The Role of Shadow Banking in the Monetary Transmission Mechanism and the Business Cycle

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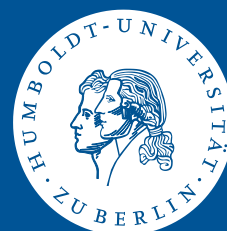
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Abstract

This paper investigates the heterogeneous impact of monetary policy shocks on financial intermediaries. I distinguish between banks and shadow banks based on their funding constraints. Because credit creation by banks responds to economy-wide productivity endogenously, bank reaction to shocks corresponds to the balance sheet channel. Shadow banks are constrained by their available funding and their behavior is better explained by the lending channel. In line with empirical observations, shadow bank lending moves in the opposite direction to bank lending following monetary policy shocks, which mitigates aggregate credit responses. The propagation of real and financial shocks is likewise altered when shadow banks are identified as a distinct sector among financial intermediaries. Following estimation of the model using Bayesian methods, a historical shock decomposition highlights the roles of banks and shadow banks in the run-up to the 2007 - 08 financial crisis.

Keywords: Shadow Banking, Monetary Policy Transmission, Credit Channel, Bayesian Methods, Search Frictions

1 Introduction

Loan issuance is traditionally understood as one of the core functions of the banking sector. However, the data show that the volume of financial intermediation via non-bank financial institutions (NBFI), i.e. the market based or shadow banking sector, has been rising in the last decades, even overtaking the traditional banking sector in several countries, see FSB (2014) [9]. Reacting to this development, Woodford (2010) [29] calls for "a framework for macroeconomic analysis in which intermediation plays a crucial role and [...] which also takes account of the fact that the U.S. financial sector is now largely market-based." Although the financial sector has been incorporated in recent models, it is still largely treated as a relatively homogeneous entity. However, empirical studies indicate that banks and shadow banks react to shocks in different ways.[1] Consider monetary policy: While banks reduce the amount of loans on their balance sheets following monetary policy tightening, shadow banks increase lending (Figure 1). This suggests that the share of credit intermediation via the shadow banking sector is an important determinant of the effectiveness of monetary policy on aggregate lending and the economy.
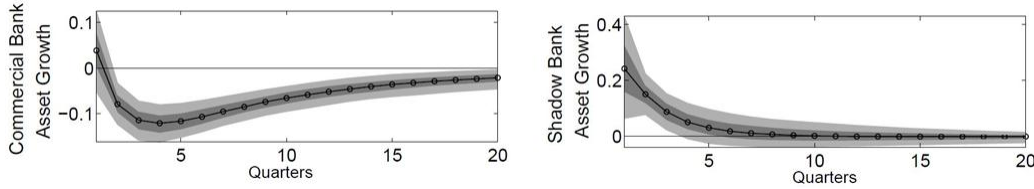

Figure 1: Impact of a 100bp increase in the monetary policy rate on bank and shadow bank lending (Source: Nelson, Pinter, Theodoridis, 2015)

In this paper I will answer the following questions: How does the monetary transmission channel via shadow banks work and how can it be modeled? How does the resulting credit intermediation of shadow banks affect the reaction of *aggregate* loan supply to monetary policy? In addition, if the inclusion of shadow banks changes the propagation of shocks, what has been its contribution to macroeconomic fluctuations in recent years?

To answer these questions I develop a structural model that distinguishes between banks and shadow banks based on their ability to create credit. I use the monetary DSGE model with financial intermediaries by Gertler and Karadi (2011) [10] (GK11 from here on) to describe bank behavior and credit creation, and I extend it with a shadow banking sector. In this model, banks create credit endogenously in the sense of "inside money" as in Kiyotaki and Moore (2004) [18]. Shadow banks need to raise funds from households to satisfy firm loan demand. I model fund raising by shadow banks as a search in the funding market for previously created deposits, which are held by the household sector. Following Wasmer and Weil (2004) [28], I model funding market frictions analogously to those on the labor market because of their comparable characteristics of "moral hazard, heterogeneity and specificity". After establishing a funding match, shadow banks have the ability to issue short-term debt (Sunderam, *forthcoming* [25]; OFR, 2013 [22]), i.e. repurchase agreements (repo).

