{E,c}(i) + W_t^c l_t^{P,c}(i) + Q_t^{k,c} k_t^{E,c}(i) + R_t^{E,c,nom} B_{t-1}^{E,c}(i) \leq \\ P_t^{E,c} y_t^{E,c}(i) + B_t^{E,c}(i) + Q_t^{k,c}(1-\delta^c) k_{t-1}^{E,c}(i). \tag{C.1.6}$$

After dividing by the consumer price level P_t^c, one obtains:

$$c_t^{E,c}(i) + w_t^c l_t^{P,c}(i) + q_t^{k,c} k_t^{E,c}(i) + R_t^{E,c} b_{t-1}^{E,c}(i) \leq p_t^{E,c} y_t^{E,c}(i) + b_t^{E,c}(i) + q_t^{k,c}(1-\delta^c) k_{t-1}^{E,c}(i) \tag{C.1.7}$$

with $p_t^{E,c} = \frac{P_t^{E,c}}{P_t^c}$ denoting the price ratio of producer price level to consumer price level, $q_t^{k,c} = \frac{Q_t^{k,c}}{P_t^c}$ denoting the real price of the capital good. Entrepreneurs in country c furthermore face constraints on the amount they can borrow from domestic banks depending on the stock of capital they hold as collateral. Regulatory loan-to-value (LTV) ratios apply for funds borrowed in each country, and regulation can be determined on the national level. The borrowing constraint is given by

$$R_{t+1}^{E,c} b_t^{E,c}(i) \leq m_E^c E_t\{q_{t+1}^{k,c}(1-\delta^c) k_t^{E,c}(i)\} \tag{C.1.8}$$

where the LTV ratio for commercial banks m_E^c is set exogenous by the regulator. We follow Iacoviello (2005) and assume that the borrowing constraint binds around the steady state such that uncertainty is absent in the model. Thus, in equilibrium, entrepreneurs face a binding borrowing constraint, such that equation C.1.8 holds with equality. The production function is given by

$$y_t^{E,c} = a_t^{E,c} (k_t^{E,c})^{(\alpha^c)} (l_t^{P,c})^{(1-\alpha^c)} \tag{C.1.9}$$

and the return to capital is defined as

$$r_t^{k,c} = \alpha^c \frac{p_t^{E,c} a_t^{E,c} (k_t^{E,c})^{(\alpha^c)} (l_t^{P,c})^{(1-\alpha^c)}}{k_t^{E,c}}. \tag{C.1.10}$$

Equation C.1.8 yields the contractual return on one unit of corporate loans:

$$R_{t+1}^{E,c} = \frac{m_E^c E_t \{q_{t+1}^{k,c}(1-\delta^c) k_t^{E,c}(i)\}}{b_t^{E,c}(i)}. \tag{C.1.11}$$

Entrepreneur Maximization Problem

Entrepreneurs maximize their lifetime consumption stream by deciding on period consumption $c_t^{E,c}(i)$ as well as on labor and capital inputs, $l_t^{P,c}(i)$ and $k_t^{E,c}(i)$, subject to the budget constraint C.1.7, the borrowing constraint C.1.8, and the production technology C.1.9. The Lagrange function is therefore given by:

$$\mathcal{L}^{E,c} = E_0 \sum_{t=0}^{\infty} \beta_E^t \Bigg[\log c_t^{E,c}(i) - \lambda_t^{E,c} \Big[c_t^{E,c}(i) + w_t^c l_t^{P,c}(i) + q_t^{k,c} k_t^{E,c}(i) + m_E^c q_t^{k,c}(1-\delta^c) k_{t-1}^{E,c}(i) -$$
$$- p_t^{E,c} a_t^{E,c} (k_t^{E,c})^{(\alpha^c)} (l_t^{P,c})^{(1-\alpha^c)} - \frac{m_E^c q_{t+1}^{k,c}(1-\delta^c) k_t^{E,c}(i)}{R_{t+1}^{E,c}} - q_t^{k,c}(1-\delta^c) k_{t-1}^{E,c}(i) \Big] \Bigg]. \tag{C.1.12}$$

The first-order conditions are given by:

1. Consumption:

$$\frac{1}{c_t^{E,c}(i)} = \lambda_t^{E,c}$$

2. Labor:

$$w_t^c = (1-\alpha^c) \frac{p_t^{E,c} y_t^{E,c}(i)}{l_t^{P,c}}$$

3. Capital:

$$\lambda_t^{E,c}\left(q_t^k - \frac{m_E^c E_t\{q_{t+1}^{k,c}(1-\delta^c)\}}{R_{t+1}^{E,c}}\right) =$$
$$\beta_E^c E_t\left\{\lambda_{t+1}^{E,c}\left[q_{t+1}^{k,c}(1-\delta^c) + \alpha^c \frac{p_{t+1}^{E,c} y_{t+1}^{E,c}(i)}{k_t^{E,c}} - m_E^c q_{t+1}^{k,c}(1-\delta^c)\right]\right\}$$

Intertemporal Capital Investment Decision

Combining the first-order conditions on the interest rate and capital, the investment Euler equation can be rewritten as:

$$\frac{q_t^{k,c}}{c_t^{E,c}(i)} = -\frac{\chi_t^c}{c_t^{E,c}(i)} + \beta_E^c E_t\left\{\frac{q_{t+1}^{k,c}(1-\delta^c) + \alpha^c \frac{p_{t+1}^{E,c} y_{t+1}^{E,c}(i)}{k_t^{E,c}(i)} - m_E^c q_{t+1}^{k,c}(1-\delta^c)}{c_{t+1}^{E,c}(i)}\right\}.$$

