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The Role of Shadow Banking for Financial Regulation

Stefan Gebauer*, Falk Mazelis†

PRELIMINARY DRAFT

February 28, 2018

Abstract

Macroprudential policies for financial institutions have received increasing prominence since the global financial crisis. These 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. For this purpose, we develop a DSGE model that differentiates between regulated, monopolistically 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. In a counterfactual analysis we compare how a macroprudential policy implemented before the crisis on all financial institutions, or just on commercial banks, would have dampened the leverage cycle.

JEL: E12, E61, F45, G23, G28

Keywords: Macroprudential Regulation, Shadow Banking, Financial Frictions

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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, in addition to supervising single financial institutions separately¹. Such a *macroprudential* approach towards financial regulation should focus on systemic developments in financial markets like swings in aggregate credit or financial market volatility, as well as on the role of financial cycles for business cycle movements².

Recently, the regulatory landscape has been changing dramatically with respect to macroprudential supervision. In most advanced economies, new institutions being responsible for macroprudential oversight and the design of adequate policy tools to counteract systemic risks evolving within financial sectors have been installed³. Furthermore, macroprudential policies depict core elements of recently implemented policy frameworks. For instance, the rules on banking regulation laid down in the latest round of Basel accords on banking regulation (*Basel III*) strongly focus on supervisory and regulatory tools that focus on macro developments in credit and risk-taking, such as rules on interbank lending, cyclical adjustments of capital requirements, and supervision on bank interconnectedness.

In this study, we will discuss the impact of non-bank financial intermediation, or more precisely, the role the *shadow banking sector* plays for financial regulation. Shadow banks, in our view, depict a set of diverse institutions conducting highly specialized tasks in the financial system. However, on an aggregate level, the shadow banking sector intermediates funds from savers to borrowers in a similar fashion as the traditional retail banking system. Given the diverse nature of financial firms involved in shadow bank credit intermediation, their regulation does not fall neatly into the court of any one regulatory authority. This might make consistent and comprehensive regulation more difficult to attain. Since shadow banks might take up some of the lending that banks have been

¹See [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.

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

³The EU-based European Systemic Risk Board (ESRB), the US Financial Stability Oversight Council (FSOC), and the Bank of England's Financial Policy Committee depict prominent examples of newly implemented institutions.

prohibited from extending due to macroprudential policies⁴, this is crucial.

We derive a dynamic stochastic general equilibrium (DSGE) model with savers and borrowers, and two types of financial institutions intermediating funds between these two groups: traditional banks and shadow banks. We then apply Bayesian techniques and rely on economic and financial data for the euro area to estimate our model. Finally, we discuss how the presence of intermediation via shadow banks can affect the setting of macroprudential policy, which is not directly enforceable on all financial intermediaries. The explicit policy tool we consider in this study are capital requirements that regulators can pose on the conventional banking system, as they play a predominant role in current regulatory approaches, such as the Basel accords. Under Basel III, capital requirements depict a key macroprudential tool regulators can apply to the commercial banking system to prevent banks from excessive leverage and risk-taking. A countercyclical requirement can be raised by regulators to avoid excessive credit growth in boom times, and can conversely be lowered whenever credit developments are subdued.

Evidence on the effectiveness of macroprudential regulation in general, as well as on the relative advantage of different policy tools is still relatively scarce. In particular, the role of heterogeneity in the financial sector for both the design of effective macroprudential policies and for the interaction of respective tools with other policy areas has not sufficiently been evaluated so far. However, heterogeneity in financial intermediaries' behavior, in combination with a varying degree of regulatory coverage of different financial market corporations, might have far-reaching implications for an adequate design of policy frameworks. We test whether macroprudential rules applied to shadow banks can stabilize credit cycles, which may ultimately increase welfare.

In the following section, we review the literature on both the current state of financial market-augmented macroeconomic models and on studies evaluating macroprudential regulation and coordination with other policy areas. We then introduce a simplified two-period version of our model to highlight the key mechanisms in Section 3, before we turn to the full-fledged DSGE model in Section 4. Sections 5 and 6 introduce the data we use and discuss the econometric procedure we employ to derive estimates of key parameters of the model. In Section 7, we use our model to simulate the effects of neglecting shadow bank intermediation in macroprudential policy, before we conclude in Section 8.

⁴See Cizel et al. (2016)

2 Literature

In response to accusations of having neglected the role of financial markets for economic stability prior to the global financial crisis, a literature on DSGE models including financial intermediaries and frictions has emerged. The approach developed in [Gertler and Karadi \(2011\)](#) and [Gertler and Kiyotaki \(2011\)](#) depicts one of the earliest frameworks for incorporating financial intermediaries in otherwise standard dynamic stochastic general equilibrium (DSGE) models. In the former study, the authors implement a financial intermediary transferring funds between households and non-financial firms in a monetary DSGE framework as developed in [Christiano et al. \(2005\)](#) and [Smets and Wouters \(2007\)](#). They incorporate financial frictions modeled as an agency problem arising between banks and households by allowing banks to divert household funds away from investment projects for private benefit. Given that households are aware of potential misconduct, the ability of banks to obtain funding via deposits is limited. Ultimately, the study shows that shocks to capital quality can turn out to be more pronounced in terms of output decline when such frictions in financial intermediation are included in the model, providing scope for unconventional credit market interventions by central banks. In [Gertler and Kiyotaki \(2011\)](#), the framework is augmented by allowing for liquidity risk as described in [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.

Another strand of macro models incorporating frictions in the intermediation of funds between borrowers and lenders focuses on the role of collateral borrowers have to place with lenders in return for funding. [Iacoviello \(2005\)](#); ? introduce housing as collateral and relate the amount of borrowing undertaken by impatient households to movements in the value of collateral. According to an additionally introduced collateral constraint borrowers face, adverse developments in housing markets as well as changes in exogenously determined loan-to-value ratios can limit the amount of lending and affect consumption and investment in the economy. Extending the approach, [Gerali et al. \(2010\)](#) introduce a banking sector in a canonical New Keynesian 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. 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.

Several other approaches for incorporating financial frictions in macro models have been proposed. Relying on early contributions by [Holström and Tirole \(1997\)](#), some studies incorporate agency problems on both sides of the credit intermediation market⁵. In these frameworks, a moral hazard problem arises on the demand side of credit (between the banks and entrepreneurs) as entrepreneurs can divert funds received by banks away from investment activities to derive private benefits due to the costs of monitoring the bank faces. In addition, another agency problem arising on the supply side of funds (between banks and depositors) constrains households from detecting whether financial intermediaries are effectively monitoring investment activities of firms. By now, banking-augmented infinite horizon models are frequently employed in the evaluation of different aspects of financial stability, such as the mechanics of bank runs⁶ or the effectiveness of (un-)conventional fiscal and monetary policies in times of financial distress⁷.

Turning to the role of financial intermediaries for macroprudential regulation, [Angelini et al. \(2014\)](#) implement collateral constraints and a macroprudential policy maker adjusting capital requirements according to a simple rule in addition to the central bank in an estimated euro area New Keynesian model. They find that macroprudential policy is particularly effective in times of financial distress, i.e. when shocks affecting credit supply hit the economy, compared to "normal times" where aggregate supply shocks appear to be more relevant. By employing a modeling framework based on the [Holström and Tirole \(1997\)](#) intermediation setup with rule-based policy makers in place, [Christensen et al. \(2011\)](#) find that strongly countercyclical regulatory policy can have beneficial stabilization properties relative to time-invariant regulation when the economy faces shocks originating in the banking sector.

Some studies furthermore evaluate the optimal degree of coordination between macroprudential policy makers and monetary policy. [Angeloni and Faia \(2013\)](#) use a banking-augmented DSGE model to evaluate rule-based monetary policies and capital regulation. Within a class of simple policy rules, the best combination includes countercyclical capital ratios and a response of monetary policy to asset prices or bank leverage. [Gelain and Ilbas \(2014\)](#) estimate a version of the [Smets and Wouters \(2007\)](#) New Keynesian DSGE

⁵See [Chen \(2001\)](#), [Meh and Moran \(2010\)](#), [Christensen et al. \(2011\)](#), or [Silvo \(2015\)](#).

⁶See for instance [Gertler and Kiyotaki \(2015\)](#); [Gertler et al. \(2016\)](#).

⁷See for instance [Gertler and Karadi \(2011\)](#) or [Cúrdia and Woodford \(2010a,b, 2011\)](#).

model augmented by a [Gertler and Karadi \(2011\)](#) financial intermediary framework for US data. In addition to an inflation-targeting central bank, they introduce a macroprudential regulator adjusting a tax/subsidy on bank capital according to a simple policy rule aiming at stabilizing both nominal credit growth and the output gap. As they find, a higher weight on output gap stabilization (the joint policy objective of both policy makers) by the macroprudential regulator results in coordination to be beneficial for reducing macroeconomic volatility. However, increasing the focus on credit growth stabilization relative to output increases the benefits of a non-cooperative setup for the macroprudential regulator, whereas the central bank performs worse in the absence of coordination. In a similar approach, [Bean et al. \(2010\)](#) rely on a model incorporating a [Gertler and Karadi \(2011\)](#) banking setup to study policy rules based on quadratic loss functions, with the physical capital gap being the financial stability objective. They 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 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 model.

All of the above studies rely on ad-hoc specified macroprudential policy rules in their models. However, first attempts have been initiated to assess the optimal degree of policy coordination by deriving jointly optimal Ramsey policies instead of implementing rule-based policies alone. [Collard et al. \(2014\)](#) focus on different types of lending instead of volumes alone and study jointly Ramsey-optimal monetary and macroprudential policies in a New Keynesian banking model. In the framework, limited liability and deposit insurance cause excessive risk-taking in the financial sector. [Silvo \(2015\)](#) uses a New Keynesian framework augmented by [Holström and Tirole \(1997\)](#) to evaluate Ramsey-optimal policies. 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 macro models described so far, the financial sector is treated in a representative-agent manner. Only recently, focus has shifted towards allowing for heterogeneity among financial intermediaries in infinite horizon models. In a recent study,

[Gertler et al. \(2016\)](#) augment the canonical [Gertler and Karadi \(2011\)](#) framework by replacing the representative intermediary by a bipolar banking system consisting of wholesale as well as retail banks. In their model, wholesale banks representing the shadow banking part of the financial system exclusively engage in interbank borrowing to fund loans, whereas retail banks follow a more traditional business model by collecting household deposits to lend to both the wholesale and the non-financial sector⁸. By abstracting from the production side of the economy, the authors use the three-sector model to study both anticipated and unanticipated bank runs on the wholesale sector. They use a calibrated model and show how the interaction between shadow banks and commercial banks through markets for securitized assets can affect dynamics in credit and that securitization in combination with high leverage in the shadow banking sector can have adverse effects on macroeconomic stability. Similar to our study, [Verona et al. \(2013\)](#) develop a model where shadow banks directly engage in intermediation of funds between households and firms. In contrast to our model, they assume shadow banks to act under monopolistic competition to derive a positive spread between lending rate of shadow banks and the risk-free rate⁹. 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 investment-fund based financial system can mitigate the drop in GDP during recessions, particularly when the economy is stuck at the zero lower bound of nominal interest rates (ZLB).

Similar to our study, [Begenau and Landvoigt \(2016\)](#) and [Fève and Pierrard \(2017\)](#) employ macroeconomic models to evaluate how the existence of shadow banks can alter the effectiveness of capital requirements as proposed by the Basel frameworks. In the former study, a general equilibrium model calibrated to the US economy and featuring both shadow and commercial banks is used to show that tightening regulation for commercial banks can result in a shift of intermediation away from safer commercial banks towards unregulated and more fragile shadow banking institutions, such that the net benefit of raising capital requirements for commercial banks only depends on the initial level of fragility in the financial system. [Fève and Pierrard \(2017\)](#) estimate a real business cycle model fea-

⁸The notion of a wholesale banking sector has already been introduced in [Gertler and Kiyotaki \(2015\)](#). Furthermore, [Gertler and Kiyotaki \(2011\)](#) already discuss interbank borrowing. However, no distinct separation between wholesale and retail banks has been undertaken in these studies.

⁹In our model, the positive spread emerges from the relatively higher default risk the saver faces when placing funds with shadow banks compared to low-risk commercial bank deposits.

turing both commercial and shadow banks with US data and, like [Begenau and Landvoigt \(2016\)](#), identify a leaking of intermediation towards shadow banks and conclude that the intended overall stabilizing effect of higher capital requirements for commercial banks can be dampened when more funds are channelled via the shadow banking sector.¹⁰

3 Two-Period Model

3.1 Benchmark Model

In the following, we present a stripped-down version of our DSGE model to explain the key mechanism, i.e. the effects of regulatory changes and the interplay of the two intermediaries, shadow and commercial banks.¹¹ The complete model presented in Section ?? 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.

3.1.1 Savers

There is an infinite amount of identical savers¹² that use resources for consumption of real goods.¹³ The saver can transfer consumption from the first to the second period by

¹⁰Alternative microfoundations for the leakage of credit towards shadow bank institutions in response to rising capital requirements were derived in the theoretical banking literature. See for instance [Plantin \(2015\)](#), [Harris et al. \(2014\)](#), or [Ordonez \(2013\)](#).

¹¹The 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](#).

¹²In our full model, savers will be households and borrowers will be firms.

¹³In this version of the model, we abstract from nominal price changes, such that all variables and interest rates are expressed in real terms here.

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 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

$$c + d^c + d^s \leq y \quad (1)$$

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 by an initial endowment of output, 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^-), as shadow bank deposits default. The second-period budget constraint in case of full repayment is thus given by

$$C^+ \leq (1 + r^{dc})d^c + (1 + r^{ds})d^s \quad (2)$$

and in case of shadow bank deposit default by

$$C^- \leq (1 + r^{dc})d^c \quad (3)$$

where

$$1 + r^{ds} \equiv \frac{1 + r^{dc}}{1 - \tau^s} \quad (4)$$

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

$$\max_{c, C^+, C^-, d^c, d^s} u(c) + \beta^s [pu(C^+) + (1 - p)u(C^-)] \quad (5)$$

where β^s depicts the discount factor savers apply.

Theorem 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

See [A.0.1](#) for details.

We exclude cases of a negative deposit ratio, i.e. $\frac{d^s}{d^c} \geq 0$.

Theorem 2: The deposit rate spread τ^s is thus 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. See [A.0.2](#) for details.

Theorem 3: The saver always consumes a fixed share of endowment y in the first period, which depends only on the discount factor β^s . See [A.0.3](#) for details.

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 .

We know from the first-order condition for shadow bank deposits that

$$C^+ = c\beta^s p(1 + r^{ds})$$

such that

$$C^+ = \beta^s p(1 + r^{ds})y\left(\frac{1}{1 + \beta^s}\right) \quad (6)$$

Using equation [69](#), we finally get

$$C^- = \frac{1-p}{p} \frac{1+r^{dc}}{r^{ds}-r^{dc}} C^+$$

such that

$$C^- = \frac{(1-p)(1+r^{dc})}{r^{ds} - r^{dc}} \beta^s (1+r^{ds}) y \left(\frac{1}{1+\beta^s} \right) \quad (7)$$

3.1.2 Borrowers

Borrowers fund consumption in period one by taking up loans from either commercial or shadow banks, whereas 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

$$c^b \leq \underbrace{b^c + b^s}_b \quad (8)$$

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,

$$C^b + (1+r^b)b \leq y^b. \quad (9)$$

The maximization problem of the borrower is given by

$$\max_{c^b, C^b, b^c, b^s} u(c^b) + \beta^b u(C^b) \quad (10)$$

Theorem 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. 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. Also, period-one consumption decreases in the lending rate r^b and in the discount factor β^b . See [A.1](#) for details.