In GK11, an increase in the monetary policy rate leads to an increase in the external finance

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[1]See Altunbas, Gambacorta and Marques-Ibanez (2009) [1]; Den Haan and Sterk (2010) [13]; Igan et al. (2013) [15]; Nelson, Pinter and Theodoridis (2015) [21].

premium for borrowers, prompting a decrease in the value of their collateral, thereby decreasing the willingness of banks to lend. The resulting deleveraging results in a credit squeeze for the real sector, disinvestment and a fall in output. Simultaneously, increased deposit rates discourage households from current consumption and instead encourage savings. In this paper, savings in the form of deposit holdings constitute available funds for the shadow banking sector. After an increase in the monetary policy rate, this increase in available funds for shadow banks results in a higher share of savings flowing into the shadow banking sector. Shadow banks lend out these additional funds and thereby alleviate the credit squeeze, mitigating the fall in investments and any consequent recession.

Shadow bank credit is constrained by the supply of available funding and their reaction is accurately explained by the lending channel (Bernanke and Gertler, 1995 [4]). Banks are less constrained by the supply of loanable funds than shadow banks since they can create credit endogenously. Their reaction to monetary policy therefore corresponds more closely to the balance sheet channel (Disyatat (2011) [8]). By incorporating the quantitatively important shadow banking sector I am able to assess the effects of the lending channel for shadow banks compared to the balance sheet channel for banks. Since the non-bank financial sectors have a different size in different jurisdictions, this model extension can help to better assess the impact of monetary policy shocks on aggregate lending and the economy, depending on the share of shadow banks in aggregate lending. In addition, the present paper lays out a simple way to extend financial models by adding a shadow banking sector, or alternatively, the recognition of a lending channel.

Existing macroeconomic models of shadow banking include Meeks, Nelson and Alessandri (2014) [20]; Verona, Martins and Drumont (2013) [27]; and Goodhart et al. (2012) [12]. The first is mainly concerned with financial stability and considers shadow banks as off balance sheet vehicles of commercial banks to unload risky loans. Verona et al. study adverse effects of excessively easy monetary policy and understand shadow banks as financial intermediaries specializing in less risky loans akin to bond issuance by investment banks. Goodhart et al. study different regulatory regimes to stop fire sales by shadow banks and take the opposite view to Verona et al., considering shadow banks to be less risk averse, but still funded by the regular banking sector, comparable to off balance sheet vehicles as in Meeks et al.

Search and matching in credit markets has been studied since Dell'Arricia and Garibaldi (1998) [6]. Den Haan, Ramey and Watson (2003) [7] analyze the business cycle effects of long-term lending relationships with frictions. Wasmer and Weil (2004) [28] study the effects of credit market frictions on labor market dynamics. What these models have in common is that the total amount of credit to be allocated is either fixed exogenously or is influenced endogenously but without any relation to credit creation by banks. This paper explicitly focuses on this interaction.

In the next section, I will describe the basic model with a simple shadow bank extension and further consider how endogenous credit (repo) creation by shadow banks can be incorporated into the analysis. Section 3 contains the model analysis, including Bayesian estimation of newly introduced structural parameters and all shock parameters, impulse response functions to monetary policy shocks and a historical shock decomposition. Section 4 concludes.

2   The Model

This section lays out the basic model. It is the monetary DSGE model with financial intermediaries by GK11. I add a second financial intermediation sector, called the non-bank financial or shadow banking sector, that issues loans to firms. Shadow banks first need to raise funds from households

in the form of deposits to engage in firm lending. Irrespective of whether shadow banks lend to the real sector directly, or whether they buy securitized credit claims of previously originated loans, shadow banks become the effective intermediary, and banks' balance sheets are freed up.

In this model the economy is populated by six types of agents: households, banks, shadow banks, non-financial goods producers that demand loans, capital producers, and monopolistically competitive retailers. A central bank conducting monetary policy is the source of monetary disturbances and completes the model. The setup is equivalent to GK11 with the addition of shadow banks and an additional household savings technology.

2.1 Households

A continuum of households of measure one exists with each household constituting a family separated into a share $1 - f$ of "workers" and a share f of "bankers". Bankers manage the financial intermediaries called banks, accumulate profits over several periods, and eventually redistribute them back to the households. Workers consume, save and supply labor. They maximize discounted lifetime utility[2]

$$\max_{C_t, B_{t+1}, L_t} E_t \sum_{i=0}^{\infty} \beta^i [ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi^{HH}}{1+\varphi} L_{t+i}^{1+\varphi}]$$

subject to the sequence of period budget constraints

$$C_t + B_{t+1} + T_t = W_t L_t + \Pi_t + R_t^w B_t.$$

Each unit of labor L_t earns the real wage W_t. B_t are savings in the form of government bonds, deposits held at banks, or fund shares with shadow banks. Government bonds and deposits are both riskless and are treated as substitutes. Savings pay the weighted interest rate R_t^w based on the allocation of deposits in banks and fund shares in shadow banks. Π_t are profits from ownership of capital producers, retailers and financial intermediaries, both banks and shadow banks. β is the discount factor, h is the habit parameter, χ^{HH} is the relative utility weight of labor and φ is the inverse Frisch elasticity of labor supply.