Following Gambacorta and Signoretti (2014), the definition of the loan-to-value constraint $b_t^{E,c} = \chi_t^c k_t^{E,c} = \frac{m_E^c q_{t+1}^{k,c}(1-\delta^c)}{R_{t+1}^{E,c}} k_t^{E,c}$. Plugging in yields:

$$\frac{q_t^{k,c} - \chi_t^c}{c_t^{E,c}(i)} = \beta_E^c E_t\left\{\frac{q_{t+1}^{k,c}(1-\delta^c) + \alpha^c \frac{p_{t+1}^{E,c} y_{t+1}^{E,c}(i)}{k_t^{E,c}(i)} - R_{t+1}^{E,c}\chi_t^c}{c_{t+1}^{E,c}(i)}\right\}$$

or:

$$E_t\left\{\frac{c_{t+1}^{E,c}(i)(q_t^{k,c} - \chi_t^c)}{\beta_E^c c_t^{E,c}(i)}\right\} = E_t\left\{q_{t+1}^{k,c}(1-\delta^c) + \alpha^c \frac{p_{t+1}^{E,c} y_{t+1}^{E,c}(i)}{k_t^{E,c}(i)} - R_{t+1}^{E,c}\chi_t^c\right\}.$$

Entrepreneurial Net Worth

Net worth of entrepreneurs in the next period is defined as the revenue from sold intermediate goods plus the market value of the capital stock inherited from the previous period minus the cost of labor input and debt:

$$\begin{aligned} E_t\{NW^c_{t+1}(i)\} &= E_t\{p^{E,c}_{t+1}y^{E,c}_{t+1}(i) - w^c_{t+1}l^{P,c}_{t+1}(i) - R^{E,c}_t b^{E,c}_t(i) + q^{k,c}_{t+1}(1-\delta^c)k^{E,c}_t(i)\} \\ &= E_t\{p^{E,c}_{t+1}y^{E,c}_{t+1}(i) - (1-\alpha^c)p^{E,c}_{t+1}y^{E,c}_{t+1}(i) - R^{E,c}_t b^{E,c}_t(i) + q^{k,c}_{t+1}(1-\delta^c)k^{E,c}_t(i)\} \\ &= E_t\left\{\left[\alpha^c\frac{p^{E,c}_{t+1}y^{E,c}_{t+1}(i)}{k^{E,c}_t(i)} - R^{E,c}_t\chi^c_t + q^{k,c}_{t+1}(1-\delta^c)\right]k^{E,c}_t(i)\right\}, \end{aligned}$$

which is the period-$t+1$ version of equation 6.9. Using this expression, the entrepreneurial budget constraint can be simplified, such that

$$E_t\{c^{E,c}_{t+1}(i)\} + q^{k,c}_t k^{E,c}_t(i) = NW^c_t(i) + \chi^c_t k^{E,c}_t(i). \tag{C.1.13}$$

We guess that next period's entrepreneurial consumption is a fraction of net worth,

$$E_t\{c^{E,c}_{t+1}(i)\} = (1-\beta^c_E)E_t\{NW^c_{t+1}(i)\},$$

and by using equation C.1.13 and the guess we get

$$\begin{aligned} E_t\{c^{E,c}_{t+1}(i)\} &= (1-\beta^c_E)E_t\left\{\left[\alpha^c\frac{p^{E,c}_{t+1}y^{E,c}_{t+1}(i)}{k^{E,c}_t(i)} - R^{E,c}_t\chi^c_t + q^{k,c}_{t+1}(1-\delta^c)\right]\right\}k^{E,c}_t(i) \\ \Leftrightarrow E_t\{c^{E,c}_{t+1}(i)\} &= (1-\beta^c_E)E_t\left\{\left[\frac{E_t\{c^{E,c}_{t+1}(i)\}(q^{k,c}_t-\chi^c_t)}{\beta^c_E c^{E,c}_t(i)}\right]\right\}k^{E,c}_t(i) \\ \Leftrightarrow k^{E,c}_t(i) &= \frac{\beta^c_E c^{E,c}_t(i)}{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t)}. \end{aligned}$$

Plugging into the budget constraint yields the initial guess

$$c^{E,c}_t(i) + q^{k,c}_t\frac{\beta^c_E c^{E,c}_t(i)}{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t)} = NW^c_t + \chi^c_t\frac{\beta^c_E c^{E,c}_t(i)}{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t)}$$

$$\begin{aligned} \Leftrightarrow c^{E,c}_t(i)\left[1 + q^{k,c}_t\frac{\beta^c_E}{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t)} - \frac{\beta^c_E\chi^c_t}{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t)}\right] &= NW^c_t \\ \Leftrightarrow c^{E,c}_t(i)\left[\frac{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t) + q^{k,c}_t\beta^c_E - \beta^c_E\chi^c_t}{(1-\beta^c_E)(q^{k,c}_t-\chi^c_t)}\right] &= NW^c_t \\ \Leftrightarrow c^{E,c}_t(i) &= (1-\beta^c_E)NW^c_t \end{aligned}$$

depicting equation 6.10 which can be expressed equivalently as:

$$k_t^{E,c}(i) = \frac{\beta_E^c}{q_t^{k,c} - \chi_t^c} NW_t^c.$$

C.1.3 Bankers

Each period bankers invest equity into domestic ($n_t^{c,h}$) and foreign banks ($n_t^{c,f}$), and pay dividends div_t^c back to patient households. Equity investment and dividends are financed by bankers' net worth $n_t^{b,c}$. Following Gertler and Kiyotaki (2011), we guess and verify that the value function is linear in net worth, $V_t^{b,c} = \nu_t^c n_t^{b,c}$. Thus the maximization can be written in recursive form as:

$$n_t^{b,c}\nu_t^c = \max_{e_t^{aggr,c}, div_t^c} \left\{ div_t^c + E_t\{\Lambda_{t+1}^c[(1-\theta_b^c) + \theta_b^c \nu_{t+1}^c] n_{t+1}^{b,c}\} \right\} \tag{C.1.14}$$

$$s.t. \begin{cases} e_t^{aggr,c} + div_t^c = n_t^{b,c} \\ e_t^{aggr,c} = n_t^{c,c} + n_t^{c,\neg c} \\ n_{t+1}^{b,c} = \rho_{t+1}^c n_t^{c,c} + \rho_{t+1}^{\neg c} n_t^{c,\neg c} \\ div_t^c \geq 0. \end{cases}$$