3.1.3 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 will first derive the frictionless benchmark case in which both banks act under perfect competition, with the only difference between the two banks being given by the degree of regulatory coverage. We will then introduce a financial friction to the shadow banking sector leading to potentially positive returns on shadow bank intermediation.

3.1.4 Commercial Banks

In this version of the model, there is a continuum of commercial banks that operate under perfect competition and fund their lending to borrowers b^c with bank net worth n^c and savers' deposits d^c . 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 representative commercial bank thus faces two constraints it has to take into account when maximizing the discounted sum of real cash flow:

$$b^c = n^c + d^c \quad (11)$$

$$c^b = \frac{\kappa}{2} \left(\frac{n^c}{b^c} - \nu \right)^2 n^c \quad (12)$$

The first constraint 11 describes the balance sheet constraint, whereas the second constraint 12 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 bank chooses deposits and loans to maximize the discounted sum of real cash flow, taking both constraints into account:

$$\max_{d^c, b^c} r^b b^c - r^{dc} d^c - \frac{\kappa}{2} \left(\frac{n^c}{b^c} - \nu \right)^2 (b^c - d^c). \quad (13)$$

First-order conditions give

$$r^b - r^{dc} = -\kappa \left(\frac{n^c}{b^c} - \nu \right) \left(\frac{n^c}{b^c} \right)^2 \quad (14)$$

The left-hand side of equation 14 depicts the spread between the lending and the borrowing rate and thus the marginal benefit from increasing lending, i.e. an increase of profits from one marginal unit of lending equal to the spread. The right-hand side depicts the marginal costs from doing so, given by an increase in the cost from deviating from ν . Thus, banks choose their loans and deposits until the marginal benefit from

increasing intermediation activity is equal to the marginal cost from deviating from the regulatory capital requirement. As the bank takes r^b , r^{dc} , κ , and ν as given, it reacts to both exogenous changes in the interest rate spread or the capital requirements by adjusting lending b^c in the short run, if we assume net worth n^c to be fix in the short run, i.e. in the two periods.

3.1.5 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 regulatory coverage, i.e. they 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” problem 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 :

$$b^s = n^s + d^s. \quad (15)$$

Like their regulated counterparts, they maximize their profits in period two, which are given by

$$\max_{d^s, b^s} (1 + r^b)b^s - (1 + r^{ds})d^s - b^s + d^s. \quad (16)$$

taking r^b and r^{ds} as given.

3.1.6 Benchmark Equilibrium

We are now able to define a benchmark equilibrium in which we assume both banks to be identical in their structure, such that the only difference between them is regulatory coverage, i.e. that 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, whereas shadow banks are unconstrained in their intermediation decisions. We will later 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 73 - 7 solve the saver problem
- (ii) Equations 80 - 82 solve the borrower problem
- (iii) Equations 11 and 14 solve the commercial bank problem
- (iv) The shadow bank problem 16 is solved, see below.
- (v) We furthermore have the securities market clearing condition

$$b = b^c + b^s \quad (17)$$

and

- (vi) condition 71 which has to hold such that negative values for deposits placed are excluded.

We now derive the equilibrium condition emerging from the shadow bank maximization problem given by equation 16. We derive this condition by making one further assumption about the exclusion of (uninteresting) corner solutions where we have either no or implausible 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 16 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 $r^b = r^{ds}$.

3.2 Financial Friction: Incentive Constraint

3.2.1 Shadow Banks

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 friction to the shadow banker's problem that will allow the shadow bank to earn a rent on intermediation activity. 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 worthwhile 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

$$(1 - \theta)(1 + r^b)b^s \geq (1 + r^{ds})d^s \quad (18)$$

Savers are aware of the potential moral hazard problem between them and the shadow banker, and thus they would not place any deposit d^s in a shadow bank whenever constraint 18 does not hold. If constraint 18 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 16 is thus changed to

$$\max_{d^s, b^s} (1 + r^b)b^s - (1 + r^{ds})d^s - b^s + d^s \quad (19)$$

subject to constraint 18.

3.2.2 Incentive Constraint Equilibrium

Introducing the moral hazard problem between savers and shadow banks changes the problem of the shadow banks and 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 73 - 7 solve the saver problem
- (ii) Equations 80 - 82 solve the borrower problem
- (iii) Equations 11 and 14 solve the commercial bank problem
- (iv) The shadow bank problem 19 is solved, see below.
- (v) We furthermore have the securities market clearing condition

$$b = b^c + b^s \quad (20)$$

and

- (vi) condition 71 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 18 such that

$$(1 - \theta)(1 + r^b)n^s \geq [\theta(1 + r^b) - (r^b - r^{ds})]d^s \quad (21)$$

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 73. Furthermore, we know that $r^b = r^{ds}$. Plugging in the derived term for d^s in equation 21 therefore yields

$$(1 - \theta)(1 + r^b) \geq [\theta(1 + r^b) - (r^b - r^{ds})] \frac{\beta^s}{1 + \beta^s} \frac{(1 + r^{ds})p - (1 + r^{dc})}{r^{ds} - r^{dc}} \frac{y}{n^s}$$

Define

$$B \equiv \frac{\beta^s}{1 + \beta^s} \frac{(1 + r^{ds})p - (1 + r^{dc})}{r^{ds} - r^{dc}} \frac{y}{n^s}$$

such that

$$(1 - \theta)(1 + r^b) \geq [\theta(1 + r^b) - (r^b - r^{ds})]B$$

and thus

$$0 \leq \theta \leq \frac{1}{1 + B} \quad (22)$$

Given our assumptions on the spread between the two deposit rates, equation 71, and on the non-negativity of model parameters 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 21 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 21 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 73, 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 21 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 73. 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 21. Solving the constraint for $d^{s,S}$ with equality gives:

$$d^{s,S} = \frac{(1 - \theta)(1 + r^b)}{r^{ds} - (1 - \theta)r^b + \theta} n^s \quad (23)$$

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

$$d^{s,S} \rightarrow \frac{1 - \theta}{\theta} n^s$$

We see from equation 23 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 in chapter 3.1.1. 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 73 and 23 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 73) with supply of deposits by shadow banks (equation 23) and solve for r^{ds} :

$$\frac{\beta^s}{1 + \beta^s} \frac{(1 + r^{ds})p - (1 + r^{dc})}{r^{ds} - r^{dc}} y = \frac{(1 - \theta)r^b}{r^{ds} - (1 - \theta)r^b} n^s \quad (24)$$

We can summarize our results for the incentive constraint friction case as:

Proposition 1. *Whenever condition 22 is satisfied, the incentive constraint friction and the benchmark equilibrium coincide. If condition 22 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.*

3.3 Evaluation

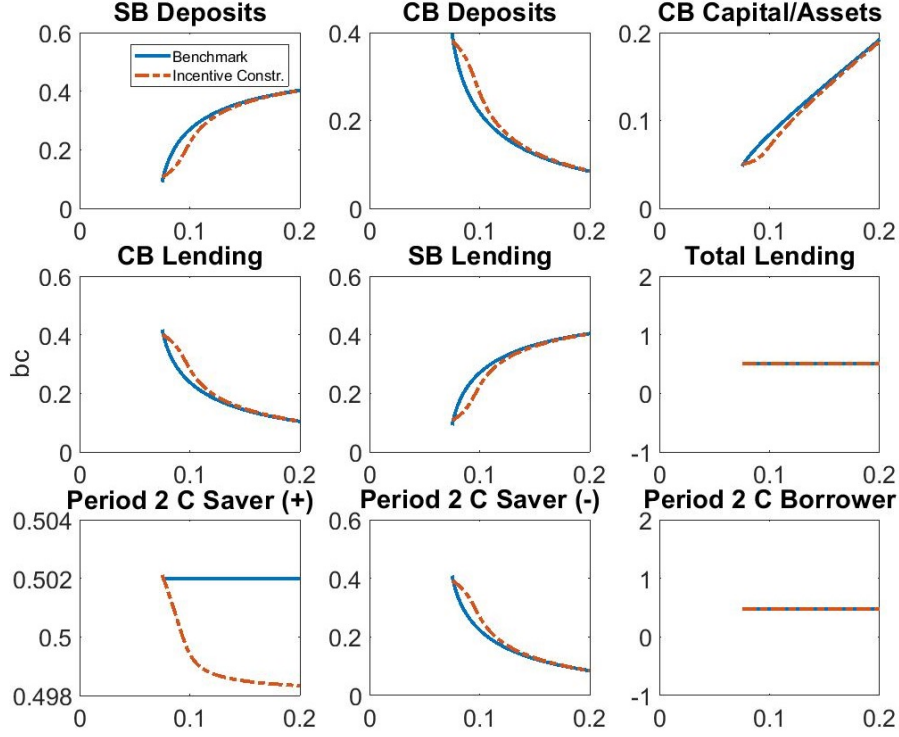
We now evaluate the effects of changes in capital requirements in the benchmark model and how introducing the incentive constraint to the shadow bank problem affects responses to regulation. In the analysis, we evaluate the reactions on and interplay between the two markets for shadow bank and commercial bank deposits whenever capital requirements are changed. For the incentive constraint model, we choose parameters such that condition 22 is violated and the friction and benchmark equilibria do not coincide. Compared to the benchmark model, we introduce one new parameter, θ , and set all other parameters as in the benchmark case, see Table 1.

Table 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
θ	0.1

In Figure 1, we report equilibrium values of endogenous variables for a grid of values of the capital requirement ν , both for the benchmark model and the incentive constraint model 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 2 and 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 73 and 74. Banks are depicted as *demanders* of deposits whereas commercial banks are characterized by a downward-sloping

Figure 1: Changes in Capital Requirements



demand curve, as indicated by equation 14, assuming that borrowing b^c and deposits d^c move in the same direction (Figure 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_{d1}^s .

According to equation 14, 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 below or equal to the requirement.¹⁴ In this case, the marginal cost of intermediation, indicated by the right-hand side of equation 14, rises. To reduce marginal costs, commercial banks can reduce their lending, b^s , and, given bank capital n^c to be fixed in the short run, thereby reduce their demand for household deposits, resulting in a shift of the deposit demand curve d_{d1}^c of commercial banks to the left in Figure 2 (d_{d2}^c). As

¹⁴We 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 justified in the case of precautionary motives, which we do not consider here. Furthermore, according to equation 14, $\frac{n^c}{b^c} \geq \nu$ would indicate a negative spread between commercial bank lending and deposit rates, in which case optimal intermediation by commercial banks would be zero.

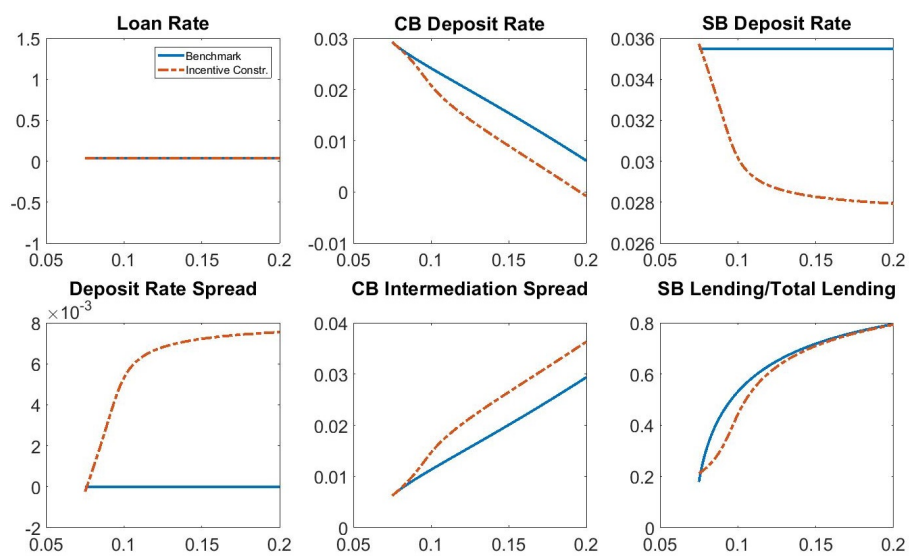


Figure 2: Commercial Bank Deposit Market

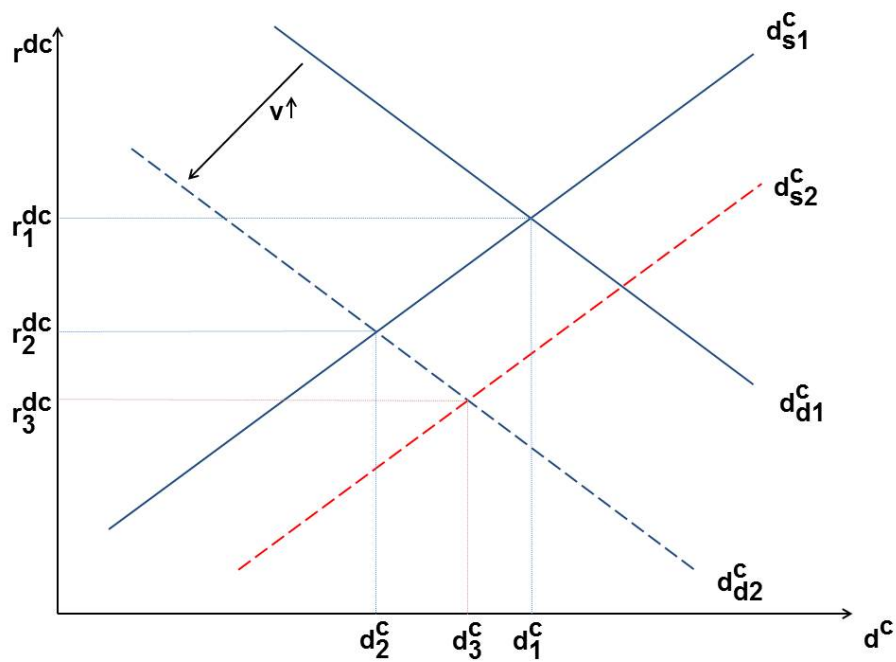
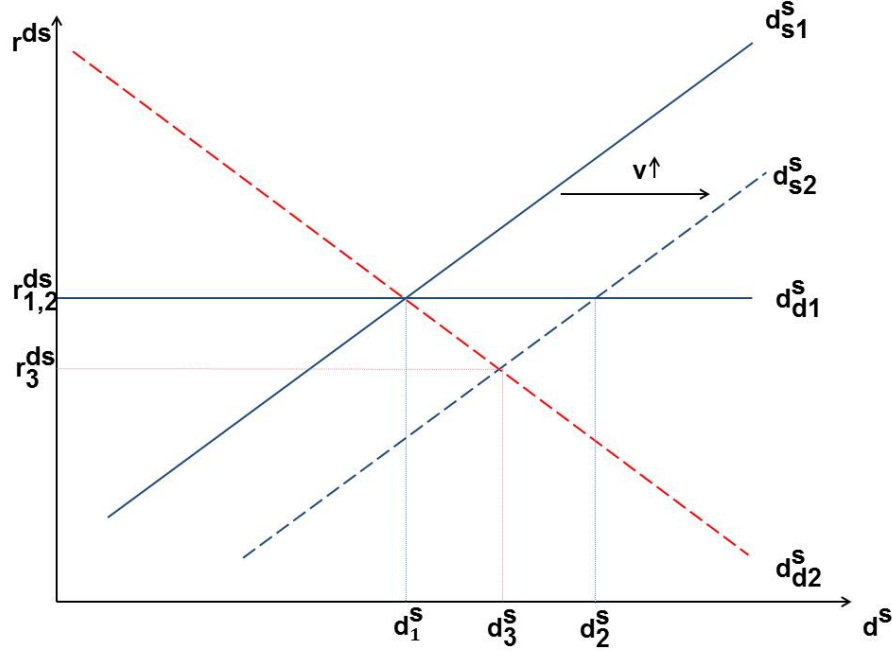


Figure 3: Shadow Bank Deposit Market



a consequence, deposit levels and rates fall with rising capital requirements, as observed in the simulation results in Figure 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 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 independent from the deposit market movements. Falling rates on commercial bank deposits increase the deposit rate spread $r^{ds} - r^{dc}$, and, according to equation 73, raise savers supply of deposits, d^s , resulting in a shift of the deposit supply curve d_{s1}^s to the right in Figure 3 (d_{s2}^s). 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 1, whenever condition 22 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_{d2}^s when the incentive constraint friction is introduced. By introducing a positive spread between 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 3, the same shift of deposit supply due to tighter commercial bank regulation as before still results in an increase in shadow bank deposits, even though 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 1, the rate on shadow bank deposits r^{ds} is now lower than r^b ; both decreasing shadow bank deposits and deposit rates are again indicated by simulations in Figure 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, shadow 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 2. Increasing capital requirements still induce the same shift of deposit demand by commercial banks as in the benchmark case (d_{d2}^c). However, the now contemporaneously induced shift in commercial bank supply of savers (d_{s2}^c), driven by developments in the shadow bank deposit market (Figure 3), ultimately leads to a new equilibrium in the commercial bank deposit market where 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 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 we derived, even though the magnitude of lending leakage is somewhat reduced when we pose restrictions on shadow banks, i.e. introduce a moral hazard problem between shadow banks and savers, as 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.