With ϱ_t denoting marginal utility of consumption, the first order conditions for consumption and labor are given by, respectively,

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

$$\varrho_t W_t = \chi^{HH} L_t^{\varphi} \tag{2}$$

with the Euler condition and marginal rate of substitution between consumption today and tomorrow given by, respectively,

$$E_t \beta \Lambda_{t,t+1} R_{t+1}^w = 1 \tag{3}$$

$$\Lambda_{t,t+1} = \frac{\varrho_{t+1}}{\varrho_t}. \tag{4}$$

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[2]For simplicity, I will abstract from equations of the individual agents and instead show their aggregate form directly, distinguishing between individual and aggregate forms as necessary. For more detail, GK11 show individual agents' equations.

2.2 Banks

Banks' balance sheets are given by

$$Q_t S_t = D_{t+1} + N_t. \tag{5}$$

Banks fund their loan portfolio S_t priced at Q_t through their net worth N_t and deposits obtained from households D_{t+1} other than their family members. Because they pay interest on deposits of R_{t+1} and earn a return R_{kt+1} on their loans, an individual bank's net worth evolves according to

$$\begin{aligned} N_{t+1} &= R_{kt+1} Q_t S_t - R_{t+1} D_{t+1} \\ &= (R_{kt+1} - R_{t+1}) Q_t S_t + R_{t+1} N_t. \end{aligned}$$

Banks want to maximize their expected terminal net wealth before they exit the industry with a probability θ per period and pay out all the accumulated profits to their respective households. Expected terminal net wealth is given by

$$\begin{aligned} V_t &= E_t \sum_{i=0}^{\infty} (1 - \theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} N_{t+1+i} \\ &= \nu_t Q_t S_t + \eta_t N_t \end{aligned}$$

where the second line is the equivalent recursive formulation. The marginal expected discounted value of net worth is η_t and ν_t is the marginal expected discounted value of expanding assets

$$\nu_t = E_t[(1 - \theta)\beta \Lambda_{t,t+1}(R_{kt+1} - R_{t+1}) + \beta \Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}] \tag{6}$$

$$\eta_t = E_t[(1 - \theta) + \beta \Lambda_{t,t+1} z_{t,t+1}\theta \eta_{t+1}] \tag{7}$$

and the growth rate in net worth $z_{t,t+1}$ and the growth rate in assets is $x_{t,t+1}$ defined below.

It is profitable to increase the loan portfolio as long as the interest rate differential is positive. To motivate an endogenous constraint on banks' ability to obtain funds, an agency problem as in GK11 and Gertler and Kiyotaki (2010) [11] is introduced: every period a banker can divert a fraction of the loan portfolio λ_t that the depositors at the bank are not able to recover. As a consequence, the bank goes bankrupt. Therefore, households will keep their deposits at individual banks only as long as the franchise value of the bank, V_t, is higher than or equal to the divertible amount, which guarantees the banker's interest in not stealing from the bank:

$$V_t \geq \lambda_t Q_t S_t.$$

The divertible fraction λ_t is a time dependent AR(1) process with persistence ρ_λ, which is included to analyze the role of trust in banks and a corresponding ability to lever up. I will assume that the constraint always binds, and after substituting and rearranging, the size of a banker's loan portfolio then depends on the size of their net wealth according to

$$Q_t S_t = \frac{\eta_t}{\lambda_t - \nu_t} N_t \tag{8}$$

and the leverage ratio can be defined as

$$\phi_t \equiv \frac{\eta_t}{\lambda_t - \nu_t}. \tag{9}$$

The growth rate in net worth $z_{t,t+1}$ and the growth rate in assets $x_{t,t+1}$ are defined as

$$
\begin{aligned}
z_{t,t+1} &= \frac{N_{t+1}}{N_t} \\
&= \frac{(R_{kt+1} - R_{t+1})Q_t S_t + R_{t+1}N_t}{N_t} \\
&= (R_{kt+1} - R_{t+1})\phi_t + R_{t+1} \quad (10) \\
x_{t,t+1} &= \frac{Q_{t+1}S_{t+1}}{Q_t S_t} \\
&= \frac{\phi_{t+1}N_{t+1}}{\phi_t N_t} \\
&= \frac{\phi_{t+1}}{\phi_t}z_{t,t+1}. \quad (11)
\end{aligned}
$$