1. <u>Shadow price of equity for bankers</u>:
   The dividend constraint binds in equilibrium, since it is not optimal to transfer dividends prior to retirement ($div_t^c = 0$). Thus, all net worth is invested in home and foreign banks, $e_t^{aggr,c} = n_t^{b,c}$. Using the the budget constraint

$$n_{t+1}^{b,c} = \rho_{t+1}^c n_t^{c,c} + \rho_{t+1}^{\neg c} n_t^{c,\neg c}$$

   in the value function of bankers yields

$$\begin{aligned} n_t^{b,c}\nu_t^c &= E_t\{\Lambda_{t+1}^c \left[(1-\theta_b^c) + \theta_b^c \nu_{t+1}^c\right] (\rho_{t+1}^c n_t^{c,c} + \rho_{t+1}^{\neg c} n_t^{c,\neg c})\} \\ \nu_t^c &= E_t\left\{ \Lambda_{t+1}^{b,c}(\rho_{t+1}^c \frac{n_t^{c,c}}{n_t^{b,c}} + \rho_{t+1}^{\neg c} \frac{n_t^{c,\neg c}}{n_t^{b,c}}) \right\} \\ \nu_t^c &= E_t\{\Lambda_{t+1}^{b,c}[\zeta_t^{n,c}\rho_{t+1}^c + (1-\zeta_t^{n,c})\rho_{t+1}^{\neg c}]\} \end{aligned}$$

where $\Lambda^{b,c}_{t+1} = \beta^c_p \frac{\lambda^c_{s,t+1}}{\lambda^c_{s,t}} \left[(1-\theta^c_b) + \theta^c_b \nu^c_{t+1}\right]$, and $\zeta^{n,c}_t = \frac{n^{c,c}_t}{n^{b,c}_t}$ denotes the degree of home bias for bankers' equity investment decisions.

2. Law of motion for bankers' net worth:

The law of motion for net worth is given by:

$$\begin{aligned} n^{b,c}_{t+1} &= \theta^c_b \left(n^{c,c}_t \rho^c_{t+1} + n^{c,\neg c}_t \rho^{\neg c}_{t+1}\right) + \chi_b(1-\theta^c_b)(n^{c,c}_t \rho^c_{t+1} + n^{c,\neg c}_t \rho^{\neg c}_{t+1}) \\ &= [\theta^c_b + \chi_b(1-\theta^c_b)](n^{c,c}_t \rho^c_{t+1} + n^{c,\neg c}_t \rho^{\neg c}_{t+1}) \end{aligned}$$

C.1.4 Corporate Banks

Corporate banks receive $e^c_t = n^{c,c}_t + RER_t n^{\neg c,c}_t = \zeta^c_e e^c_t + (1-\zeta^c_e)e^c_t$ units of equity from domestic and foreign investors. We denote the equity home bias on banks' balance sheets as ω^c_e. Banks maximize net present value (NPV), subject to a balance sheet constraint and a capital requirement constraint:

$$\max_{d^c_t, a^c_t} \int_0^\infty \Lambda^{tot,c}_{t+1} \max\{\omega^c_{t+1} R^{a,c}_{t+1} a^c_t - R^{c,d}_t d^c_t - \tau^{DI,c}_t, 0\} \mathrm{d}F_c(\omega^c_{t+1}) \\ - \zeta^c_e \nu^c_t e^c_t - (1-\zeta^c_e)\nu^{\neg c}_t e^c_t \quad \text{(C.1.15)}$$

$$s.t. \begin{cases} a^c_t = d^c_t + e^c_t \\ e^c_t \geq \phi^c_t a^c_t \\ a^c_t = b^{E,c}_t + q^{k,c}_{t+1} b^{g,c}_t. \end{cases}$$

Banks discount their expected NPV by weighting home and domestic bankers' discount factor with the corresponding amount of equities:

$$\begin{aligned} \Lambda^{tot,c}_{t+1} &= \frac{\zeta^c_e \Lambda^{b,c}_{t+1} e^c_t + (1-\zeta^c_e)\Lambda^{b,\neg c}_{t+1} e^c_t}{e^c_t} \\ &= \zeta^c_e \Lambda^{b,c}_{t+1} + (1-\zeta^c_e)\Lambda^{b,\neg c}_{t+1}. \end{aligned}$$

Each bank is hit by an idiosyncratic asset return shock ω^c_{t+1} that follows a log normal distribution. The equity investments $\zeta^c_e e^c_t$ and $(1-\zeta^c_e)e^c_t$ are valued at equilibrium opportunity cost ν^c_t and $\nu^{\neg c}_t$. If the asset return is sufficiently low after an adverse realization of the idiosyncratic shock, the bank defaults on its debt and obtains zero payoff.