3.4 Financial Friction: Borrowing Constraint

Finally, we introduce a second friction in the model that is located between the borrower and the banks, affecting lending of both shadow banks and commercial banks. We follow Iacoviello (2005) and require borrowers to pose collateral to the 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.

3.4.1 Borrowers

As in section 3.1.2, 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. 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 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

$$E\{K\} = p^b k + (1 - p^b)k^- \quad (25)$$

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 $m^c \in (0, 1)$ 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. 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:

$$(1 + r^b)b^c \leq E\{K\} \quad (26)$$

Equation 28 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 28 such that

$$(1 + r^b)b^c \leq \frac{E\{K\}}{k}k \quad (27)$$

we get the commercial bank collateral constraint

$$(1 + r^b)b^c \leq m^c k \quad (28)$$

with $m^c = \frac{E\{K\}}{k}$

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 probability 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 acquire more funds relative to period-one capital holdings, as the loan-to-value ratio m^c rises.

For shadow bank lending, we do not assume an explicit regulatory loan-to-value ratio that borrowers have to adhere to. Even though aware of the risk of the occurrence of the low-capital state in period two, shadow banks are willing to provide funds beyond the level borrowers can acquire from commercial banks. However, whereas in expectation all lending by commercial banks will be backed with collateral K in period two, shadow bankers are aware of the risk that they will not be able to draw on borrower collateral in period two and thus face potential losses in period two. Therefore, they will charge higher interest on their loans in comparison to commercial banks, and the loan rate spread will depend on the probability of ending up in the high-capital regime p^b :

$$1 + r^{bs} = \frac{1 + r^{bc}}{p^b} \quad (29)$$

Due to the higher rate charged on shadow bank loans whenever $p < 1$, 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 und regulation m^c .¹⁵ 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

$$(1 + r^b)b^s \leq k - E\{K\}$$

or

$$(1 + r^b)b^s \leq (1 - \frac{E\{K\}}{k})k$$

or

$$(1 + r^b)b^s \leq (1 - m^c)k$$

The maximization problem of the borrower is now given by

$$\max_{c^b, C^b, b^c, b^s} u(c^b) + \beta^b u(C^b) \quad (30)$$

or

$$\max_{b^c, b^s} u(b^c + b^s) + \beta^b u(K - (1 + r^{bc})b^c - (1 + r^{bs})b^s) \quad (31)$$

s.t. constraints ?? and 3.4.1

From constraint 3.4.1 we know that

$$\frac{(1 + r^{bs})b^s}{1 - m^c} \leq k \quad (32)$$

and thus, assuming equality,

¹⁵Generally, 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.

(33)

4 DSGE Model

In the previous section, we highlighted the main mechanism of how capital requirements for commercial banks can generate a shift of credit away from commercial banks towards shadow banks. In this section, we embed the framework in a full-fledged DSGE model. Households serve as savers and provide funds to firms that act as borrowers, represented by different values for the discount factor used in the utility functions of both agents: we assume the discount factor for impatient entrepreneurs to be lower than for patient households. Households cannot directly provide funds to borrowing firms, but have to place deposits in financial intermediaries which are then providing loans to firms which use the funds for production purposes. Households can decide between two types of intermediaries to place deposits, shadow banks and commercial banks. As in the two-period model described in the previous section, commercial banks face regulatory capital requirements, whereas shadow banks are not obliged by regulation to back a minimum of assets with equity. However, due to the lack of regulation and government support schemes such as deposit insurance, investing in shadow banks is more risky from the household's perspective. As indicated in the previous section, default risk can result in a positive spread between the rates households demand from shadow banks compared to commercial banks on the placed deposits.

The lack of regulation and deposit insurance results in a moral hazard problem between shadow banks and depositors (households). In the spirit of [Gertler and Karadi \(2011\)](#), we assume that shadow bankers, due to a lack of regulation, can secretly divert a share of funds provided by depositors and transfer the proceeds to the household owning the intermediary. Whenever the benefits from doing so exceed the returns from behaving honestly, shadow bankers face an incentive to 'run away'. As indicated in the previous section, this friction in the shadow bank deposit markets ensures that households' willingness to switch completely to shadow banks whenever regulation for commercial banks increases is limited. 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.

In the DSGE model, we also incorporate a borrowing constraint on the loan market. As in [Gerali et al. \(2010\)](#), we assume that borrowers have to fulfill a certain loan-to-value ratio when they want to receive loans from intermediaries. Entrepreneurs can only borrow up a certain amount of their physical capital that they own and use for production purposes.

Households provide labor to entrepreneurs and either consume income or save by placing deposits with the intermediaries. Entrepreneurs produce intermediate goods and sell them on a competitive market to retailers, which differentiate them and sell them in a monopolistically competitive market. Furthermore, capital goods producers are introduced to derive a market price for capital. The central bank conducts monetary policy by setting the short-term policy rate according to a Taylor-type policy rule¹⁶, and a macro-prudential regulator adjusts the capital requirement for commercial banks in response to movements in credit volumes.

In the following, we only discuss parts of the model where we either differ from [Gerali et al. \(2010\)](#) due to the introduction of shadow banks, or those parts that are crucial to the analysis, for instance the wholesale sector of commercial banks. For other parts, we narrowly follow [Gerali et al. \(2010\)](#), for instance in modeling market power in loan and deposit markets between entrepreneurs and households and commercial banks, the labor market framework, the setup of capital and final goods producers, as well as monetary policy. The only difference between our model and [Gerali et al. \(2010\)](#) with respect to these model parts is that we do not discuss housing in this study. We therefore exclude impatient households which were introduced to implement a housing market and allowed for an evaluation of how borrowing constraints for households posing housing collateral impact macroeconomic developments. The loan branches of commercial banks act under monopolistic competition as in [Gerali et al. \(2010\)](#), by differentiating wholesale loans at no cost and lending them at a markup rate to entrepreneurs. Similarly, the deposit entities of commercial banks take deposits from households in a monopolistic competitive setting (thereby paying deposit rates with a respective markdown) and channel these deposits to the wholesale branch balance sheet.

4.1 Households

The representative patient household i maximizes the expected utility

¹⁶In this model, we abstract from any unconventional monetary policy and assume that the economy is not at the zero lower bound (ZLB) of nominal interest rates.

$$E_0 = \sum_{t=0}^{\infty} \beta_{HH}^t [(1 - a^{HH}) \varepsilon_t^z \log(c_t^{HH}(i) - a^{HH} c_{t-1}^{HH}) - \frac{l_t^{HH}(i)^{1+\phi^{HH}}}{1 + \phi^{HH}}] \quad (34)$$

which depends on current individual consumption ($c_t^{HH}(i)$) as well as lagged aggregate consumption (c_t^{HH}) and working hours l_t^{HH} . Labor disutility is parameterized by ϕ^{HH} . Preferences are subject to a disturbance affecting consumption (ε_t^z). Household choices are undertaken subject to the budget constraint:

$$c_t^{HH}(i) + d_t^{HH,C}(i) + d_t^{HH,S}(i) \leq w_t^{HH} l_t^{HH}(i) + \frac{(1 + r_{t-1}^{dC}) d_{t-1}^{HH,C}(i)}{\Pi_t} + \frac{(1 + r_{t-1}^{dS}) d_{t-1}^{HH,S}(i)}{\Pi_t} + t_t^{HH}(i) \quad (35)$$

The flow of expenses includes current consumption and real deposits to be made to both commercial and shadow banks, $d_t^{HH,C}(i)$, $d_t^{HH,S}(i)$. Due to the difference in the discount factor for households (β_{HH}^t) and entrepreneurs (β_E^t), as discussed in the next section, households only place deposits, but do not borrow any funds from financial market agents. Resources consist of wage earnings $w_t^{HH} l_t^{HH}(i)$ (where w_t^{HH} is the real wage rate for the labor input of each household), gross interest income on last period deposits $(1 + r_{t-1}^{dC}) d_{t-1}^{HH,C}(i) / \Pi_t$ and $(1 + r_{t-1}^{dS}) d_{t-1}^{HH,S}(i) / \Pi_t$ (where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is gross inflation¹⁷), and lump-sum transfers t_t^P that include dividends from firms and banks (of which patient households are the ultimate owners).

4.2 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

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E) \quad (36)$$

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:

¹⁷We follow [Iacoviello \(2005\)](#) in stating debt contracts in nominal terms.

$$\begin{aligned}
c_t^E(i) + w_t^{HH} l_t^{HH}(i) + (1 + r_{t-1}^b) b_{t-1}^{E,C}(i) / \Pi_t + (1 + r_{t-1}^b) b_{t-1}^{E,S}(i) / \Pi_t + q_t^k k_t^E(i) \\
= \frac{y_t^E(i)}{x_t} + b_t^{E,C}(i) + b_t^{E,S}(i) + q_t^k (1 - \delta) k_{t-1}^E(i) \quad (37)
\end{aligned}$$

with δ 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 produced by the entrepreneur (y_t^E) 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

$$y_t^E(i) = a_t^E k_{t-1}^E(i)^\alpha l_t^E(i)^{1-\alpha} \quad (38)$$

The (stochastic) total factor productivity (TFP) is given by a_t^E . The firm faces a constraint on the amount it can borrow from financial intermediaries, relating the borrowing to the value of collateral. We assume that creditors can repossess the assets of the entrepreneur at a proportional transaction cost, in case the firm defaults on its debt obligations. The collateral value of the entrepreneur is determined by its physical capital stock in the period of repayment ($t + 1$), which is given by $(1 - \delta) k_t^E \Pi_{t+1}$.¹⁸ Thus, the entrepreneur faces constraints on borrowing towards both financial intermediaries, such that the two respective borrowing constraints are given by

$$(1 + r_t^b) b_t^{E,C}(i) \leq m_t^C \alpha_t^E E_t \{ q_{t+1}^k (1 - \delta) k_t^E(i) \Pi_{t+1} \} \quad (39)$$

$$(1 + r_t^b) b_t^{E,S}(i) \leq m_t^S (1 - \alpha_t^E) E_t \{ q_{t+1}^k (1 - \delta) k_t^E(i) \Pi_{t+1} \} \quad (40)$$

Entrepreneurs gross borrowings from either commercial or shadow banks are thus limited by three factors: first, the loan-to-value (LTV) ratio m_t^n , with $n = C, S$ limits the amount borrowers can demand from each financial intermediary. The LTV ratio for commercial banks m_t^C can be interpreted as an exogenous determinant of firm leverage set by the regulator, and we therefore assume the LTV for commercial banks to be de-

¹⁸In [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.

scribed by an exogenous process.¹⁹ Second, the market value of collateral at the period of repayment ($t + 1$), $E_t\{q_{t+1}^k(1 - \delta)k_t^E(i)\Pi_{t+1}\}$ in combination with the LTV ratios determines the total amount of nominal gross debt the entrepreneur can acquire. Finally, the claimable collateral value has to be shared among creditors in case of default. Thus, α_t^E depicts the share of total collateral (housing) value the commercial bank can claim in case of default, whereas $(1 - \alpha_t^E)$ is collected by shadow banks, the second creditor group.²⁰ The claimable amount for each creditor naturally depends on the amount lent in the first place, such that we can define

$$\alpha_t^E = \frac{b_t^{E,C}(i)}{b_t^{E,C}(i) + b_t^{E,S}(i)}$$

In our model, we assume that the borrowing constraints bind around the steady state. We thus follow [Iacoviello \(2005\)](#) in assuming that the size of the shocks is "sufficiently small" such that we are assuming uncertainty to be absent.²¹ Thus, in equilibrium, entrepreneurs face binding borrowing constraints, such that equations , 36 and 37 hold with equality.

4.3 Banks

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.

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 to central bank

¹⁹In contrast, the LTV ratio applying to shadow bank lending, m_t^S , is treated as an endogenous variable in the model, as we assume, similar to the setup on the deposit side of financial intermediation, that shadow bank funding is not directly subject to a regulatory requirement, but reacts in response to developments on deposit markets on the one side and to the commercial bank loan market on the other side. Shadow bankers thus choose the requirement they demand from borrowers endogenously according to their own business models in our setup.

²⁰It makes sense to state these two constraints explicitly here to allow for an evaluation of a regulatory change w.r.t. commercial banks, affecting m_t^C but leaving m_t^S unchanged, and the effect of such a change on relative borrowing shares.

²¹[Iacoviello \(2005\)](#) discusses the deviation from the certainty equivalence case in the Appendix C of his paper.

financing and government guarantees such as deposit insurance schemes.²² Thus, in the view of households and firms, commercial banks depict safe deposit institutions, given that 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 banks²³, 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 in 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 competitive.

Shadow banks, in contrast to commercial banks, face no regulatory burden but are also not covered by structural support schemes. This lack of regulation opens up a moral hazard problem between the creditors and the shadow bank, as it allows the shadow bankers to divert funds secretly for private use. Furthermore, as we understand shadow banks not as single entities, but as conglomerates of a wide array of specialized financial vehicles and conduits that, in combination, mimic traditional banking intermediation, we assume shadow banks to operate in perfectly competitive markets, where entry and exit is common. 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.

4.3.1 Commercial Banks

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 ($d_t^{HH,C}$). The wholesale bank balance sheet is thus given by

²²Even 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.

²³The 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)

$$b_t^C = k_t^C + d_t^C \quad (41)$$

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 :

$$c_t^C = \frac{\kappa_k^C}{2} \left(\frac{k_t^C}{b_t^C} - \nu_t^C \right)^2 k_t^C \quad (42)$$

Theoretically, the cost works in both direction, as holding capital below the requirement causes costs from stricter monitoring by the regulator, additional legal obligations, and bad signalling. Holding a higher capital-to-asset ratio than required indicates - absent precautionary motives which we ignore here - inefficiencies, as we assume internal financing to be preferable to external financing, a fact widely accepted in the finance literature. Thus, bank capital and the regulatory requirements play a crucial role in the amount of credit provided by the commercial bank, with resulting consequences for both the role of shadow bank intermediation and, ultimately, for the real economy.