Since a constant share $1 - \theta$ of bankers dies every period and distributes its retained earnings to their households, $f(1 - \theta)$ workers become new bankers. They receive the same start-up net worth N_{nt} as in GK11. Net worth of existing banks N_{et} and new banks N_{nt} make up aggregate net worth N_t according to

$$
\begin{aligned}
N_t &= N_{et} + N_{nt} & (12) \\
N_{et} &= \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]N_{t-1} & (13) \\
N_{nt} &= \omega Q_t S_{t-1}. & (14)
\end{aligned}
$$

Note that existing net worth is predetermined. The only way banks can react to changing loan demand within the period is via the adjustment of the leverage ratio, as well as via the change of capital prices Q_t in the start-up net worth N_{nt}. The leverage ratio reacts to a change in economy-wide productivity endogenously, as can be seen by its dependence on the borrowing rate and monetary policy rate in equation 6.

2.3 Shadow Banks

Shadow banks cannot create credit, but instead sell fund shares, FS_t, to households[3]. The amount of loans S_t^{SB} that shadow banks can issue to the goods producers is therefore given by their balance sheet constraint:

$$
Q_t S_t^{SB} = FS_t. \quad (15)
$$

The shadow bank is a simple intermediary with no liquidity transformation on its balance sheet in line with the loanable funds model. To raise funds from households, shadow banks spend v_t in advertisements for their fund shares FS_t, which have a probability q_t of being successfully matched with a deposit. The idea behind this is to model investor-fund heterogeneity implicitly as in Wasmer and Weil (2004) [28]. Shadow banks need to advertise their operations, which is costly. However, not every advertisement speaks to every household. Households may disagree with investment conditions, the targeted borrower base or the fund manager. Therefore every advertisement only has a certain probability of being matched with a given deposit by a household and stays unmatched otherwise.

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[3]I will introduce deposit-like credit claims of shadow banks in Section 2.8.

Accordingly, shadow banks maximize their discounted future profits by choosing fund advertisements and loan issuance S_t^{SB}:

$$\max_{v_t, S_t^{SB}} E_t \sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+i} \Pi_{t+i}^{SB}$$

with shadow bank profits

$$\Pi_t^{SB} = (R_{kt} - R_t^{SB}) Q_{t-1} S_{t-1}^{SB} - v_t.$$

Shadow bank profits are made up of the interest rate differential times the volume of funds they intermediate net of advertising expenses. The interest rates they pay on fund shares, R_t^{SB}, is negotiated further below.

Once a shadow bank has exchanged fund shares for deposits with households, the match will stay put until the household withdraws the initial bank deposit. As is common with separation of firm-worker matches in the search and matching literature, I do not model fund redemption explicitly, but instead assume a constant probability of separation χ^{SB}, which results in a law of motion for fund shares: Shadow banks' period t sources of funding consist of the fund shares that have not been redeemed plus the new matches from fund advertisement given by

$$FS_t = (1 - \chi^{SB}) FS_{t-1} + q_t v_t. \tag{16}$$

The first order conditions for posting fund unit advertisements and loan issuance are, respectively,

$$\tilde{\varrho}_t = \frac{1}{q_t},$$

$$\tilde{\varrho}_t Q_t = \beta \Lambda_{t,t+1} \left\{ (R_{kt+1} - R_{t+1}^{SB}) Q_t + \tilde{\varrho}_{t+1} (1 - \chi^{SB}) Q_t \right\}$$

with $\tilde{\varrho}_t$ the Lagrangian multiplier on the constraint (16). Combining these equations results in the Euler condition for fund advertisements:

$$\frac{1}{q_t} = E_t \beta \Lambda_{t,t+1} \left\{ (R_{kt+1} - R_{t+1}^{SB}) + (1 - \chi^{SB}) \frac{1}{q_{t+1}} \right\}. \tag{17}$$

New advertisements will be posted until the marginal cost of matching an additional fund unit equals the marginal benefit of having matched an additional fund unit, which is the combination of the interest rate differential and avoided future search costs by having established a match in the previous period.