Furthermore, the bank earns the average rate of return $R_t^{a,c}$ on total assets a_t^c. The average return depends on the return on corporate loans and government bonds:

$$
\begin{aligned}
&R_{t+1}^{a,c} a_t^c = R_{t+1}^{E,c} b_t^{E,c} + R_{t+1}^{gov,c} q_{t+1}^{k,c} b_t^{g,c} \\
&\Leftrightarrow R_{t+1}^{a,c} = \zeta_t^{a,c} R_{t+1}^{E,c} + (1-\zeta_t^{a,c}) R_{t+1}^{gov,c},
\end{aligned}
$$

with $\zeta_t^{a,c} = \frac{b_t^{E,c}}{a_t}$ and $R_{t+1}^{gov,c} = R_t^{rfr,c} + \phi_{debt}^c (b_t^{g,c} - b^{g,c})^2$, with the loan returns given by equation C.1.11. Since debt financing is always cheaper than equity financing, the capital constraint always binds:

$$
\begin{aligned}
a_t^c &= b_t^{E,c} + q_{t+1}^{k,c} b_t^{g,c} = \frac{e_t^c}{\phi_t^c} \\
d_t^c &= (1-\phi_t^c)\frac{e_t^c}{\phi_t^c}.
\end{aligned}
$$

Banks can default on their debt if the net asset return turns negative. Then, the constraint $\overline{\omega}_{t+1}^c R_{t+1}^{a,c} a_t^c - R_t^d d_t^c - \tau_t^{DI,c} = 0$ yields the threshold of bank default, $\overline{\omega}_{t+1}^c$:

$$
\overline{\omega}_{t+1}^c = \frac{R_t^{d,c} d_t^c}{R_{t+1}^{a,c} a_t^c} + \frac{\tau_t^{DI,c}}{R_{t+1}^{a,c} a_t^c} = (1-\phi_t^c)\left(\frac{R_t^{d,c}}{R_{t+1}^{a,c}} + \frac{\tau_t^{DI,c}}{R_{t+1}^{a,c} d_t^c}\right).
$$

The bank problem can be rewritten by replacing a_t^c and d_t^c and by splitting the integral:

$$
\begin{aligned}
NPV_{b,t} &= \int_0^{\overline{\omega}_{t+1}^c} \Lambda_{t+1}^{tot,c} 0 \mathrm{d}F_c(\omega_{t+1}^c) \\
&+ \int_{\overline{\omega}_{t+1}^c}^{\infty} \Lambda_{t+1}^{tot,c} \{\omega_{t+1}^c R_{t+1}^{a,c} a_t^c - (R_t^{d,c} + \tau_t^{DI,c}) d_t^c\} \mathrm{d}F_c(\omega_{t+1}^c) - [\zeta_e^c \nu_t^c + (1-\zeta_e^c)\nu_t^{\neg c}] e_t^c \\
&= \int_{\overline{\omega}_{t+1}^c}^{\infty} \Lambda_{t+1}^{tot,c} \left\{\omega_{t+1}^c R_{t+1}^{a,c} \frac{e_t^c}{\phi_t^c} - (R_t^{d,c} + \tau_t^{DI,c})(1-\phi_t^c)\frac{e_t^c}{\phi_t^c}\right\} \mathrm{d}F_c(\omega_{t+1}^c) - \\
&- [\zeta_e^c \nu_t^c + (1-\zeta_e^c)\nu_t^{\neg c}] e_t^c \\
&= \left(\Lambda_{t+1}^{tot,c} \frac{R_{t+1}^{a,c}}{\phi_t^c} \int_{\overline{\omega}_{t+1}^c}^{\infty} \{\omega_{t+1}^c - \overline{\omega}_{t+1}^c\} \mathrm{d}F_c(\omega_{t+1}^c) - \zeta_e^c \nu_t^c - (1-\zeta_e^c)\nu_t^{\neg c}\right) e_t^c,
\end{aligned}
$$

where the integral can be written as:[1]

$$
\begin{aligned}
&\int_{\overline{\omega}^c_{t+1}}^{\infty} \omega^c_{t+1} \mathrm{d}F_c(\omega^c_{t+1}) - \int_{\overline{\omega}^c_{t+1}}^{\infty} \overline{\omega}^c_{t+1} \mathrm{d}F_c(\omega^c_{t+1}) \\
\Leftrightarrow & E_t\{\omega^c_{t+1} | \omega^c_{t+1} \geq \overline{\omega}^c_{t+1}\} \mathbb{P}\{\omega^c_{t+1} \geq \overline{\omega}^c_{t+1}\} - \overline{\omega}^c_{t+1} \mathbb{P}\{\omega^c_{t+1} \geq \overline{\omega}^c_{t+1}\} \\
\Leftrightarrow & \frac{\left[1 - \Phi\left(\frac{\ln(\overline{\omega}^c_t) - \frac{(\sigma_c z^{b,c}_t)^2}{2}}{\sigma_c z^{b,c}_t}\right)\right]}{\left[1 - \Phi\left(\frac{\ln(\overline{\omega}^c_t) + \frac{(\sigma_c z^{b,c}_t)^2}{2}}{\sigma_c z^{b,c}_t}\right)\right]} \left[1 - \Phi\left(\frac{\ln(\overline{\omega}^c_t) + \frac{(\sigma_c z^{b,c}_t)^2}{2}}{\sigma_c z^{b,c}_t}\right)\right] - \overline{\omega}^c_{t+1}\left[1 - \Phi\left(\frac{\ln(\overline{\omega}^c_t) + \frac{(\sigma_c z^{b,c}_t)^2}{2}}{\sigma_c z^{b,c}_t}\right)\right] \\
\Leftrightarrow & 1 - \Phi\left(\frac{\ln(\overline{\omega}^c_t) - \frac{(\sigma_c z^{b,c}_t)^2}{2}}{\sigma_c z^{b,c}_t}\right) - \overline{\omega}^c_{t+1}\left[1 - \Phi\left(\frac{\ln(\overline{\omega}^c_t) + \frac{(\sigma_c z^{b,c}_t)^2}{2}}{\sigma_c z^{b,c}_t}\right)\right] \\
\Leftrightarrow & 1 - \Gamma_c(\overline{\omega}^c_{t+1}).
\end{aligned}
$$

Due to the contracting problem between patient households and banks, $1 - \Gamma_c(\overline{\omega}^c_{t+1})$ represents the net share the corporate bank receives, and $\Gamma_c(\overline{\omega}^c_{t+1})$ determines the patient household's gross share.