Bank capital k_t^C is accumulated from retained earnings only:

$$\Pi_t k_t^C = (1 - \delta^C) k_{t-1}^C + j_{t-1}^C \quad (43)$$

where j_t^C depicts overall commercial bank profits derived from the three branches of the bank. Capital management costs are captured by δ^C . The wholesale branch thus maximizes the discounted sum of real cash flows:

$$\begin{aligned} \mathcal{L}^w = \max_{b_t^C, d_t^C} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P [& (1 + r_t^b) b_t^C - b_{t+1}^C \Pi_{t+1} + d_{t+1}^C \Pi_{t+1} - (1 + r_t^{dC}) d_t^C + \\ & + (k_{t+1}^C \Pi_{t+1} - k_t^C) - \frac{\kappa_k^C}{2} \left(\frac{k_t^C}{b_t^C + b_t^S} - \nu_t^C \right)^2 k_t^C] \quad (44) \end{aligned}$$

where we assume the net wholesale loan rate r_t^b 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 38 to get:

$$r_t^b b_t^C - r_t^{dC} d_t^C - \frac{\kappa_k^C}{2} \left(\frac{k_t^C}{b_t^C} - \nu_t^C \right)^2 k_t^C$$

We can thus express the maximization problem as:

$$\mathcal{L}^w = \max_{b_t^C, d_t^C} r_t^C b_t^b - r_t^{dC} d_t^C - \frac{\kappa_k^C}{2} \left(\frac{k_t^C}{b_t^C} - \nu_t^C \right)^2 k_t^C \quad (45)$$

The first-order conditions yield the following expression:

$$r_t^b = r_t^{dC} - \kappa_k^C \left(\frac{k_t^C}{b_t^C} - \nu_t^C \right) \left(\frac{k_t^C}{b_t^C} \right)^2 \quad (46)$$

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

$$r_t^b - r_t = -\kappa_k^C \left(\frac{k_t^C}{b_t^C} - \nu_t^C \right) \left(\frac{k_t^C}{b_t^C} \right)^2 \quad (47)$$

This expression is the equivalent to equation 14 in the two-period model of section 3.1.4 and 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 is again increasing whenever the deviation of commercial bank capital holdings from the regulatory requirement increases.

4.3.2 Shadow Banks

In contrast to the commercial banking sector, shadow banks do not operate under monopolistic competition. The shadow banking sector is assumed to consist of a multitude of differentiated and specialized business entities, which, taken together, engage in similar intermediation activity as commercial banks. Given the flexibility and the heterogeneity of the shadow banking system, we assume shadow banks to operate under perfect competition. As shadow banks are not covered by government support schemes such as deposit insurance, shadow bank creditors have an incentive to monitor deposits held with shadow banks more closely and abstain from providing additional funds if leverage gets too high or the default probability of the shadow bank increases.

Instead of being constrained by regulation, as commercial banks are, shadow banks' ability to acquire external funds is only limited by a moral hazard problem as illustrated in the two-period problem (section 3.2) that limits the creditors' willingness to provide external funds. In the infinite horizon version of the model, shadow bankers have an incentive to save their way out of the financing constraint by accumulating retained earnings, implying an optimal capital ratio of hundred percent. To avoid such excessive and unrealistic capital accumulation, 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.

Compared to commercial bank loans, lending by shadow banks occurs not only via traditional loans, but to some extent via financial claims that shadow banks, such as investment or mutual funds, hold against borrowers. Oftentimes, these invested funds are collateralized and traded on financial markets. We therefore assume shadow bank lending to occur in the form of financial claims, which are traded at a certain market price. For simplicity, we follow [Gertler and Karadi \(2011\)](#) and assume that the relative price for tradeable shadow bank claims, $b_t^{E,S}$, is equal to the market price for capital q_t^k . The balance sheet of each shadow bank j in each period is given by

$$q_t^k b_t^{E,S}(j) = d_t^{HH,S}(j) + k_t^S(j) \quad (48)$$

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 $d_t^{HH,S}(j)$ and net worth, or shadow bank capital $k_t^S(j)$.

Shadow bankers earn an interest rate on their claims, and we assume, due to arbitrage, that they receive the same net real rate on their claims as commercial banks receive on their loans, r_t^b/Π_t . 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:

$$k_{t+1}^S(j) = (1 + r_t^b/\Pi_t)q_t^k b_t^{E,S}(j) - (1 + r_t^{dS})/\Pi_t d_t^{HH,S}(j) \quad (49)$$

or

$$k_{t+1}^S(j) = (r_t^b - r_t^{dS})/\Pi_t q_t^k b_t^{E,S}(j) + (1 + r_t^{dS})/\Pi_t k_t^S(j) \quad (50)$$

For the shadow banker, as long as the real return on lending, $(r_t^b - r_t^{dS})/\Pi_t$ 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

$$v_t(j) = \max E_t \sum_{i=0}^{\infty} (1 - \sigma^S) \sigma^{S^i} \beta^{S^{i+1}} k_{t+1+i}^S(j) \quad (51)$$

or

$$v_t(j) = \max E_t \sum_{i=0}^{\infty} (1 - \sigma^S) \sigma^{S^i} \beta^{S^{i+1}} [(r_{t+i}^b - r_{t+i}^{dS})/\Pi_t q_{t+i}^k b_{t+i}^{E,S}(j) + (1 + r_{t+i}^{dS})/\Pi_t k_{t+i}^S(j)] \quad (52)$$

Without the moral hazard problem, as indicated by the analysis in section 3.1.5 for the two-period case, the spread earned on intermediation, $(r_{t+i}^b - r_{t+i}^{dS})/\Pi_t$, is equal to zero when we either do not assume regulatory constraints for shadow banks or abstract from any friction in the intermediation process of shadow banks. In this situation, we could end up with corner solutions, i.e. where placing any level of regulation on commercial banks, acting as a 'tax' on intermediation by these institutions, could result in a shift of all the intermediation away from commercial to shadow banks, which we do not observe in reality. Therefore, we introduce the same moral hazard problem as introduced in section 3.2 of the two-period version of the model that leads to the possibility of positive spreads earned by shadow banks. We again allow for the possibility for shadow banks to divert a fraction of available funds, θ^S , and use them for private benefits²⁴ at the beginning of each period. Depositors 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:

$$v_t(j) \geq \theta^S q_t^k b_t^{E,S}(j) \quad (53)$$

²⁴We assume that shadow banks are owned by households, such that the funds are ultimately transferred back to the parent household of shadow bank j . However, we follow [Gertler and Karadi \(2011\)](#) and assume that households cannot use their own shadow banker for intermediation, but place deposits with a shadow bank owned by a different household.

Equation 50 is the infinite-horizon equivalent to incentive constraint 18 in the two-period model²⁵. Following Gertler and Karadi (2011), we can rewrite it as:

$$v_t(j) = \nu_t^S q_t^k b_t^{E,S}(j) + \eta_t^S k_t^S(j) \quad (54)$$

with

$$\nu_t^S = E_t\{(1 - \sigma^S)\beta^S(r_t^b - r_t^{dS})/\Pi_t + \beta^S \sigma^S \chi_{t,t+1}^S \nu_{t+1}^S\} \quad (55)$$

and

$$\eta_t^S = E_t\{(1 - \sigma^S) + \beta^S \sigma^S z_{t,t+1}^S \eta_{t+1}^S\} \quad (56)$$

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

$$\eta_t^S k_t^S(j) + \nu_t^S q_t^k b_t^{E,S}(j) \geq \theta^S q_t^k b_t^{E,S}(j) \quad (57)$$

With constraint 54 being binding, bank capital determines the amount that the shadow banker can lend out:

$$q_t^k b_t^{E,S}(j) = \frac{\eta_t^S}{\theta^S - \nu_t^S} k_t^S(j) = \phi_t^S k_t^S(j) \quad (58)$$

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 55 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

²⁵The interest rate term on the right-hand side of equation 18 is missing here, as we do not have fixed shadow bank capital anymore, 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 , shadow banks use net worth $k_t^S(j)$ together with deposits $d_t^{HH,S}(j)$ 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 $r_t^b/\Pi_t - r_t^{dS}/\Pi_t$ on intermediation at the end of period t , and these returns are then part of the capital stock in the next period, $k_{t+1}^S(j)$

requirement that limits their leverage, are prone to an endogenous capital constraint that limits their ability to increase leverage.²⁶

Rewriting bank capital as

$$k_{t+1}^S(j) = [(r_t^b - r_t^{dS})/\Pi_t \phi_t^S + (1 + r_t^{dS})/\Pi_t] k_t^S(j) \quad (59)$$

we get

$$z_{t,t+1}^S = \frac{k_{t+1}^S(j)}{k_t^S(j)} = (r_t^b - r_t^{dS})/\Pi_t \phi_t^S + (1 + r_t^{dS})/\Pi_t \quad (60)$$

and

$$\chi_{t,t+1}^S = \frac{q_{t+1}^k b_{t+1}^{E,S}(j)}{q_t^k b_t^{E,S}(j)} = \frac{\phi_{t+1}^S}{\phi_t^S} z_{t,t+1}^S \quad (61)$$

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 lending:

$$q_t^k b_t^{E,S} = \phi_t^S k_t^S \quad (62)$$

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, $k_t^{S,n}$:

$$k_t^S = k_t^{S,c} + k_t^{S,n} \quad (63)$$

As a fraction σ^S of existing shadow bankers survives each period, we know that at period t , we have for $k_t^{S,c}$

$$k_t^{S,c} = \sigma^S [(r_{t-1}^b - r_{t-1}^{dS})/\Pi_{t-1} \phi_{t-1}^S + (1 + r_{t-1}^{dS})/\Pi_{t-1}] k_{t-1}^S \quad (64)$$

²⁶We 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 22 in the two-period case, an equilibrium with a binding incentive constraint is characterized by $0 < \nu_t^S < \theta^S$, which can be shown with equation 55.

For new shadow bankers, we assume that they get some start-up capital from the household the shadow banker belongs to. This startup 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:

$$k_t^{S,n} = \omega^S q_t^k b_{t-1}^{E,S} \quad (65)$$

Combining equations 60, 61 and 62, we get the following law of motion for shadow bank capital:

$$k_t^S = \sigma^S [(r_{t-1}^b - r_{t-1}^{dS})/\Pi_{t-1} \phi_{t-1}^S + (1 + r_{t-1}^{dS})/\Pi_{t-1}] k_{t-1}^S + \omega^S q_t^k b_{t-1}^{E,S} \quad (66)$$

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 section 3.1.1, we provided 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 72 in the two-period model:

$$1 + r_t^{dS} = \frac{1 + r_t^{dC}}{1 - \tau^S \varepsilon_t^\tau} \quad (67)$$

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.

4.4 Macroprudential Regulation

In addition to shadow banks, we introduce a macroprudential regulator to the framework of Gerali et al. (2010) and assume that the regulator sets the capital requirement for commercial banks according to a Taylor-type rule and thus adjusts capital requirements ν_t^C whenever commercial bank credit deviates from its steady state value:

$$\nu_t^C = \overline{\nu^C}^{(1-\rho^\nu)} \nu_{t-1}^C (\rho^\nu) \left(\frac{b_t^{E,C}}{\overline{b^{E,C}}} \right)^{\phi^\nu} \varepsilon_t^\nu \quad (68)$$

The macroprudential policy rule resembles the *countercyclical capital requirement* on commercial bank balance sheets introduced with the Basel III accords in stating that the macroprudential authority raises the requirement on the capital-to-asset ratio whenever credit granted by the banking sector rises above the level perceived as stable, and lowers the requirement whenever the credit gap is negative. In the model, the regulator thus raises the capital-to-asset ratio ν_t^C above (below) the steady state level of capital requirements $\overline{\nu^C}$ whenever aggregate bank credit $b_t^{E,C}$ deviates positively (negatively) from its steady state value $\overline{b^{E,C}}$. The reaction parameter ϕ^ν determines the degree of policy sensitivity. Furthermore, we allow for exogenous shocks to the capital requirements, indicated by ε_t^ν , and assume an autoregressive shock process and assume smoothing in the adjustment of capital requirements, governed by parameter ρ^ν .

5 Data

In the following, we explain the data set used in the estimation of model parameters. All real economic variables are drawn from the European System of Accounts (ESA 2010) quarterly financial and non-financial sector accounts, provided by the ECB and Eurostat. Information on commercial bank balance sheets is gathered from the data set on "Monetary Financial Institutions" (MFIs) collected by the ECB. The data base provides detailed balance sheet information on all institutions relevant for the estimation of monetary aggregates (credit institutions, money market funds, national central banks and the ECB). Interest rate data are drawn from different sources within the ECB Statistical Data Warehouse and harmonized in line with the procedure recommended by [Gerali et al. \(2010\)](#).²⁷ For shadow bank variables, we use information provided in the ECB's data base on different monetary and other financial institutions, as discussed below.

5.1 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

²⁷See Appendix B for a detailed description of the variables.

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 nonstationary seasonally adjusted data (real consumption, real investment, bank deposits and loans) by using demeaned log-differenced data and demean all interest and inflation rates.

5.2 Shadow Bank Data

In addition to the variables on commercial bank and real activity, we include data on the shadow banking sector 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 and furthermore include information on shadow bank capital.²⁸ In doing so, we are able to include an empirical measure of shadow bank leverage, in our model defined as shadow bank capital in relation to total lending provided, in the estimation.

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*"

²⁸See Appendix B.

(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. For instance, the insurance corporations and pension funds sector (ICPFs) is mainly engaged in activities that are not related to shadow bank activities, 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 intermediation²⁹, 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 2).³⁰

Table 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

The OFI sector, in line with the broad definition of shadow banks given by the FSB, covers non-MMF investment funds³¹. Whereas some studies highlight the increasing role of direct investment fund lending to the non-financial private sector in the euro area since

²⁹See for instance Adrian (2014), Adrian and Liang (2014), Pozsar et al. (2010), or FSB (2017, 2011)

³⁰Detailed information on the composition of the OFI sector 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 only initiated in 2008 and 2009, respectively. Also, harmonized data on MMFs is available only from 2006 onwards in the MFI statistics, but can be gathered from other sources for earlier years (see Appendix B). 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. As highlighted by Doyle et al. (2016), one should therefore be aware of the fact that not all institutions in the remaining half of the OFI aggregate could unambiguously be declared as shadow banks.

³¹In contrast to investment funds, MMFs provide no direct lending to real economic agents, and are

the recent global financial crisis (Doyle et al., 2016), other studies discuss the special role 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 substantailly different than commercial banks, and therefore question whether the definition of shadow banks being intermediaries outside the regulatory system given by the FSB applies to investment funds. We therefore use as a robustness check alternative measures of shadow banks equity and loans that exclude investment fund values in a second estimation of the model (Scenario 2 in Table 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.

6 Estimation

We use the data set described in the previous chapter and 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 zero lower bound (ZLB) on nominal interest rates was essentially reached in early 2014 in the euro area when the deposit rate, the lower rate of the interest rate corridor decided upon by the ECB, was set at minus ten basis points.³² In total, we use twelve time series,³³ and we apply the Metropolis-Hastings algorithm to derive draws from the posterior distribution, by running 10 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).³⁴

therefore naturally absent from any shadow bank lending aggregate in the study. However, as MMFs are still of all of our shadow bank definitions applied, they will be considered in the aggregate equity holding of the shadow banking sector.

³²See for instance Cœuré (2015) for a discussion of the beginning of the ZLB period in the euro area. We provide evidence on a shorter sample period in Section 6.3 to account for the fact that the effective ZLB was potentially reached before that date.

³³See charts in Figure 9 of Appendix B

³⁴Details on convergence statistics and identification tests are available upon request.

6.1 Calibration and Prior Distributions

Table 3 shows values for the calibrated parameters. In most cases, we apply the calibration of Gerali et al. (2010). In addition, by incorporating shadow banks and macroprudential regulation in the model, we introduce five new parameters: τ^S , θ^S , σ^S , ρ^ν , and ϕ^ν . While we estimate the last three parameters with Bayesian methods, we calibrate the first two parameters to avoid the issue of non-identified parameter estimates.³⁵ 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 annualized spread is four percentage points in steady state, acknowledging that the variation in actual returns on the micro-level can be large. However, we set both the deposit rate spread and the nonobservable share of divertible shadow bank funds, θ^S , such that shadow bank leverage is approximately five percent in steady state. We provide steady-state values for different calibrations of θ^S in the baseline estimated model in Table 4. Changing the value of θ^S has implications for shadow bank balance sheet components, but leaves steady-state values for other model variables largely unchanged.