2.3.1   Matching

Individual savers and individual shadow banks searching for funds randomly meet and evaluate the potential for a match in isolation. In the aggregate, this behavior is approximated via a matching technology. To compute the probability of matching a shadow bank looking for funds with a household I assume a funding market matching function $m(v_t, D_{t+1} - FS_t)$ that is increasing in its arguments, the number of fund unit advertisements v_t and the number of 'unemployed' funds $D_{t+1} - FS_t$. If a unit of deposits has been exchanged for a fund share, it is not available for the remaining searching shadow banks any longer and hence 'employed'. I define unemployed funds as

$$D_{t+1}^u \equiv D_{t+1} - FS_t. \tag{18}$$

Assuming a constant returns to scale matching function, the probability that a shadow bank will find suitable funding is then

$$q(\theta_t) = m(1, \theta_t^{-1}) = \frac{m(v_t, D_{t+1}^u)}{v_t} = s\theta_t^{-\xi} \tag{19}$$

with matching elasticity ξ, matching efficiency s, and funding market tightness θ_t given by

$$\theta_t \equiv \frac{v_t}{D_{t+1}^u}. \tag{20}$$

2.3.2 Interest Rate Bargaining

Because of the existence of search frictions, shadow banks enjoy a rent on established matches. I assume that the interest rates shadow banks pay on funds raised is determined via Nash bargaining over these surpluses. ω^{HH} signifies the relative bargaining power of households. Interest rates R_{t+1}^{SB} are negotiated that maximize a convex combination of the surpluses,

$$R_{t+1}^{SB} = argmax \quad \omega^{HH} ln V_t^{HH} + (1 - \omega^{HH}) ln V_t^{SB}.$$

The resulting interest rate that shadow banks pay for funds raised is (see Appendix A.1 for details)

$$R_{t+1}^{SB} = (1 - \omega^{HH})R_{t+1} + \omega^{HH} \{R_{kt+1} + \theta_{t+1}\}. \tag{21}$$

If household bargaining power is low, shadow banks can get away with paying only the interest rate R_{t+1} that banks pay on their deposits. With increasing bargaining power, shadow banks need to share expected profits with investing households.

The interest rate that households receive on their savings is the weighted average of interests payments from holdings of deposits and holdings of fund shares

$$R_t^w = R_t \frac{D_t}{B_t} + R_t^{SB} \frac{FS_{t-1}}{B_t}. \tag{22}$$

2.4 Goods Producers

Perfectly competitive goods producers manufacture intermediate goods and sell them to the retailer at the relative intermediate output price P_{mt}. Goods producers need to finance their capital expenditures via loans from intermediaries, which they may borrow without frictions, i.e. intermediaries can enforce all of their claims. However, since banks are constrained in the amount of deposits they can issue and shadow banks are constrained in the amount of funds they can raise, lending by intermediaries is capital constrained, which affects the supply of funds to firms and therefore the required interest rate for borrowing, R_{kt+1}. Except for the addition of another source of funding, capital producers are identical to those in GK11.

The firm maximizes its profits by choosing capital K_{t+1} and labor L_t optimally each period.

$$\max_{K_{t+1}, L_t} E_t \sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+1} \left[P_{mt} Y_t + (Q_t - \delta)\xi_t K_t - W_t L_t - R_{kt} K_t Q_{t-1} \right]$$

with production output given by

$$Y_t = A_t(\xi_t K_t)^\alpha L_t^{1-\alpha} \tag{23}$$

where α is the capital share, Q_t is the real price of capital, δ is the depreciation rate and W_t are wages.

The first-order conditions are

$$R_{kt+1} Q_t = P_{mt+1} \alpha \frac{Y_{t+1}}{K_{t+1}} + (Q_{t+1} - \delta) \tag{24}$$

$$P_{mt}(1-\alpha)\frac{Y_t}{L_t} = W_t. \tag{25}$$

Firms do not earn any profits and pay out ex post returns to capital as interest payments, resulting in no profits state by state. They pay out all their profits to their creditors, who are a combination of banks and shadow banks according to

$$K_{t+1} = S_t + S_t^{SB}. \tag{26}$$

2.5 Capital Producers

Following GK11, capital producers buy leftover capital from goods producers which they refurbish, for which the price is unity. Units of new capital are made using input of final output and are then sold to goods producers at Q_t, which capital producers set by solving

$$\max_{I_{nt}} E_t \sum_{\tau=t}^\infty \beta^{\tau-t} \Lambda_{t,\tau} \left\{ (Q_\tau - 1)I_{n\tau} - f\left(\frac{I_{n\tau} + I_{SS}}{I_{n\tau-1} + I_{SS}}\right)(I_{n\tau} + I_{SS}) \right\}$$

with

$$I_{nt} \equiv I_t \mu_t - \delta \xi_t K_t.$$

Following the literature on the importance of marginal efficiency of investment (Justiniano, Primiceri, Tambalotti, 2010) [17], investment specific shocks μ_t affect the transformation of gross investment into net investment. The functional form of $f(.)$ obeys $f(1) = f'(1) = 0$ and $f''(1) > 0$. $f(.)$ determines capital adjustment costs with the steady state value for investments given by I_{SS}. The capital producer thus creates profits outside of the steady state. Households receive profits from sales of new capital at price Q_t, which is given by the first-order condition

$$Q_t = 1 + f(.) + \frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}}f'(.) - E_t\beta\Lambda_{t,t+1}\left(\frac{I_{nt+1} + I_{SS}}{I_{nt} + I_{SS}}\right)^2 f'(.). \tag{27}$$