Finally, banks are only willing to provide loans as long as the NPV from intermediating funds is positive:

$$
E_t\left\{\Lambda^{tot,c}_{t+1}[1 - \Gamma_c(\overline{\omega}^c_{t+1})]\frac{R^{a,c}_{t+1}}{\phi^c_t}\right\} \geq \zeta^c_e \nu^c_t + (1 - \zeta^c_e)\nu^{\neg c}_t.
$$

In equilibrium, the above condition holds with equality to avoid an infinite supply of loans. By definition, the return on bank equity is given by $\rho^c_{t+1} = \left(1 - \Gamma_c(\overline{\omega}^c_{t+1})\right)\frac{R^{a,c}_{t+1}}{\phi^c_t}$. Consequently, the opportunity cost of equity funding is pinned down in equilibrium by the following condition:

$$
E_t\{\Lambda^{tot,h}_{t+1}\rho^h_{t+1}\} = \zeta^h_e \nu^h_t + (1 - \zeta^h_e)\nu^f_t
$$

and symmetrically by

$$
E_t\{\Lambda^{tot,f}_{t+1}\rho^f_{t+1}\} = \zeta^f_e \nu^f_t + (1 - \zeta^f_e)\nu^h_t.
$$

[1] See section C.1.4.

Finally, the quarterly default rate of banks can be defined as:

$$\psi_t^c = \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right).$$

Idiosyncratic Shocks to Returns

The idiosyncratic shocks in the model follow a log-normal distribution with $\ln(\omega_t^c) \sim N(-0.5\sigma_c^2, \sigma_c^2)$:

$$\begin{aligned}
E_t\{\omega_t^c | \omega_t^c \geq \overline{\omega}_t^c\} &= e^{-\frac{(\sigma_c z_t^{b,c})^2}{2} + \frac{(\sigma_c z_t^{b,c})^2}{2}} \frac{1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2} - (\sigma_c z_t^{b,c})^2}{\sigma_c z_t^{b,c}}\right)}{1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)} \\
&= \frac{1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) - \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)}{1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)}
\end{aligned}$$

The expected share of deposits ending up in default in the next period is defined as:

$$\begin{aligned}
G(\omega_{t+1}^c) &= E_t\{\omega_{t+1}^c | \omega_{t+1}^c < \overline{\omega}_{t+1}^c\} \mathbb{P}\{\omega_{t+1}^c < \overline{\omega}_{t+1}^c\} \\
&= \int_0^{\overline{\omega}_{t+1}^c} \omega_{t+1}^c f(\omega_{t+1}^c) d\omega_{t+1}^c \int_0^{\overline{\omega}_{t+1}^c} f(\omega_{t+1}^c) d\omega_{t+1}^c \\
&= \frac{\Phi\left(\frac{\ln(\overline{\omega}_t^c) - \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)}{\Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)} \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right) \\
&= \Phi\left(\frac{\ln(\overline{\omega}_t^c) - \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right).
\end{aligned}$$

The deposit contract guarantees that in the no-default case ($\omega_{t+1}^c \geq \overline{\omega}_{t+1}^c$), the bank pays a fixed rate of asset returns $\frac{\overline{\omega}_t^c R_t^{a,c}}{1-\phi_{t-1}^c} - \tau_{t-1}^{DI,c}$ to the households. The bank keeps the difference $(\omega_{t+1}^c - \overline{\omega}_{t+1}^c)\frac{R_t^{a,c}}{1-\phi_{t-1}^c} - \tau_{t-1}^{DI,c}$ for herself. In case of default ($\omega_{t+1}^c < \overline{\omega}_{t+1}^c$), the bank does not receive any return and the household pays a fraction μ_c for recovery. Thus, the household payoff is $(1-\mu_c)\left(\frac{\overline{\omega}_t^c R_t^{a,c}}{1-\phi_{t-1}^c} - \tau_{t-1}^{DI,c}\right)$. The gross share of deposits going to patient households is defined as:

$$\begin{aligned}
\Gamma(\overline{\omega}_t^c) &= \int_0^{\overline{\omega}_t^c} \omega_t^c f(\omega_t^c) d\omega_t^c + \overline{\omega}_t^c \int_{\overline{\omega}_t^c}^{\infty} f(\omega_t^c) d\omega_t^c \\
&= E_t\{\omega_t^c | \omega_t^c < \overline{\omega}_t^c\} \mathbb{P}\{\omega_t^c < \overline{\omega}_t^c\} + \overline{\omega}_t^c \mathbb{P}\{\omega_t^c \geq \overline{\omega}_t^c\} \\
&= \frac{\Phi\left(\frac{\ln(\overline{\omega}_t^c) - \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)}{\Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)} \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right) + \overline{\omega}_t^c \left[1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)\right] \\
&= \Phi\left(\frac{\ln(\overline{\omega}_t^c) - \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right) + \overline{\omega}_t^c \left[1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)\right].
\end{aligned}$$

Due to positive monitoring costs, the net share of returns from a diversified deposit portfolio patient households receive is given by:

$$\Gamma(\overline{\omega}_t^c) - \mu_c G(\omega_t^c) = \underbrace{\left(1-\mu_c\right)\Phi\left(\frac{\ln(\overline{\omega}_t^c) - \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)}_{\text{share of return under default}} + \underbrace{\overline{\omega}_t^c \left[1 - \Phi\left(\frac{\ln(\overline{\omega}_t^c) + \frac{(\sigma_c z_t^{b,c})^2}{2}}{\sigma_c z_t^{b,c}}\right)\right]}_{\text{share of return under no default}}.$$

With the threshold going to infinity in the limit, the net share of returns converges to $\lim_{\overline{\omega}_{t+1}^c \to \infty} \Gamma(\overline{\omega}_t^c) - \mu_c G(\omega_{t+1}^c) = 1 - \mu_c$.