Furthermore, we ensure in the calibration in combination with α^E in steady state that the share of shadow bank intermediation in total intermediation is approximately one-third in steady state. 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). Our value of θ^S thus turns out to be lower than the calibrated value in the study of Gertler and Karadi (2011), where the authors settled on a value of 0.381 in the calibration of the US model.³⁶ Furthermore, we set the steady state commercial bank capital requirement, $\overline{\nu^C}$, equal to 10.5 percent, which resembles the overall level of capital-to-asset holdings demanded from commercial banks under Basel III.

For the prior distributions, we widely follow Gerali et al. (2010) for the parameters already estimated in their studies. Only for the Taylor-rule parameter on output, ϕ^y , we use a Beta-distribution as the prior compared to the Normal distribution used in the orig-

³⁵When all five parameters were included in the estimation, we were either not able to identify all parameters in the estimation, or not able to derive satisfactory convergence results with a meaningful number of replications in the Metropolis-Hastings algorithm.

³⁶An economic interpretation of the lower value could be given by a lower degree of creditor protection in the US financial system.

Table 3: Calibrated Parameters

Parameter	Description	Value
τ^S	Deposit rate spread parameter	0.01
θ^S	SB Share of Divertible Funds	0.2
$\overline{\nu^C}$	Steady state capital requirement	0.105
$\overline{\alpha^E}$	Steady state share of commercial bank lending	0.69
ϕ^{HH}	Inverse Frisch elasticity of labour supply	1
β_{HH}^t	Discount factor of household	0.9943
β_E^t	Discount factor entrepreneur	0.975
$\overline{m^C}$	Steady state LTV ratio of entrepreneur vs. Commercial banks	0.3
$\overline{m^S}$	Steady state LTV ratio of entrepreneur vs. shadow banks	0.3
α	Capital share in production function	0.3
ε^d	Deposit rate markdown given by $\frac{\varepsilon^d}{\varepsilon^d - 1}$	-1.46
ε^{bE}	Loan rate markup given by $\frac{\varepsilon^{bE}}{\varepsilon^{bE} - 1}$	2.5
ε^y	Goods market markup given by $\frac{\varepsilon^y}{\varepsilon^y - 1}$	6
ε^l	Labor market markup given by $\frac{\varepsilon^l}{\varepsilon^l - 1}$	5
δ^k	Depreciation rate physical capital	0.025
δ^b	Bank capital management cost	0.1046
ι^d	Deposit rate indexation parameter	0
ι^{bE}	Firm loan rate indexation parameter	0

Table 4: Changes in Steady State Values With Variations in θ^S

Steady-State Values	$\theta^S = 0.1$	$\theta^S = 0.2$	$\theta^S = 0.5$	$\theta^S = 0.7$	$\theta^S = 0.9$
<i>Shadow banks</i>					
SB leverage	10.09	5.29	2.01	1.44	1.12
SB loans	0.79	0.79	0.79	0.79	0.79
SB deposits	0.71	0.64	0.40	0.24	0.08
SB capital	0.08	0.15	0.39	0.55	0.70
<i>Commercial banks</i>					
CB leverage	10.08	10.08	10.08	10.08	10.08
CB loans	1.76	1.76	1.76	1.77	1.77
CB deposits	1.60	1.60	1.60	1.61	1.61
CB capital	0.16	0.16	0.16	0.16	0.16
CB lending/Total lending	0.69	0.69	0.69	0.69	0.69
<i>Real economy</i>					
Output	1.59	1.59	1.58	1.58	1.58
Consumption	1.36	1.36	1.36	1.36	1.36
Investment	0.21	0.21	0.21	0.21	0.21
Hours worked	0.78	0.78	0.78	0.78	0.79

inal study, as we were not confident in using a prior distribution that would allow for negative values of the parameter. Tables 5 to 7 report prior and posterior distributions for structural parameters as well as parameters describing exogenous processes. In contrast to Gerali et al. (2010), we take the posterior modes as parameter estimates, whereas the median values of the posterior were used in the original study, which we also report for comparability.

In total, we estimate three additional structural parameters that we introduce by implementing the shadow banking sector and a macroprudential regulator to the model. For the shadow bank non-default probability σ^S , we set the mean of the Beta-distribution applied to 75 percent, which is lower than the calibrated value in the original study by Gertler and Karadi (2011). We expect more frequent entry and exit in the shadow banking sector than the authors assumed for the US financial system (including commercial banks); they set calibration to derive an average intermediary lifetime of about nine years. Our value of 75 percent, in contrast, results in an average lifetime of only one year, and we allow for a relatively flat and uninformative prior shape to account for the high degree of uncertainty around this value. Again, the large variety of the institutions subsumed under our definition of shadow banks results in largely diverging lifetimes of firms, with some institutions such as special purpose vehicles only being in place for several days in some cases, whereas other institutions, such as investment funds, might exist for several years.³⁷ We therefore assume frequent entry and exit to be a particular feature of the shadow banking system, whereas commercial banks are assumed to live for an infinite time in the model.

We furthermore estimate two parameters related to the macroprudential rule we introduce; the smoothness parameter ρ^ν , and the parameter that describes the sensitivity of macroprudential regulation to movements in credit, θ^s . Similar as for the parameter governing the sluggishness in interest rate adjustment, our prior guess is that 75 percent of the persistence in capital requirements is due to the level set in the previous period by the regulator. For the estimation of θ^s , we set the prior mean to 2.4, which is in line with what Rubio and Carrasco-Gallego (2016) identified as an optimally set parameter in a similar policy rule introduced in a comparable DSGE model setup without shadow banks. We use the same priors for all exogenous process parameters, including the parameters related to the two newly introduced shocks to commercial bank capital requirements (ε_t^ν) and the spread between shadow bank and commercial bank returns (ε_t^T), see Tables 6 and 7.

³⁷The value of 75 percent is also substantially lower than values usually applied when a similar framework is used to model entry and exit in the non-financial corporate sector (Bernanke et al., 1999). As for commercial banks, we expect the average lifetime of a non-financial corporation to be substantially higher than for shadow banking entities subsumed under our definition.

Table 5: Prior and Posterior Distributions: Baseline Structural Parameters

Parameter		Prior Distribution			Posterior Distribution				Gerali et al. (2010)
		Distribution	Mean	Std.Dev.	5 Perc.	Median	95 Perc.	Mode	(Median)
σ^S	SB Survival Probability	Beta	0.75	0.10	0.23	0.35	0.47	0.34	-
ρ^ν	Capital Requirement Smoothing	Beta	0.75	0.10	0.56	0.70	0.83	0.73	-
ϕ^ν	Macroprudential Policy	Normal	2.4	0.50	2.52	3.21	3.90	3.09	-
κ^p	Price Stickiness	Gamma	50.0	20.00	11.33	22.55	35.72	18.04	28.65
κ^w	Wage Stickiness	Gamma	50.0	20.00	47.86	79.95	115.39	63.66	99.90
κ^i	Investm. Adj. Cost	Gamma	2.5	1.0	1.61	2.61	3.80	2.18	10.18
κ^d	Deposit Rate Adj. Cost	Gamma	10.0	2.5	1.39	2.26	3.27	1.95	3.50
κ^{bE}	Loan Rate Adj. Cost	Gamma	3.0	2.5	0.98	1.56	2.23	1.47	9.36
κ_k^C	CCR Deviation Cost	Gamma	10.0	5.0	42.83	61.24	80.44	71.65	11.07
ϕ^π	TR Coefficient π	Gamma	2.0	0.5	3.59	4.53	5.53	4.43	1.98
ϕ^y	TR Coefficient y	Gamma	0.50	0.20	1.28	2.17	3.04	2.38	0.35
ϕ^r	Interest Rate Smoothing	Beta	0.75	0.10	0.70	0.74	0.79	0.72	0.77
ι^p	Price indexation	Beta	0.50	0.15	0.25	0.46	0.69	0.54	0.16
ι^w	Wage indexation	Beta	0.50	0.15	0.22	0.43	0.65	0.45	0.28
α^{HH}	Habit Formation Households	Beta	0.50	0.10	0.69	0.77	0.84	0.73	0.86

Note: Results are based on 10 chains with 500,000 draws each based on the MH algorithm.

Table 6: Prior and Posterior Distributions: Baseline Exogenous Processes (AR Coefficients)

Parameter		Prior Distribution			Posterior Distribution				Gerali et al. (2010) (Median)
		Distribution	Mean	Std.Dev.	5 Perc.	Median	95 Perc.	Mode	
ρ^τ	Deposit Rate Spread	Beta	0.8	0.1	0.66	0.76	0.86	0.80	-
ρ^ν	Capital Requirement	Beta	0.8	0.1	0.91	0.95	0.98	0.95	-
ρ^z	Consumer Preference	Beta	0.8	0.1	0.77	0.85	0.91	0.86	0.39
ρ^a	Technology	Beta	0.8	0.1	0.63	0.79	0.93	0.84	0.94
ρ^{mE}	Entrepreneur LTV	Beta	0.8	0.1	0.98	0.99	1.00	0.99	0.89
ρ^d	Deposit Rate Markdown	Beta	0.8	0.1	0.71	0.80	0.89	0.82	0.84
ρ^{bE}	Loan Rate Markup	Beta	0.8	0.1	0.65	0.81	0.96	0.86	0.83
ρ^{qk}	Investment Efficiency	Beta	0.8	0.1	0.67	0.79	0.89	0.78	0.55
ρ^y	Price Markup	Beta	0.8	0.1	0.67	0.84	0.98	0.84	0.31
ρ^l	Wage Markup	Beta	0.8	0.1	0.55	0.68	0.81	0.69	0.64
ρ_k^C	Commercial Bank Capital	Beta	0.8	0.1	0.93	0.96	0.99	0.96	0.81

Note: Results are based on 10 chains with 200,000 draws each based on the MH algorithm.

Table 7: Prior and Posterior Distributions: Baseline Exogenous Processes (Standard Deviations)

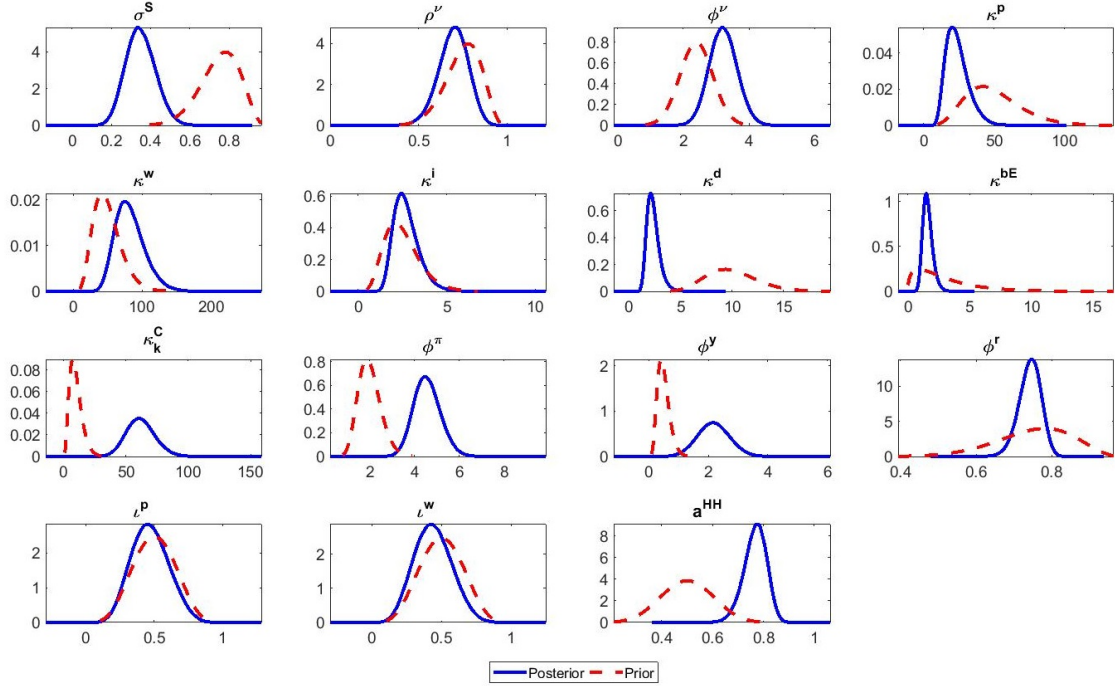
Parameter		Prior Distribution			Posterior Distribution				Gerali et al. (2010) (Median)
		Distribution	Mean	Std.Dev.	5 Perc.	Median	95 Perc.	Mode	
σ^τ	Deposit Rate Spread	Inverse Gamma	0.01	0.05	0.168	0.203	0.241	0.197	-
σ^ν	Capital Requirement	Inverse Gamma	0.01	0.05	0.028	0.039	0.052	0.034	-
σ^z	Consumer Preference	Inverse Gamma	0.01	0.05	0.009	0.013	0.016	0.012	0.027
σ^a	Technology	Inverse Gamma	0.01	0.05	0.003	0.004	0.005	0.003	0.006
σ^{mE}	Entrepreneur LTV	Inverse Gamma	0.01	0.05	0.003	0.004	0.005	0.004	0.007
σ^d	Deposit Rate Markdown	Inverse Gamma	0.01	0.05	0.134	0.171	0.214	0.159	0.032
σ^{bE}	Loan Rate Markup	Inverse Gamma	0.01	0.05	0.002	0.007	0.016	0.005	0.063
σ^{qk}	Investment Efficiency	Inverse Gamma	0.01	0.05	0.008	0.014	0.021	0.014	0.019
σ^r	Monetary Policy	Inverse Gamma	0.01	0.05	0.004	0.004	0.005	0.004	0.002
σ^y	Price Markup	Inverse Gamma	0.01	0.05	0.002	0.008	0.085	0.005	0.598
σ^l	Wage Markup	Inverse Gamma	0.01	0.05	0.478	0.740	1.041	0.632	0.561
σ_k^C	Commercial Bank Capital	Inverse Gamma	0.01	0.05	0.055	0.064	0.074	0.064	0.031

Note: Results are based on 10 chains with 500,000 draws each based on the MH algorithm.

6.2 Posterior Distributions

Both prior and posterior distributions for our parameter estimates are plotted in Figures 4 to 6. Compared to [Gerali et al. \(2010\)](#), we derive qualitatively similar estimates. As in the original study, we observe a larger degree of wage stickiness compared to price stickiness, as indicated by a larger value for κ^w compared to κ^p (Table 5). Translating our parameter estimates on wage and price stickiness from the Rotemberg framework used to model price and wage rigidities to a Calvo setup, the slope of the Phillips curve would be given by XXX in the latter case. Furthermore, Taylor-rule coefficients are relatively large compared to standard parameter values derived in the literature, potentially due to the introduction of a new macroprudential policy maker and the absence of policy coordination. The fact that the objective of the macroprudential policy maker – credit level stabilization – does not intervene directly with central bank objectives – output and price stability – potentially induces some counteracting policy behaviour compared to the model without shadow banks and macroprudential regulation³⁸.

Figure 4: Prior and Posterior Distributions: Baseline Structural Parameters



³⁸If we would design policies such that objectives overlap, this could change. For instance [Gelain and Ilbas \(2014\)](#) show that introducing output stabilization as an objective to macroprudential policy can affect response parameters in monetary policy rules as well, if the two policies are not undertaken in a coordinated manner.