2.6 Retailers

Retailers buy intermediate goods from goods producers at the relative intermediate output price P_{mt}. Final output is the CES composite of a continuum of output by each retailer f with the elasticity of substitution ϵ, given by

$$Y_t = \left[\int_0^1 Y_{ft}^{\frac{\epsilon-1}{\epsilon}} df\right]^{\frac{\epsilon}{\epsilon-1}}.$$

Because users of final output minimize costs, we get

$$Y_{ft} = \left(\frac{P_{jt}}{P_t}\right)^{-\epsilon} Y_t$$

$$P_t = \left[\int_0^1 P_{ft}^{1-\epsilon} df\right]^{\frac{1}{1-\epsilon}}.$$

Each retailer can reset prices with probability $1 - \gamma$ each period. Retailers will otherwise index their prices to lagged inflation. The retailers then choose their reset price P_t^* optimally to solve

$$\max_{P_t^*} E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+1} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i}(1 + \pi_{t+k-1})^{\gamma_p} - P_{mt+i}\right] Y_{ft+i}.$$

The first-order condition is given by

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+1} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i}(1 + \pi_{t+k-1})^{\gamma_p} - \frac{\epsilon}{\epsilon - 1} P_{mt+i}\right] Y_{ft+i} = 0.$$

The evolution of the price level is given by

$$P_t = [(1 - \gamma)(P_t^*)^{1-\epsilon} + \gamma(\Pi_{t-1}^{\gamma_p} P_{t-1})^{1-\epsilon}]^{1/(1-\epsilon)}. \tag{28}$$

2.7 Resources and Policy

The aggregate resource constraint is given by

$$Y_t = C_t + v_t + I_t + f\left(\frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}}\right)(I_{nt} + I_{SS}) + G_t, \tag{29}$$

capital evolves according to

$$K_{t+1} = \xi_t K_t + I_{nt} \tag{30}$$

and stochastic government expenditures are financed via lump sum taxes

$$G_t = T_t. \tag{31}$$

Monetary policy is characterized by a Taylor rule. The nominal interest rate is given by i_t, with a steady state interest rate of i_{SS}, the natural rate of output given by Y_t^*, an interest rate smoothing parameter ρ, the inflation coefficient κ_π and the output gap coefficient κ_y:

$$i_t = (1 - \rho)[i_{SS} + \kappa_\pi \pi_t + \kappa_y(logY_t - logY_t^*)] + \rho i_{t-1} + \epsilon_t. \tag{32}$$

The exogenous shock to monetary policy enters the nominal interest rate as ϵ_t. The nominal interest rate has an effect on the economy through the Fisher relation

$$1 + i_t = R_{t+1} E_t(1 + \pi_{t+1}). \tag{33}$$

2.8 Extension: Repo creation by Shadow Banks

Some shadow banks can issue repo, B_{t+1}^{SB}, just like banks issue deposits. Not every agent in the economy accepts these credit claims as payment. Only deposits are accepted by everyone[4]. Therefore, shadow banks have to always have deposits available, which they raise on the funding markets from households. Their credit claim issuance depends on the amount of funds raised. Shadow banks' balance sheets are now given by

$$Q_t S_t^{SB} = B_{t+1}^{SB} + FS_t. \tag{34}$$

Shadow banks can now fund their loan portfolio S_t^{SB} priced at Q_t through raising funds FS_t and through issuing credit claims B_{t+1}^{SB}. Shadow banks have a fiduciary duty with respect to the fund shares that they manage. They will therefore maximize their net wealth. Since the interest rate on credit claims is determined in the period in which they are issued, it is not risky and equal to the interest rate paid on deposits, R_{t+1}. Shadow banks' net worth then evolves according to

$$FS_{t+1} = R_{kt+1}Q_t S_t^{SB} - R_{t+1}B_{t+1}^{SB}$$
$$= (R_{kt+1} - R_{t+1})Q_t S_t^{SB} + R_{t+1}FS_t.$$