C.1.5 National Deposit Insurance Fund

The national deposit insurance guarantees some fraction κ_t^c of deposits by building up a fund that compensates depositors in case of bank default. The deposit insurance fund balance is given by

$$DI_{t+1}^c = DI_t^c + \tau_t^{DI,c} - \kappa_t^c \Omega_{t+1}^c \tag{C.1.16}$$

where a share κ_t^c of the total default costs Ω_t^c is insured by the national DI in each country. Banks pay a contribution $\tau_t^{DI,c}$ to the fund, and the fund capital target is set relative to total outstanding deposits in the steady state:

$$DI_t^{target,c} = \gamma_{DI}^c d^c. \tag{C.1.17}$$

The costs of deposit default in each country are defined as the difference between forgone return on deposits, $R^{d,c}_{t-1}d^c_{t-1}$, and the share $(1-\mu^c)$ of gross assets $\omega^c_t R^{a,c}_t a^c_{t-1}$ that can be recovered, net of the contributions to the national DI:

$$\Omega^c_t = \int_0^{\overline{\omega}^c_t} \{R^{d,c}_{t-1}d^c_{t-1} - (1-\mu_c)\omega^c_t R^{a,c}_t a^c_{t-1} + \tau^{DI}_{t-1}\} f(\omega^c_t) d\omega^c_{t-1}. \tag{C.1.18}$$

From the banks' balance sheet and capital requirement constraint we get

$$d^c_{t-1} = (1-\phi^c_{t-1})a^c_{t-1}, \tag{C.1.19}$$

and from the default threshold:

$$R^{d,c}_{t-1} = \frac{\overline{\omega}^c_t R^{a,c}_t}{1-\phi^c_{t-1}} - \frac{\tau^{DI,c}_{t-1} R^{a,c}_t}{R^{a,c}_t d^c_{t-1}}, \tag{C.1.20}$$

we can rewrite the costs of default as:

$$\begin{aligned}
\Omega^c_t &= \int_0^{\overline{\omega}^c_t} \left\{ \left(\frac{\overline{\omega}^c_t}{1-\phi^c_{t-1}} - \frac{\tau^{DI,c}_{t-1}}{R^{a,c}_t d^c_{t-1}} \right) R^{a,c}_t (1-\phi^c_{t-1}) a^c_{t-1} - (1-\mu_c)\omega^c_t R^{a,c}_t a^c_{t-1} + \tau^{DI}_{t-1} \right\} f(\omega^c_t) d\omega^c_t \\
&= \int_0^{\overline{\omega}^c_t} \left\{ \overline{\omega}^c_t - \frac{\tau^{DI,c}_{t-1}(1-\phi^c_{t-1})}{R^{a,c}_t d^c_{t-1}} - (1-\mu_c)\omega^c_{t-1} + \frac{\tau^{DI}_{t-1}(1-\phi^c_{t-1})}{R^{a,c}_t d^c_{t-1}} \right\} f(\omega^c_t) d\omega^c_t R^{a,c}_t a^c_{t-1} \\
&= \left[\int_0^{\overline{\omega}^c_t} \overline{\omega}^c_t f(\omega^c_t) d\omega^c_t - (1-\mu_c) \int_0^{\overline{\omega}^c_t} \omega^c_t f(\omega^c_t) d\omega^c_t \right] R^{a,c}_t a^c_{t-1} \\
&= \left[\overline{\omega}^c_t \Phi\left(\frac{\ln(\overline{\omega}^c_t + \frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) - (1-\mu_c)\Phi\left(\frac{\ln(\overline{\omega}^c_t) - (\frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) \right] R^{a,c}_t a^c_{t-1} \\
&= \left[\overline{\omega}^c_t \Phi\left(\frac{\ln(\overline{\omega}^c_t + \frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) - \Phi\left(\frac{\ln(\overline{\omega}^c_t) - (\frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) + \mu_c \Phi\left(\frac{\ln(\overline{\omega}^c_t) - (\frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) \right] R^{a,c}_t a^c_{t-1} \\
&= \left[\overline{\omega}^c_t - \overline{\omega}^c_t + \overline{\omega}^c_t \Phi\left(\frac{\ln(\overline{\omega}^c_t + \frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) - \Phi\left(\frac{\ln(\overline{\omega}^c_t) - (\frac{(\sigma_c z^{b,c}_t)^2}{2})}{\sigma_c z^{b,c}_t} \right) + \mu_c G(\omega^c_{t+1}) \right] R^{a,c}_t a^c_{t-1} \\
&= [\overline{\omega}^c_t - \Gamma(\overline{\omega}^c_t) + \mu_c G(\omega^c_{t+1})] R^{a,c}_t a^c_{t-1}.
\end{aligned}$$

Finally, we get:

$$\Omega^c_t = [\overline{\omega}^c_t - \Gamma_c(\overline{\omega}^c_t) + \mu_c G_c(\overline{\omega}^c_t)] \frac{R^{a,c}_t}{1-\phi^c_{t-1}} d^c_{t-1}. \tag{C.1.21}$$

Banks contribute to the fund in each period by the amount $\tau_{t-1}^c d_t^c$, and the contribution rate is given by the following rule:

$$\tau_t^{DI,c} = \tau^{DI,c} + \chi_\tau^c [DI^{target,c} - E_t\{DI_{t+1}^c\}]. \tag{C.1.22}$$

Furthermore, whenever national fund capital is below target, the share of covered deposits is reduced:

$$\kappa_t^c = \kappa^c - \chi_\kappa^c [DI^{target,c} - DI_{t+1}^c]. \tag{C.1.23}$$