Figure 5: Prior and Posterior Distributions: Baseline Exogenous Processes (AR Coefficients)

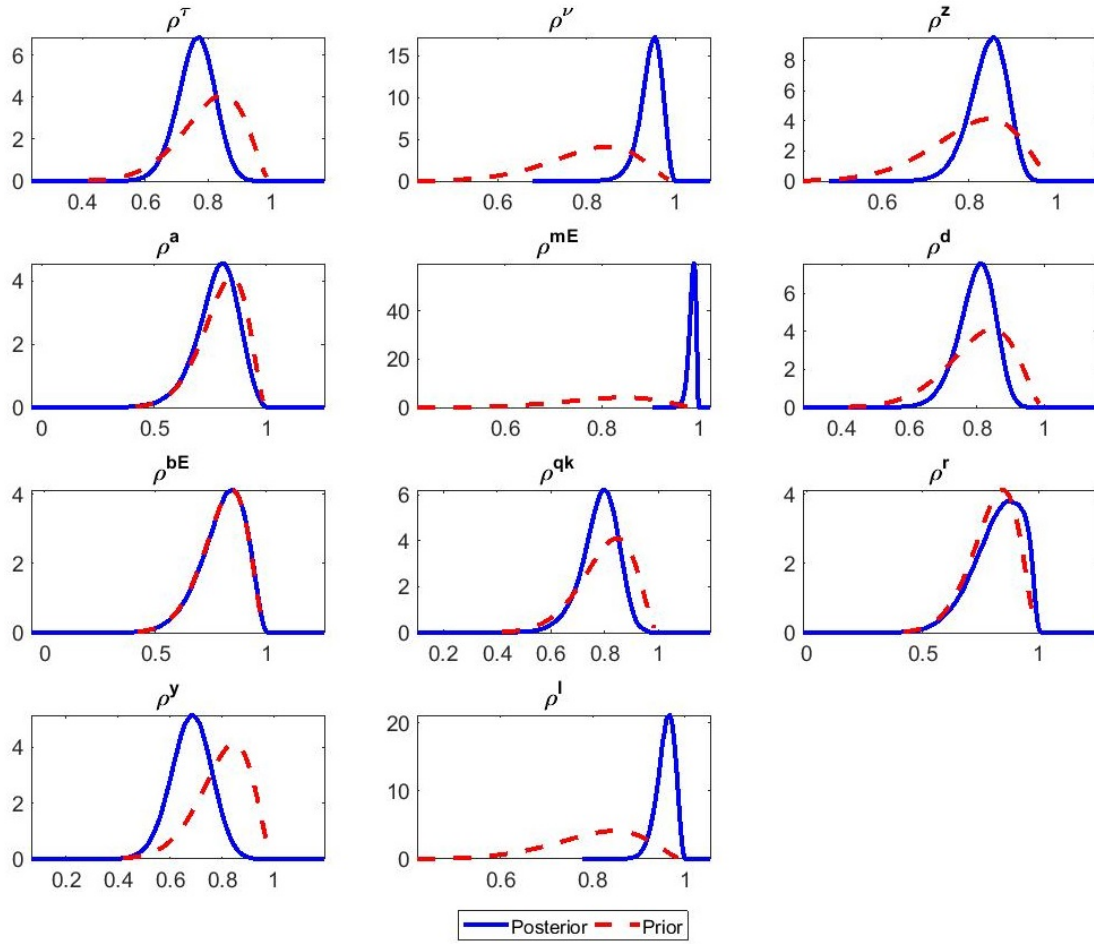
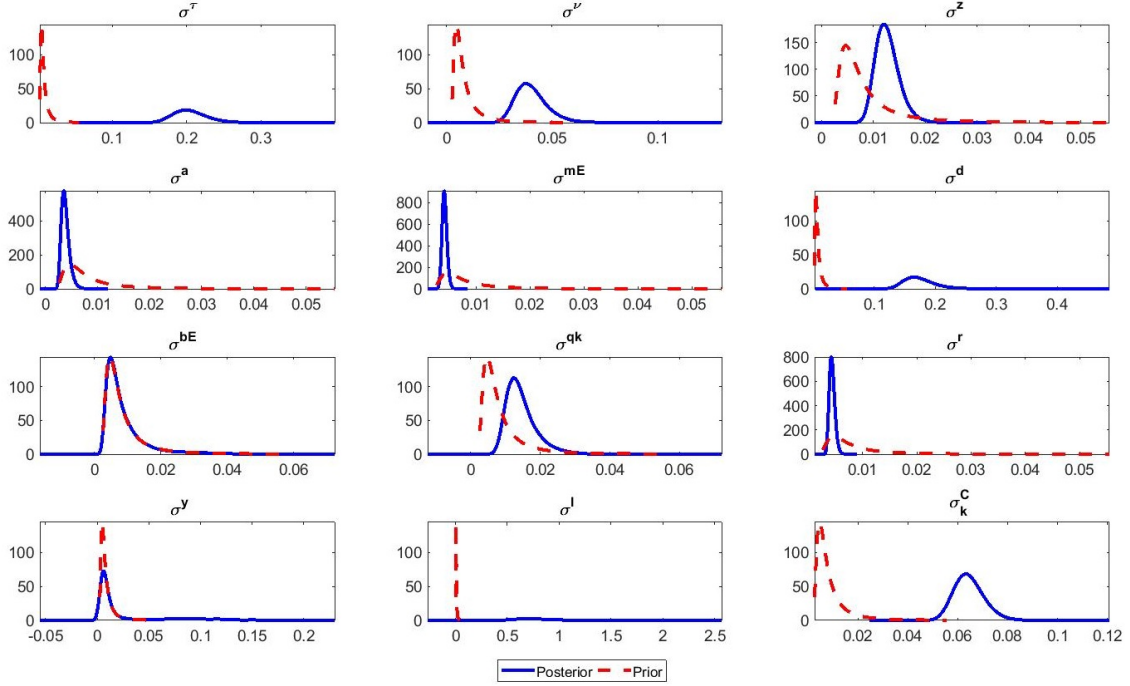


Figure 6: Prior and Posterior Distributions: Baseline Exogenous Processes (Standard Deviations)



Changing the model setup by excluding borrowing from households, as well as introducing a second market for deposits (shadow bank deposits), alters the adjustment process of both deposit and loan rates to changes in the policy rate. While [Gerali et al. \(2010\)](#) find a more sluggish adjustment for the loan rate compared to deposit rates (indicated by a larger value for loan rate adjustment costs), we find the opposite effect. With the introduction of a second deposit market, where no cost on interest rate adjustments is occurring, we see that the sensitivity of commercial bank deposit rates towards changes in monetary policy appears to be lower than previously estimated. Some share of adjustment now occurs via shadow bank deposit markets, where rates are allowed to adjust frictionlessly. Furthermore, with some share of intermediation being undertaken by shadow banks not prone to adjustment costs in interest rates, the overall adjustment cost for (homogeneous) loans is reduced, as only a share of loan-granting institutions (commercial banks) are now prone to adjustment costs.

Turning to the parameters introduced to the estimation by augmenting the model with shadow banks and macroprudential regulation, we see that the estimated survival probability of shadow banks, σ^S , is significantly lower than the value [Gertler and Karadi \(2011\)](#) used in the calibration for the US financial system, such that the average lifetime of shadow banks in our model turns out to be relatively short, at approximately three to

four months. Capital requirement adjustment is rather smooth, as indicated by a value of 0.73 for ρ'' . Finally, we derive a value of 3.09 for the sensitivity parameter of the macroprudential policy rate ϕ'' indicating a slightly stronger reaction to credit movements as assumed in the calibrated model of [Rubio and Carrasco-Gallego \(2016\)](#), potentially again due to potential counteracting behaviour between monetary and macroprudential policy makers.

We furthermore see that the shock processes turn out to be more persistent than in [Gerali et al. \(2010\)](#), particularly for consumer preference shocks, shocks to investment efficiency, and price markup shocks. For both newly introduced shocks (deposit rate spread shocks and shocks to capital requirements), the degree of persistence is high.

6.3 Robustness and Evaluation

As a first means of model evaluation, we report the variance decomposition of our baseline model in Table 8 to explain the contribution of the structural shocks of the model to the movement in macroeconomic and financial variables. Generally, shocks to capital requirements and deposit rate spreads are able to explain a large share of variation in commercial bank and, to a lower extent, in shadow bank balance sheets, whereas their effect on macroeconomic variables such as output, consumption, and inflation is limited. Only investment appears to be affected by a change in the spread between shadow bank and commercial bank deposit rates. In comparison to monetary policy shocks, the effects of unexpected changes in capital requirements on financial intermediaries' balance sheets is large. However, the effect of capital regulation shocks on interest rates appears modest, and other financial market shocks, for instance to bank capital and interest rate markups appear more relevant for the variation in interest rates.

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 ZLB phase in the euro area, we provide evidence on estimated parameters 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 shadow banking in the euro area. To take both considerations into account, we re-estimate our model for the period of 1999:Q1 to 2008:Q4, thereby excluding the post-financial crisis and ZLB 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 Table 9. In Addition, we

restate our baseline estimation results for comparison.

Table 8: Variance Decomposition Baseline Model

	Cap. Requ.	Dep. Rate Spread	Mon. Policy	Techn.	Other Real	Other Financial
Policy Rate	1.57	2.03	1.80	4.24	15.31	75.06
Loan Rate	2.01	6.27	1.37	3.36	13.72	73.26
Inflation	0.91	0.97	17.17	18.77	19.82	42.37
Output	1.45	4.32	13.43	11.87	25.69	43.23
Consumption	0.55	5.94	7.83	18.57	59.96	7.15
Investment	2.70	19.33	10.13	10.04	28.41	29.38
CB Deposit Rate	1.30	2.44	1.49	9.93	42.23	42.59
SB Deposit Rate	0.87	34.74	1.00	6.64	28.26	28.50
Deposit Rate Spread	0.93	29.99	1.07	7.12	30.31	30.56
SB Lending	4.33	3.20	0.14	0.38	0.64	91.33
SB Deposits	4.15	3.41	0.26	0.43	0.88	90.88
SB Capital	4.24	3.21	0.34	0.41	0.86	90.93
CB Lending	67.16	13.46	0.56	0.73	2.51	15.60
CB Deposits	48.84	9.79	0.40	0.53	1.82	38.62
CB Capital	5.18	46.18	0.63	0.11	1.50	46.39
CB Profits	5.97	21.14	1.99	0.56	3.39	66.96
SB Leverage	21.47	21.44	1.96	4.95	5.38	44.79
Capital Requirement	9.35	43.54	0.73	0.86	5.53	39.98

Note: "Other Real" includes shocks to consumer preferences, investment efficiency, and wage and price markup shocks. "Other Financial" includes shocks to commercial bank capital, the entrepreneur loan-to-value ratio with respect to commercial bank lending, and shocks to markdowns and markups on deposit and loan rates, respectively.

Table 9: Prior and Posterior Distributions: Structural Parameters Whole Sample and Pre-Crisis Period

		Baseline				Pre-Crisis			
		Posterior Distribution				Posterior Distribution			
Parameter		5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode
σ^S	SB Survival Probability	0.23	0.35	0.47	0.34	0.40	0.56	0.71	0.56
ρ^ν	Capital Requirement Smoothing	0.56	0.70	0.83	0.73	0.70	0.82	0.94	0.87
ϕ^ν	Macroprudential Policy	2.52	3.21	3.90	3.09	2.64	3.36	4.08	3.30
κ^p	Price Stickiness	11.33	22.55	35.72	18.04	13.36	27.25	44.07	26.13
κ^w	Wage Stickiness	47.86	79.95	115.39	63.66	43.98	73.47	106.40	59.09
κ^i	Investm. Adj. Cost	1.61	2.61	3.80	2.18	4.86	7.24	9.80	5.97
κ^d	Deposit Rate Adj. Cost	1.39	2.26	3.27	1.95	3.90	6.13	8.51	5.69
κ^{bE}	Loan Rate Adj. Cost	0.98	1.56	2.23	1.47	0.57	1.13	1.78	0.92
κ_k^C	CCR Deviation Cost	42.83	61.24	80.44	71.65	44.92	63.57	82.62	73.21
ϕ^π	TR Coefficient π	3.59	4.53	5.53	4.43	2.40	3.18	4.00	2.74
ϕ^y	TR Coefficient y	1.28	2.17	3.04	2.38	0.19	0.50	0.85	0.49
ϕ^r	Interest Rate Smoothing	0.70	0.74	0.79	0.72	0.70	0.75	0.81	0.73
ι^p	Price indexation	0.25	0.46	0.69	0.54	0.16	0.36	0.57	0.40
ι^w	Wage indexation	0.22	0.43	0.65	0.45	0.21	0.43	0.66	0.38
α^{HH}	Habit Formation Households	0.69	0.77	0.84	0.73	0.56	0.65	0.74	0.59

Note: Results are based on 10 chains with 500,000 draws each based on the MH algorithm. Columns 3 to report the posterior moments from the baseline estimation in Table 5, whereas columns 7 to 10 report results from the estimation using the sample 1999 Q:1 to 2008:Q4.

Whereas result from the pre-crisis period estimation are qualitatively comparable to the baseline estimates, some quantitative differences in parameter estimates can be observed. for instance, the shadow bank survival probability almost 20 percentage points larger in the pre-crisis estimation, which almost doubles the lifetime of the representative shadow bank compared to the baseline scenario. More frequent entry and exit behaviour in the post-crisis shadow banking sector mimics the strong liquidation of off-balance sheet vehicles and other specialized vehicles in the aftermath of the financial crisis. Furthermore, price and wage stickiness is larger in the pre-crisis period, compared to the overall sample. Strikingly, coefficients on output and inflation in the monetary policy rule are significantly lower in the pre-crisis estimation, indicating a more aggressive reaction of monetary policy in response to changes in output and prices in the post-crisis period, reflecting the sharp reduction in policy rates in the aftermath of the financial crisis and later over the course of the European debt crisis.

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 5 (Scenario 2 in Table 2). We report parameter estimates in Table 10, again in comparison to our baseline estimation.

Table 10: Prior and Posterior Distributions: Structural Parameters With and Without Investment Funds

		Baseline				Excluding Investment Funds			
		Posterior Distribution				Posterior Distribution			
Parameter		5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode
σ^S	SB Survival Probability	0.23	0.35	0.47	0.34	0.17	0.28	0.40	0.27
ρ^ν	Capital Requirement Smoothing	0.56	0.70	0.83	0.73	0.56	0.70	0.83	0.73
ϕ^ν	Macroprudential Policy	2.52	3.21	3.90	3.09	2.48	3.19	3.89	3.02
κ^p	Price Stickiness	11.33	22.55	35.72	18.04	23.44	39.50	57.34	38.63
κ^w	Wage Stickiness	47.86	79.95	115.39	63.66	55.06	86.48	120.69	70.91
κ^i	Investm. Adj. Cost	1.61	2.61	3.80	2.18	8.13	10.84	13.71	9.27
κ^d	Deposit Rate Adj. Cost	1.39	2.26	3.27	1.95	2.40	3.98	5.80	3.38
κ^{bE}	Loan Rate Adj. Cost	0.98	1.56	2.23	1.47	1.28	2.29	3.45	2.02
κ_k^C	CCR Deviation Cost	42.83	61.24	80.44	71.65	43.47	60.60	78.58	74.05
ϕ^π	TR Coefficient π	3.59	4.53	5.53	4.43	2.98	3.79	4.64	3.34
ϕ^y	TR Coefficient y	1.28	2.17	3.04	2.38	0.20	0.52	0.90	0.50
ϕ^r	Interest Rate Smoothing	0.70	0.74	0.79	0.72	0.72	0.76	0.81	0.73
ι^p	Price indexation	0.25	0.46	0.69	0.54	0.12	0.27	0.44	0.28
ι^w	Wage indexation	0.22	0.43	0.65	0.45	0.27	0.48	0.70	0.48
a^{HH}	Habit Formation Households	0.69	0.77	0.84	0.73	0.62	0.69	0.75	0.65

Note: Results are based on 10 chains with 500,000 draws each based on the MH algorithm. Columns 3 to report the posterior moments from the baseline estimation in Table 5, whereas columns 7 to 10 report results from the estimation using shadow banking data excluding information on investment funds.