The net wealth of a shadow bank evolves until its fund shares are redeemed for deposits as

$$V_t^{SB} = E_t \sum_{i=0}^{\infty} \chi^{SB}(1 - \chi^{SB})^i \beta^{i+1}\Lambda_{t,t+1+i}FS_{t+1+i}$$
$$= \nu_t^{SB}Q_t S_t^{SB} + \eta_t^{SB}FS_t$$

with η_t^{SB} being the marginal expected discounted value of fund shares and ν_t^{SB} being the marginal expected discounted value of expanding assets

$$\nu_t^{SB} = E_t[\chi^{SB}\beta\Lambda_{t,t+1}(R_{kt+1} - R_{t+1}) + \beta\Lambda_{t,t+1}(1 - \chi^{SB})x_{t,t+1}^{SB}\nu_{t+1}^{SB}] \tag{35}$$
$$\eta_t^{SB} = E_t[\chi^{SB} + \beta\Lambda_{t,t+1}z_{t,t+1}^{SB}(1 - \chi^{SB})\eta_{t+1}^{SB}] \tag{36}$$

and the growth rate in shadow bank assets $z_{t,t+1}^{SB}$ and the growth rate in shadow bank net worth

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[4]See Hicks' (1989 [14]) explanation of different acceptabilities of money in the context of the market for bills of exchange (Chapter 6), and Pozsar (2014) [24] who writes that "banks and demand deposits are special [...] because of their unique role in forming the backbone of the payments system and facilitating the payments of all entities lower in the system-hierarchy."

$x_{t,t+1}^{SB}$, respectively,

$$z_{t,t+1}^{SB} = \frac{FS_{t+1}}{FS_t}$$

$$= \frac{(R_{kt+1} - R_{t+1})Q_t S_t^{SB} + R_{t+1} FS_t}{FS_t}$$

$$= (R_{kt+1} - R_{t+1})\phi_t^{SB} + R_{t+1} \tag{37}$$

$$x_{t,t+1}^{SB} = \frac{Q_{t+1} S_{t+1}^{SB}}{Q_t S_t^{SB}}$$

$$= \frac{\phi_{t+1}^{SB} FS_{t+1}}{\phi_t^{SB} FS_t}$$

$$= \frac{\phi_{t+1}^{SB}}{\phi_t^{SB}} z_{t,t+1}^{SB}. \tag{38}$$

I now introduce the same incentive constraint for shadow banks as GK11 and Gertler and Kiyotaki (2010) assume for banks: every period a shadow banker can divert a fraction of the loan portfolio λ_t^{SB} that the holders of credit claims on the shadow bank would not be able to recover. As a consequence, the shadow bank would go bankrupt. As is the case for banks, the divertible share is a stochastic process to shed light on the role of trust in shadow banks, and the resulting ability to leverage. Households will hold credit claims on shadow banks only as long as the franchise value of the shadow bank is higher than or equal to the divertible amount,

$$V_t^{SB} \geq \lambda_t^{SB} Q_t S_t^{SB}.$$

When the incentive constraint binds, the size of a shadow banker's loan portfolio depends on the size of their net wealth according to

$$Q_t S_t^{SB} = \frac{\eta_t^{SB}}{\lambda_t^{SB} - \nu_t^{SB}} FS_t^{SB} \tag{39}$$

and the leverage ratio can be defined as

$$\phi_t^{SB} = \frac{\eta_t^{SB}}{\lambda_t^{SB} - \nu_t^{SB}}. \tag{40}$$

Since one additional unit of fund shares now leads to more than one additional unit of loans to the real economy, equation (15) is modified to equation (39). The Euler condition for fund advertisements changes accordingly:

$$\frac{1}{q_t} = E_t \beta \Lambda_{t,t+1} \left\{ R_{kt+1} \phi_t^{SB} - R_{t+1}^{SB} - (\phi_t^{SB} - 1)R_{t+1} + \frac{1 - \chi^{SB}}{q_{t+1}} \right\}. \tag{41}$$

The increased profit opportunity through credit claim issuance is also reflected in the bargained interest rate:

$$R_{t+1}^{SB} = R_{t+1} + \omega^{HH} \left[\phi_t^{SB}(R_{kt+1} - R_{t+1}) + \theta_{t+1} \right]. \tag{42}$$

Households' savings now consist of deposits held at banks, fund shares at shadow banks, and credit claims of shadow banks. The resulting weighted interest rate they earn is

$$R_t^w = R_t \frac{B_t}{B_t + FS_t + B_t^{SB}} + R_t^{SB} \frac{FS_t}{B_t + FS_t + B_t^{SB}} + R_t \frac{B_t^{SB}}{B_t + FS_t + B_t^{SB}}. \tag{43}$$

3 Model Analysis

In this section, I will first pin down the model parameterization using calibration and Bayesian estimation. Next, I analyze how monetary policy shocks propagate through the economy, both with and without shadow banks[5]. I then conduct a historical shock decomposition. The differing reactions of both channels are explained and their practical relevance is examined thereafter. The model is solved via first order perturbation around the deterministic steady state.