C.1.6 Capital Goods Producers

Competitive capital producers create new capital, repair depreciated capital, and are owned by saving households. Firms maximize profits by choosing investment I_t^c,

$$\max_{I_t^c} E_t \sum_{\tau=t}^{\infty} (\beta_p^c)^\tau \frac{\Lambda_{\tau+1}^c}{\Lambda_\tau^c} \left\{ (q_\tau^{k,c} - 1) I_\tau - f^c \left(\frac{I_\tau^c}{I_{\tau-1}^c} \right) I_\tau^c \right\}, \tag{C.1.24}$$

where $f(\cdot)^c$ denotes the functional form of investment adjustment costs, which, following Christiano et al. (2005), is given by:

$$\frac{\psi_i^c}{2} \left(\frac{I_t^c}{I_{t-1}^c} - 1 \right)^2 \tag{C.1.25}$$

ψ_i^c measures the inverse elasticity of net investments to changes in the price of capital $q_t^{k,c}$. The first order condition defines the price of capital as follows:

$$q_t^{k,c} = 1 + f_t^c(\cdot) + f_t^{c\prime}(\cdot) \frac{I_t^c}{I_{t-1}^c} - \beta_p^c E_t \left\{ \frac{\Lambda_{t+1}^c}{\Lambda_t^c} f_{t+1}^c{}'(\cdot) \left(\frac{I_{t+1}^c}{I_t^c} \right)^2 \right\} \tag{C.1.26}$$

C.1.7 Market Clearing

International Goods Market

In each country perfectly competitive firms produce the final demand by aggregating a continuum of domestically produced an imported goods for households, entrepreneurs and capital producer. The aggregate demand bundle for domestic households, entrepreneurs and capital producers is compound by the following technology:[2]

$$x_t^c = \left[(\zeta^c)^{\frac{1}{\eta^c}} (x_t^{c,c})^{\frac{\eta^c-1}{\eta^c}} + (1-\zeta^c)^{\frac{1}{\eta^c}} (x_t^{c,\neg c})^{\frac{\eta^c-1}{\eta^c}} \right]^{\frac{\eta^c}{\eta^c-1}}, \tag{C.1.27}$$

where x_t^c is a placeholder for household and entrepreneurs consumption demand ($c_t^{p,c}$, $c_t^{E,c}$) and capital producers investment demand (I_t^c). $\zeta_c > 0$ measures the degree of openness of the final good, the fraction of goods produced in the foreign economy. η^c denotes the elasticity of substitution between home- and foreign-produced goods. From the profit maximization of the final good produces we can derive the optimal demand functions for home and imported goods:

$$x_t^{c,c} = \zeta^c (p_t^{e,c})^{-\eta^c} x_t^c \tag{C.1.28}$$

$$x_t^{c,\neg c} = (1-\zeta^h)(p_t^{e,c} T_t)^{-\eta^c} x_t^c \tag{C.1.29}$$

Following Benigno (2004), the terms of trade are foreign producer prices relative to domestic producer prices: $T_t = \frac{P_t^{e,f}}{P_t^{e,h}}$. National government consumption g_t is assumed to be produced only by national firms. The clearing condition guarantees that the supply of domestically produced goods is equal to domestic and foreign demand.

The real exchange rate can be defined with the help of the terms of trade and the relative consumer prices in both countries:

$$RER_t = T_t \frac{p_t^{e,h}}{p_t^{e,f}}. \tag{C.1.30}$$

In both regions the goods markets clearing condition hold in equilibrium:

$$y_t^{E,c} = Y_t^c = \zeta^c (p_t^{e,c})^{-\sigma^c} c_t^c + g_t^c + (1-\zeta^{\neg c}) \left(\frac{p_t^{e,\neg c}}{T_t} \right)^{-\sigma^{\neg c}} c_t^{\neg c} \tag{C.1.31}$$

where $c_t^c = c_t^{P,c} + c_t^{E,c} + I_t^c$ denotes the aggregate demand for consumption and investment goods of domestic households and entrepreneurs and $c_t^{\neg c}$ denotes the aggregate demand of foreign households and entrepreneurs. The trade balance - measured in domestic prices - is defined as difference between real exports and real imports:

$$tb_t = ex_t^h + T_t im_t^h, \tag{C.1.32}$$

with $ex_t^h = c_t^{P,fh} + c_t^{E,fh} + I_t^{fh}$ and $im_t^h = c_t^{P,hf} + c_t^{E,hf} + I_t^{hf}$.

[2] From the perspective of the foreign economy the consumption bundle aggregation is structurally equal.

International Financial Market

Market clearing on the international financial market implies that the supplied equity from bankers have to satisfied the demand for equity for both domestic and foreign banks:

$$e_t^h = n_t^{h,h} + \frac{1}{RER_t} n_t^{f,h}, \tag{C.1.33}$$

$$e_t^f = n_t^{f,f} + RER_t n_t^{h,f}. \tag{C.1.34}$$

Further, since bankers will not pay dividends prior retirement, invested equity has to match total bankers net worth:

$$n_t^{b,h} = n_t^{h,h} + n_t^{h,f}, \tag{C.1.35}$$

$$n_t^{b,f} = n_t^{f,f} + n_t^{f,h}. \tag{C.1.36}$$

Shock Processes

Household Preference Shock:

$$z_t^{c,c} = (1 - \rho_c^c) z^{c,c} + \rho_c^c z_{t-1}^{c,c} + \epsilon_t^c \tag{C.1.37}$$

Productivity Shock:

$$a_t^{E,c} = (1 - \rho_a^c) a^{E,c} + \rho_a^c a_{t-1}^{E,c} + \epsilon_t^a \tag{C.1.38}$$

Bank Risk Shock:

$$z_t^{b,c} = (1 - \rho_b^c) z^{b,c} + \rho_b^c z_{t-1}^{b} + \epsilon_t^b \tag{C.1.39}$$

Government Consumption Shock:

$$g_t^c = (1 - \rho_g^c) g^c + \rho_g^c g_{t-1}^c + \epsilon_t^g \tag{C.1.40}$$

C.2 Appendix: Data

Real GDP: Real gross domestic product, euro area 19 (fixed composition) and Germany, deflated using GDP deflator (index), calendar and seasonally adjusted data (National accounts, Main aggregates (Eurostat ESA2010)).