7 Policy Experiment

We use our estimated model to evaluate whether disregarding credit intermediation via the shadow banking sector in macroprudential policy decisions has quantitative implications for the macroeconomy. Furthermore, in a counterfactual analysis, we assess how regulators would have set capital requirements under a countercyclical policy rule as given by equation 65, had it been in place throughout the existence of the common currency. To do so, we re-estimate our model without a countercyclical macroprudential policy maker, thereby mimicing the regulatory landscape before Basel III. We then introduce a policy-maker following a countercyclical rule in the pre-Basel III world relying on our estimated sensitivity parameter, ρ' and simulate the development of capital requirements over the course of the monetary union. 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.

7.1 Impulse Responses

Before discussing the counterfactual analysis, we derive impulse responses for two policy shocks: a standard monetary policy shock and a shock to 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 whether commercial bank and shadow bank intermediation is differently affected by unexpected changes in monetary policy. We then evaluate the impact of unanticipated increase of capital requirements to discuss potential leakage towards shadow bank intermediation in response to tighter regulation.

We evaluate two alternative specifications of the model. In the benchmark specification, we use the model as presented in section 4, i.e., both shadow banks and commercial banks are present in the model and the macroprudential regulator follows a countercyclical capital requirement rule targeting developments in commercial bank credit (equation 65). We furthermore evaluate a second version of our model where we exclude the shadow banking sector. We assess how the macroeconomy would react to the same shocks if we would assume that credit intermediation only occurs through the traditional banking system. This version of the model resembles the standard setup in financial friction DSGE models where the financial system is assumed to be a homogeneous sector which can be represented in a representative-agent manner.

FIGURE TO BE ADDED

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. \(2013\)](#) find that some institutions (money market mutual funds, security broker-dealers) increase their asset holdings after monetary policy easing, whereas issuers of asset-backed securities (ABS) decrease their balance sheets after monetary policy tightening, with respective implications for intermediation activity by different institutions. [Pescatori and Sole \(2016\)](#) use a VAR framework including data on commercial banks, ABS issuers, and other finance companies, such as insurance companies and mortgage pools, 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 nonbank intermediary sector increases, which indicates a relative dampening of the transmission channel as nonbanks step in as lenders whenever commercial banks reduce credit provisions. Similarly, [Den Haan and Sterk \(2011\)](#), using US flow-of-funds data, find that nonbank 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, shadow banks that are highly levered and 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. \(2015\)](#) find similar results, even though their definition of shadow banks differs from the one of [Mazelis \(2016\)](#). For European banks, [Altunbas et al. \(2009\)](#) show that institutions engaged to a large extent in nonbank activities, such as securitization, are less affected by monetary policy shocks, a finding in line with the above studies on US intermediaries: a larger share of nonbank activity insulates credit intermediation from monetary policy shocks, thus dampening the transmission of policy shocks, *ceteris paribus*.

The second set of impulse responses with respect to a change in capital requirements set by a macroprudential regulator (Figure XX) refers to the same model setups: with and without the shadow banking sector being present. The responses serve as a first indication whether our model is able to generate a leakage behaviour in intermediation as indicated by the analysis of the two-period model in section 3.

FIGURE TO BE ADDED

7.2 Counterfactual Simulation

Finally, we evaluate how a change in the macroprudential policy rule would affect dynamics in the economy. Under Basel III, regulators can require higher capital ratios from commercial banks whenever credit growth is high. More precisely, under Basel III, commercial banks are required to hold capital-to-asset ratios of 10.5 percent.³⁹ Additionally, national regulators are allowed to adjust capital requirements by an absolute value of 2.5 percent under the countercyclical capital buffer, such that the corridor for countercyclical regulation is given by 8 to 14 percent. However, 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. Thus, in our baseline version of the policy rule, we assumed that regulators closely follow developments in commercial banking credit, but do not take shadow bank intermediation explicitly into account. However, in a first-best situation, regulators would be able to adjust capital requirements/lending restrictions in a similarly structured and coherent framework for non-bank financial institutions as they are doing for commercial banks under the Basel regulations. However, given the large degree of heterogeneity and specialization in the shadow banking system, installing a macroprudential framework with a universal tool such as capital requirements is not feasible. Even though regulatory approaches towards special types of entities are under way and partly implemented (FSB, 2017), a unified framework for regulating non-bank finance is still out of reach.

In the following counterfactual analysis, we discuss three different types of regulators and evaluate how each type would have set capital requirements under her interpretation of Basel III, if the framework would have been in place already in 1999 and throughout the existence of the euro area.⁴⁰ To derive the counterfactual scenario, we re-estimate the baseline model of section 6, but change the regulatory environment to the pre-Basel III standards of banking regulation (Basel II). Before the implementation of Basel III, the requirement on total capital holdings was 8 percent, and no countercyclical adjustment of requirements was intended. Therefore, our pre-Basel III model does not feature a

³⁹The Basel III regulation capital requirement consist of different types of 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.

⁴⁰In 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.

countercyclical capital requirement rule ($\phi^\nu = 0$) and the steady state capital requirement, $\overline{\nu^C}$, is equal to 8 percent. Columns 3 to 6 of Tables 11 to 13 provide estimation results for the pre-Basel III estimation. We then implement, in the estimated Basel II model, our three different types of regulators under Basel III, respectively by setting $\overline{\nu^C} = 0.105$ and by introducing the countercyclical rule given by equation 65 and setting $\phi^\nu = 3.09$, as reported in Table 5. All of the three regulators can apply capital requirements only to the commercial banking system, but cannot enforce explicit regulation on the shadow banking system. The difference between the three types emerges from the degree to which shadow banking is considered when setting policy for commercial banks.

We first discuss a naive regulator that simply neglects the existence of shadow banking and assumes that intermediation is only conducted via the traditional banking system. Thus, when evaluating this regulator, we completely exclude the shadow banking sector from the estimated model in Tables 11 to 13. We do not re-estimate the model without shadow banks, as we want to capture the effect of an ignorant regulator neglecting intermediation outside the regulatory banking system, even though it is present. The naive regulator sets policy according to the rule given by equation 65, and the absence of shadow banks in the naive regulation model implies that regulation affects the total financial system, and thus the complete credit intermediation directly. Even if not fully realistic, the naive regulator reflects, on the policy side, the strong focus on commercial banking activity in the discussion of financial market regulation among policy makers, and the primary focus on establishing macroprudential tools for the regulation of the commercial banking system, as under Basel III. Furthermore, on the theoretical side, we use a version of our model where we exclude the possibility of shadow bank intermediation completely in the evaluation of the naive regulator. Thus, the naive regulator discussion is based on a model setup that closely resembles models employed in the post-crisis financial friction DSGE literature where intermediation is predominantly conducted by a homogeneous banking sector that is directly and universally affected by financial regulation.

Second, we evaluate the policy setting of a moderate regulator that is aware of the existence of shadow banking, but only focuses on developments in commercial credit when setting capital requirements for commercial banks. The moderate regulator therefore depicts the regulatory framework in our baseline model of chapter 4, and he also follows a rule as described by equation 65.

Table 11: Prior and Posterior Distributions: Structural Parameters With and Without Investment Funds - Basel II Regulation

		Baseline				Excluding Investment Funds			
		Posterior Distribution				Posterior Distribution			
Parameter		5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode
σ^S	SB Survival Probability	0.09	0.14	0.20	0.11	0.08	0.14	0.20	0.15
ρ^ν	Capital Requirement Smoothing	0.47	0.63	0.79	0.66	0.47	0.63	0.79	0.65
ϕ^ν	Macroprudential Policy	-	-	-	-	-	-	-	-
κ^p	Price Stickiness	33.90	51.70	71.21	42.95	34.28	52.25	70.91	54.04
κ^w	Wage Stickiness	46.35	79.28	116.18	64.10	47.08	79.48	113.32	90.78
κ^i	Investm. Adj. Cost	7.59	10.14	12.85	10.54	7.64	10.19	12.89	12.01
κ^d	Deposit Rate Adj. Cost	2.79	4.41	6.29	4.20	2.76	4.38	6.30	3.50
κ^{bE}	Loan Rate Adj. Cost	1.36	2.61	4.09	2.45	1.40	2.63	4.07	2.08
κ_k^C	CCR Deviation Cost	23.84	40.58	58.53	23.58	24.64	40.59	58.56	47.66
ϕ^π	TR Coefficient π	3.06	4.00	4.95	3.92	3.10	4.02	4.93	4.09
ϕ^y	TR Coefficient y	0.22	1.22	2.06	1.14	0.26	1.20	2.02	1.33
ϕ^r	Interest Rate Smoothing	0.73	0.77	0.81	0.76	0.73	0.77	0.81	0.75
ι^p	Price indexation	0.08	0.19	0.31	0.18	0.08	0.19	0.31	0.18
ι^w	Wage indexation	0.26	0.48	0.70	0.55	0.28	0.49	0.70	0.45
α^{HH}	Habit Formation Households	0.64	0.71	0.78	0.71	0.64	0.71	0.78	0.70

Note: Estimates are based on a version of the model used to estimate Table 10 where $\phi^\nu = 0$ and $\nu^C = 0.08$. Results are based on 10 chains with 200,000 draws each based on the MH algorithm. Columns 3 to report the posterior moments from the baseline estimation in Table 5, whereas columns 7 to 10 report results from the estimation using shadow banking data excluding information on investment funds.

Table 12: Prior and Posterior Distributions: Exogenous Processes (AR Coefficients) With and Without Investment Funds - Basel II Regulation

		Baseline				Excluding Investment Funds			
		Posterior Distribution				Posterior Distribution			
Parameter		5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode
ρ^τ	Deposit Rate Spread	0.83	0.89	0.95	0.91	0.82	0.89	0.95	0.89
ρ^ν	Capital Requirement	0.49	0.67	0.82	0.66	0.49	0.67	0.82	0.68
ρ^z	Consumer Preference	0.64	0.73	0.97	0.70	0.59	0.73	0.90	0.72
ρ^a	Technology	0.82	0.91	0.99	0.93	0.84	0.91	0.98	0.95
ρ^{mE}	Entrepreneur LTV	0.98	0.99	1.00	0.99	0.98	0.99	1.00	0.99
ρ^d	Deposit Rate Markdown	0.71	0.81	0.90	0.85	0.71	0.81	0.90	0.86
ρ^{bE}	Loan Rate Markup	0.65	0.81	0.96	0.80	0.65	0.82	0.96	0.73
ρ^{qk}	Investment Efficiency	0.75	0.84	0.93	0.85	0.74	0.84	0.93	0.82
ρ^y	Price Markup	0.66	0.82	0.97	0.86	0.65	0.82	0.97	0.88
ρ^l	Wage Markup	0.63	0.76	0.88	0.80	0.64	0.76	0.87	0.80
ρ_k^C	Commercial Bank Capital	0.93	0.96	0.99	0.97	0.93	0.96	0.99	0.97

Note: Estimates are based on a version of the model used to estimate Table 10 where $\phi^\nu = 0$ and $\nu^C = 0.08$. Results are based on 10 chains with 200,000 draws each based on the MH algorithm. Columns 3 to report the posterior moments from the baseline estimation in Table 5, whereas columns 7 to 10 report results from the estimation using shadow banking data excluding information on investment funds.

Table 13: Prior and Posterior Distributions: Exogenous Processes (Standard Deviations) With and Without Investment Funds - Basel II Regulation

		Baseline				Excluding Investment Funds			
		Posterior Distribution				Posterior Distribution			
Parameter		5 Perc.	Median	95 Perc.	Mode	5 Perc.	Median	95 Perc.	Mode
σ^τ	Deposit Rate Spread	0.161	0.191	0.224	0.189	0.160	0.191	0.223	0.192
σ^ν	Capital Requirement	0.074	0.129	0.197	0.204	0.075	0.129	0.193	0.101
σ^z	Consumer Preference	0.018	0.025	0.034	0.024	0.018	0.025	0.032	0.021
σ^a	Technology	0.004	0.005	0.006	0.004	0.004	0.005	0.006	0.004
σ^{mE}	Entrepreneur LTV	0.003	0.003	0.004	0.003	0.003	0.003	0.004	0.003
σ^d	Deposit Rate Markdown	0.152	0.204	0.263	0.184	0.152	0.203	0.263	0.182
σ^{bE}	Loan Rate Markup	0.002	0.007	0.018	0.005	0.002	0.007	0.015	0.004
σ^{qk}	Investment Efficiency	0.003	0.005	0.007	0.005	0.003	0.005	0.007	0.004
σ^r	Monetary Policy	0.004	0.004	0.005	0.004	0.004	0.004	0.005	0.004
σ^y	Price Markup	0.002	0.007	0.091	0.004	0.002	0.007	0.023	0.004
σ^l	Wage Markup	0.403	0.657	0.970	0.542	0.422	0.664	0.942	0.700
σ_k^C	Commercial Bank Capital	0.071	0.083	0.096	0.081	0.071	0.083	0.096	0.084

Note: Estimates are based on a version of the model used to estimate Table 10 where $\phi^\nu = 0$ and $\nu^C = 0.08$. Results are based on 10 chains with 200,000 draws each based on the MH algorithm. Columns 3 to report the posterior moments from the baseline estimation in Table 5, whereas columns 7 to 10 report results from the estimation using shadow banking data excluding information on investment funds.