Government consumption: Real government consumption, euro area and Germany, deflated using GDP deflator (index=2015), calendar and seasonally adjusted data (National accounts, Main aggregates (Eurostat ESA2010)).

Real exports of goods and services: Exports of goods and services, Germany, chain-linked volumes, calendar and seasonally adjusted data (national accounts, main aggregates (Eurostat ESA2010)).

Real imports of goods and services: Imports of goods and services, Germany, chain-linked volumes, calendar and seasonally adjusted data (national accounts, main aggregates (Eurostat ESA2010)).

Current account balance: Current account balance as percentage of GDP, euro area 19 (fixed composition) and Germany (OECD Main Economic Indicators data base).

Real business investment: Real gross fixed capital formation (GFCF) of non-financial corporations, euro area 19 (fixed composition), deflated using GDP deflator (index=2015), calendar and seasonally adjusted data (national accounts, main aggregates (Eurostat ESA2010)).

Total employment: Total employment in persons, total economy, all activities, euro area 19 (fixed composition) and Germany, calendar and seasonally adjusted data (national accounts, employment (Eurostat ESA2010)).

GDP Deflator: Euro area: Price level is based on HICP inflation, index year 2015, euro area 19 (fixed composition), calendar and seasonally adjusted data (Indices of Consumer prices, (Eurostat)). Germany: Price level is based on HICP inflation, index year 2015, calendar and seasonally adjusted data (Statistisches Bundesamt).

Total government bond holdings: Euro area and Germany: Holdings by euro area MFIs (excluding central banks) of short- and long-term maturity debt securities issued by general government resident in EU countries, sample 1997:Q4 to 2019:Q1, changing composition, deflated using GDP deflator (index=2015), (national central banks, balance sheet items ECB SDW).

Corporate bank loans: Real outstanding amounts of commercial bank (MFIs excluding ESCB) loans to non-financial corporations, euro area (changing composition), deflated using HICP, calendar and seasonally adjusted data.

Corporate bank deposits: Real deposits placed by euro area households (overnight deposits, with agreed maturity up to two years, redeemable with notice up to 3 months), outstanding amounts, euro area (changing composition), deflated using HICP, calendar and seasonally adjusted data.

Bank equity holdings by home and foreign investors: Positions held by domestic shareholder to total positions held by euro area residents, all bank entities in the euro area and Germany directly supervised by the ECB (Shareholders Report, Thomson Reuters Eikon).

Share of deposits covered by deposit insurance: Share of deposits covered by national insurance scheme, annual data 2011 to 2015, euro area 19 (GDP-weighted average) and Germany (JRC European Union Banking Statistics).

Bank default rates: Expected bank default based on credit default swap spreads. Expected defaults are calculated by authors using the CDS spreads and US 5y-treasury yields as a proxy for the risk-free rate. We include all bank entities in the euro area and Germany directly supervised by the ECB (Datastream for CDS spread).

Bank equity returns: Return on equity in percent, deposit takers, euro area 19 (Financial Soundness Indicators, IMF).

Bank price-to-book ratios: Euro area: Price-to-book ratio for European banks based on the "EURO STOXX Banks" index, sample 1998:Q4 to 2019:Q1 (Bloomberg). Germany: Price-to-book ratio of German banks based on (1) a weighted average of P/B ratios of German banks (before 2003:Q1) and (2) the "DAX SECTOR BANKS" index, sample 1999:Q4 to 2019:Q1 (from 2003:Q1, both Bloomberg).

Interest rate on corporate bank loans: Annualized agreed rate (AAR) on commercial bank loans to non-financial corporations with maturity over one year, euro area (changing composition), new business coverage. Before 2003: Retail interest Rates Statistics (RIR), not harmonized data. Starting 2003:Q1: MFI Interest Rate Statistics (MIR), harmonized data.

Interest rate on corporate bank deposits: Commercial bank interest rates on household deposits, weighted rate from rates on overnight deposits, with agreed maturity up to two years, redeemable at short notice (up to three months), euro area (changing composition), new business coverage. Before 2003: Retail interest Rates Statistics (RIR), not harmonized data. Starting 2003:Q1: MFI Interest Rate Statistics (MIR), harmonized data.

United States 5-year yields on treasuries: 5-year nominal yields on US treasuries. Proxy for the nominal risk-free rate used in the calculation of bank default rates from CDS spreads. (Board Of Governors of the Federal Reserve System).

United States real long-term treasury yields: Long-term real rate average on outstanding TIPS with maturities of more than 10 years (US Department of the Treasury).

Erklärung gem. §4 Abs. 2

Hiermit erkläre ich, dass ich mich noch keinem Promotionsverfahren unterzogen oder um Zulassung zu einem solchen beworben habe, und die Dissertation in der gleichen oder einer anderen Fassung bzw. Überarbeitung einer anderen Fakultät, einem Prüfungsausschuss oder einem Fachvertreter an einer anderen Hochschule nicht bereits zur Überprüfung vorgelegen hat.

Stefan Gebauer
Berlin, 20. Mai 2020

Erklärung gem. §10 Abs. 3

Hiermit erkläre ich, dass ich für die Dissertation folgende Hilfsmittel und Hilfen verwendet habe:

- Matlab R2018b
  - Optimization Toolbox
  - Statistics Toolbox
  - Econometrics Toolbox
  - Financial Toolbox
  - Panel Data Toolbox
  - Dynare Toolbox
  - RISE Toolbox
- Microsoft Office
- Stata 13
- EViews 9
- LaTeX
- Siehe auch Literatur- und Quellenangaben

Auf dieser Grundlage habe ich die Arbeit selbstständig verfasst.

Stefan Gebauer
Berlin, 20. Mai 2020