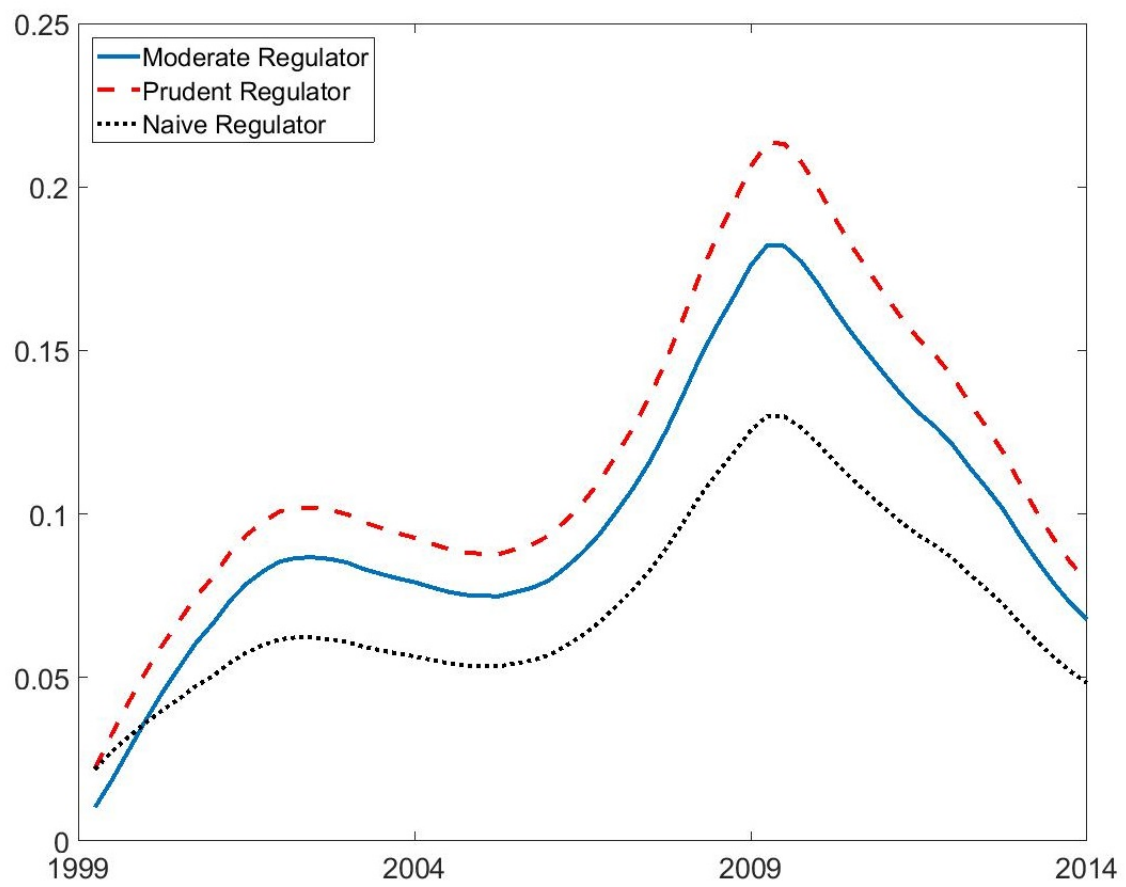
Finally, a prudent regulator is introduced that is not only aware of credit intermediation of shadow banks, but explicitly takes lending by the shadow banking sector into account when deciding on capital requirements for commercial banks. Despite the lack of a unifying regulatory framework for shadow bank institutions, the regulator is able to derive broad estimates of credit intermediation taking place outside the regulated banking sector, and can therefore potentially consider not only aggregate credit stemming from commercial banks she regulates in decision-making, but also movements of *overall* credit. The policy rule stated in equation 65 is thus altered for the prudent regulator such that:

$$\nu_t^C = \overline{\nu^C}^{(1-\rho^\nu)} \nu_{t-1}^{C \ (\rho^\nu)} \left(\frac{b_t^{E,C} + b_t^{E,S}}{\overline{b^{E,C}} + \overline{b^{E,S}}} \right)^{\phi^\nu} \varepsilon_t^\nu \quad (69)$$

For all regulatory regimes, we use the identified shock processes from the estimation of the respective model versions to simulate the evolution of endogenous model variables over the period 1999 – 2014 and derive a time series of hypothetical capital requirements the respective regulator would have set in response. The respective time series for the three regulators are reported in Figure 7.

All three regulators would have applied some form of countercyclical regulation – reducing capital requirements in times of financial distress and raising requirement in phases of excessive lending by commercial banks – and would have prescribed a stepwise tightening of capital standards throughout the early 2000s. However, all policy makers would have prescribed levels of requirements substantially lower than the Basel III overall requirement of 10.5 percent at the beginning of the sample. Even more, roughly until 2001 – 2002, all regulators would have prescribed capital requirements sharply below the levels under both Basel II (8 percent total requirement) and Basel III (10.5 percent). Thereafter, until 2005-2006, a moderate regulator would have prescribed capital requirements circulating around the Basel II level of 8 percent, whereas only the prudent regulator taking overall credit into account would have required banks to hold capital levels around the Basel III level of 10.5 percent. The low levels prescribed by the rules at the beginning of the sample could be related to the Dotcom bubble burst at the beginning of the 2000s and the aftermath of the Asian crisis of the late-1990s and the related turbulences in financial markets. All rules would have furthermore prescribed a sharp tightening of credit standards from the mid-2000s onwards, in response to massive credit growth in the European banking sector. From 2009 onwards, in response to the global financial crisis of 2008 and over the course of the European debt crisis, all countercyclical regulators would have prescribed a sharp reduction in capital requirements due to subdued lending activity in the euro area.

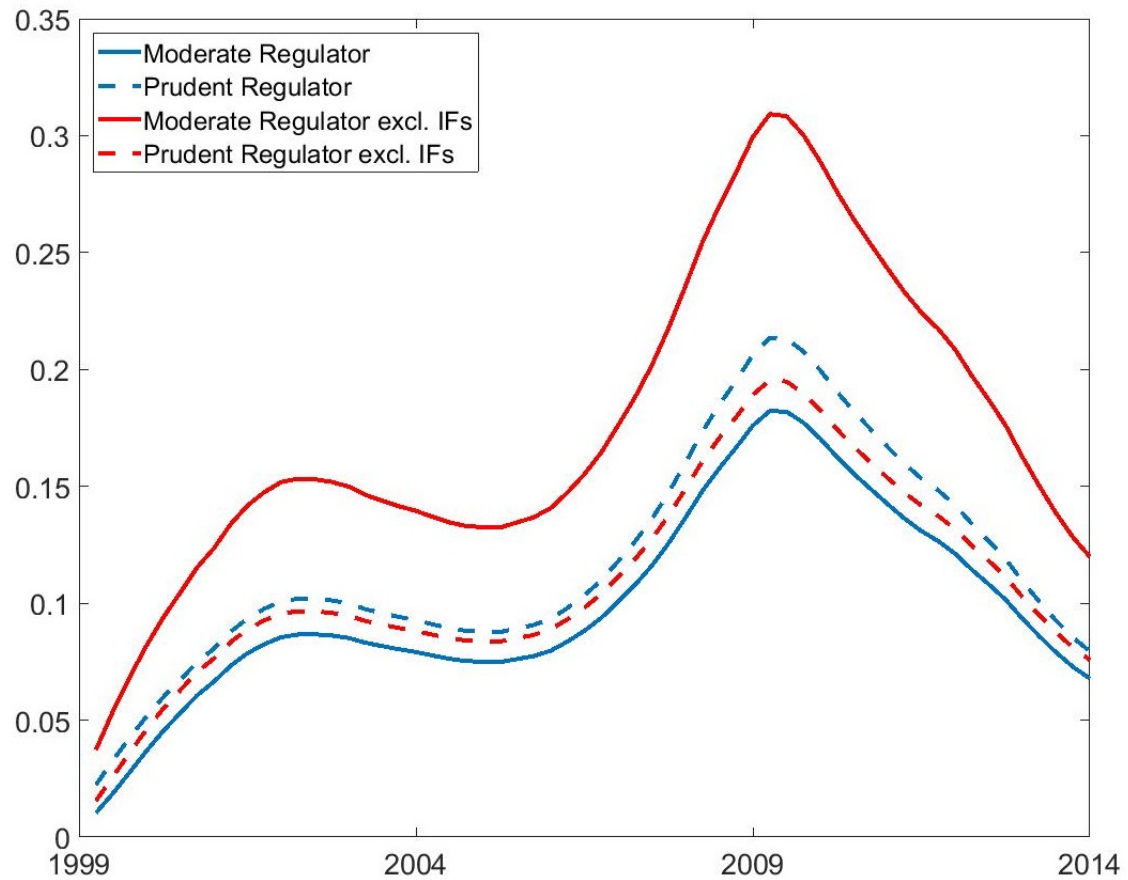
Figure 7: Counterfactual Analysis: Different Regulatory Regimes



Whereas all regulators would have acted in a countercyclical manner, the prudent regulator concerned with both credit intermediation from commercial and shadow banks, would have set relatively higher levels of requirements throughout the sample period. The naive regulator, however, would have prescribed capital requirements substantially below the levels suggested by both Basel II and Basel III until the onset of the financial crisis. At the peak of the financial crisis, the difference in the capital requirement suggested by the two regulators would have been almost 5 percentage points.

We furthermore evaluate both regulators that acknowledge the existence of shadow banks in a setting where we apply our alternative definition of shadow banks and exclude investment funds from the shadow bank aggregates (see Scenario 2 in Table 2). We therefore analogously re-estimate our model featuring the Basel II framework using our alternative shadow banking data described in section 5, see columns 7 to 10 in Tables 11 to 13. We then, again, implement the Basel III setup stemming from the estimation reported in Table 10 ($\phi^\nu = 3.02$ and $\overline{\nu^C} = 0.105$) and simulate the path of requirements set by the two policy makers acknowledging shadow banks as above. The respective prescriptions are plotted in Figure 8.

Figure 8: Counterfactual Analysis: Different Shadow Bank Definitions



Interestingly, excluding investment funds from the shadow bank aggregate alters the relative levels suggested by the moderate and prudent regulators. In the alternative specification, a regulator considering both shadow bank and commercial bank credit would prescribe relatively lower levels of capital holdings as in the benchmark case.

8 Conclusion

TO BE WRITTEN

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A Appendix: Two-Period Model

A.0.1 Theorem 1

Subject to constraints 1, 2 and 3 in equation 5, the first-order conditions of the saver can be combined to yield:

$$1 + r^{dc} = \frac{u'(c)}{\beta^s [pu'(C^+) + (1-p)u'(C^-)]} \quad (70)$$

$$1 + r^{ds} = \frac{u'(c)}{\beta^s [pu'(C^+)]} \quad (71)$$

With log-utility, taking ratios of equations 67 and 68, we get

$$\frac{1 + r^{ds}}{1 + r^{dc}} = 1 + \frac{1-p}{p} \frac{C^+}{C^-} \quad (72)$$

and plugging in constraints 2 and 3 yields

$$\frac{d^s}{d^c} = \frac{(1 + r^{ds})p - (1 + r^{dc})}{(1 + r^{ds})(1 - p)} \quad (73)$$

A.0.2 Theorem 2

$\frac{d^s}{d^c} \geq 0$. This implies that

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

and thus

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

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 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

$$1 + r^{ds} = \frac{1 + r^{dc}}{p} \quad (74)$$

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

$$1 + r^{ds} = \frac{1 + r^{dc}}{1 - \tau^s} \quad (75)$$

that we stated above.

A.0.3 Theorem 3

We can derive an expression for commercial bank deposits from equation 70:

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

We furthermore get from equation 68 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 70 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

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

Define the numerator of the term on the left-hand side of the above equation as x such that

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

Then

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

Plugging back in yields

$$d^s = \frac{\beta^s}{1 + \beta^s} \frac{(1 + r^{ds})p - (1 + r^{dc})}{r^{ds} - r^{dc}} y \quad (76)$$

and therefore

$$d^c = \frac{\beta^s}{1 + \beta^s} \frac{(1 + r^{ds})(1 - p)}{r^{ds} - r^{dc}} y \quad (77)$$

Finally, using equations 73 and 74 in constraint 1, with equality we get

$$c = y \left(\frac{1}{1 + \beta^s} \right) \quad (78)$$

A.1 Theorem 4

Plugging in constraints 8 and 9, the maximization yields

$$\max_{b^c, b^s} u(b) + \beta^b u(y^b - (1 + r^b)b) \quad (79)$$

$$1 + r^b = \frac{u'(c^b)}{\beta^b u'(C^b)} \quad (80)$$

Assuming log-utility we get

$$1 + r^b = \frac{C^b}{\beta^b c^b}. \quad (81)$$

Solving equation 9 for b and plugging in equation 8 yields the intertemporal budget constraint

$$c^b + \frac{C^b}{1 + r^b} \leq \frac{y^b}{1 + r^b} \quad (82)$$

Equation 79 states that present discounted value of borrower consumption cannot exceed present discounted wealth.

Solving 78 for C^b and substituting in 79 yields

$$c^b \leq \frac{y^b}{(1 + r^b)(1 + \beta^b)} \quad (83)$$

indicating that period-one consumption decreases in the lending rate r^b and in the discount factor β^b .

Combining equations 8 and 80 ultimately gives

$$b \leq \frac{y^b}{(1+r^b)(1+\beta^b)} \quad (84)$$

From the intertemporal budget constraint 79 we get with equality

$$C^b = y^b - (1+r^b)c^b$$

such that

$$C^b = y^b \frac{1}{1+\beta^b} \quad (85)$$

B Appendix: Data

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 log-differenced data to have 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 9.

B.1 Real Economic Data

Real GDP: Real gross domestic product, euro area 19 (fixed composition), deflated using 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) overall index, quarterly changes, euro area (changing composition), net inflation rate, calendar and seasonally adjusted data.

Wage inflation: Labour 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.

B.2 Commercial Bank 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: Annualised 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 Q1 2003: 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 Q1 2003: MFI Interest Rate Statistics (MIR), harmonized data.

B.3 Shadow Bank Data

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.

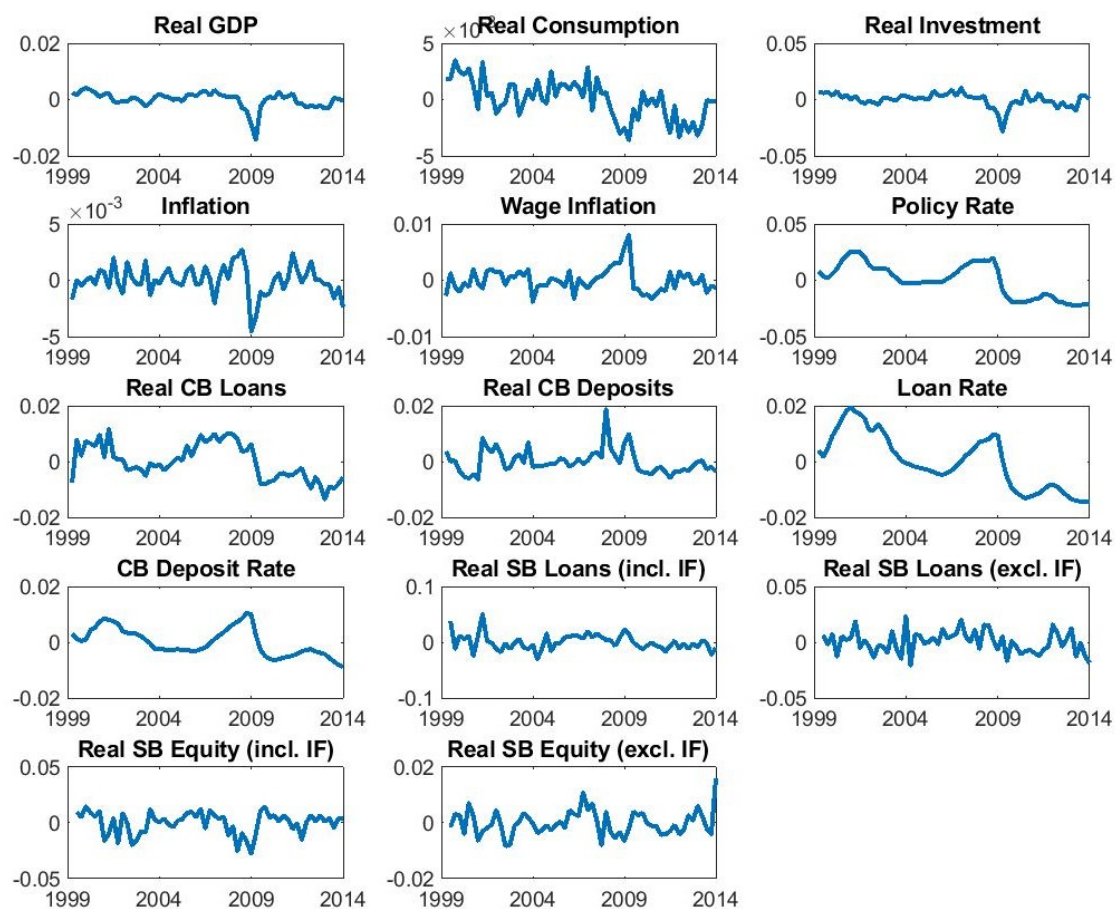
Shadow bank equity (including investment funds): Equity issued by OFI sector, excluding insurance corporations and pension funds, including investment fund shares/units, including money market fund (MMF) shares/units, euro area 19 (fixed composition), deflated using HICP, calendar and seasonally adjusted 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.

Shadow bank equity (excluding investment funds): Equity issued by OFI sector, excluding insurance corporations and pension funds, excluding investment fund shares/units, including money market fund (MMF) shares/units, euro area 19 (fixed composition), deflated using HICP, calendar and seasonally adjusted data.

Figure 9: 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.