3.1 Parameterization

Most of the structural parameters are fixed and taken from GK11. The new parameters that follow the introduction of the shadow banking sector in Section 2.3 are the separation rate χ^{SB}, household bargaining power ω^{HH}, matching efficiency s and matching elasticity ξ. A new parameter from the shadow banks' ability to create repo in Section 2.8 is the mean value of λ_t^{SB}, the fraction of its loan portfolio a shadow banker may divert each period. Table 1 shows the fixed structural parameter values and their source.

All parameters describing the shock processes and structural parameters describing shadow banks are estimated using Bayesian methods. Banks are defined as US-chartered depository institutions and credit unions. Shadow banks combine Finance Companies, Funding Corporations, Asset-backed Security Issuers and Money Market Mutual Funds. The macroeconomic time series underlying the data for observables are real GDP, real investment, real government expenditures and the GDP price deflator (all from the Bureau of Economic Analysis). Data on banks and shadow banks are taken from the Flows of Funds. For both sectors, we include time series on financial assets as well as the amount of fixed income liabilities. Since the model is expressed in log-deviations from steady state for estimation purposes, I take the log difference from the HP filtered trend (smoothing parameter is set to 1600). The data have a quarterly frequency and range from 1985:Q1 to 2008:Q4. Although earlier data are available, the shadow banking sector was a much smaller component of aggregate credit before 1985. I drop data after 2008 because the financial crisis and its aftermath had significant effects on the regulation and perception of the shadow banking sector. This is likely to have caused structural breaks and would change the parameters underlying the financial sector.

Although variable and increasing, shadow banks' balance sheets averaged about 50% of bank balance sheets from 1990 to 2007 (Flows of Funds). The prior for the matching efficiency is chosen such that the steady state credit intermediation by shadow banks is about 50%, see Table 2. For the separation rate, I choose a value of 5% to correspond with the quarterly redemption rates of mutual funds in the US (Investment Company Institute, 2014 [16]). The priors for household bargaining power ω^{HH} and matching elasticity ξ are relatively uninformative Beta distributions centered around 0.5 and allowing for values in the open interval between 0 and 1. I choose a prior mean for λ_t^{SB}, the fraction of assets a shadow banker may divert, equal to the corresponding

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[5]I will consider the case with repo creation by shadow banks. For an analysis without repo creation, see a previous version of this paper at https://ideas.repec.org/p/hum/wpaper/sfb649dp2014-056.html

Symbol	Value	Description	Source
Households			
β	0.99	Discount rate	GK (2011)
h	0 / 0.815	Habit	GK (2011)
χ^{HH}	3.409	Relative utility weight of labor	GK (2011)
φ	0.276	Inverse Frisch elasticity of labor supply	GK (2011)
Banks			
λ	0.381	Fraction of bank assets that can be diverted	GK (2011)
ω	0.002	Proportional transfer to the incoming banks	GK (2011)
θ	0.972	Survival rate of a banker	GK (2011)
Goods Producers			
α	0.33	Effective capital share	GK (2011)
δ	0.025	Depreciation rate	GK (2011)
Retail Firms			
ϵ	4.167	Elasticity of substitution	GK (2011)
γ	0.779	Probability of keeping prices fixed	GK (2011)
γ_p	0.241	Price indexation	GK (2011)
Government			
G/Y	0.2	Steady state proportion of government expenditures	GK (2011)
κ_π	1.5	Inflation coefficient of Taylor rule	GK (2011)
κ_y	0.125	Output gap coefficient of Taylor rule	GK (2011)
ρ_i	0.8	Smoothing parameter of the Taylor rule	GK (2011)
Shocks			
ρ_a	0.95	Autocorrelation of technology shock	GK (2011)
σ_a	0.01	Standard deviation of technology shock	GK (2011)
σ_i	0.005	Standard deviation of interest rate shock	GK (2011)

Table 1: Calibrated parameter Values

parameter for banks from GK11. The priors for all persistence parameters are Beta distributions with a mean of 0.5 and a standard deviation of 0.2. The priors for the white noise processes on the innovations are Inverse Gamma distributions with means taken from GK11 and standard deviations of 0.05. The shock processes are a priori independent. I run 10 Monte Carlo Markov Chains with 100.000 draws each over the full sample period. Convergence is reached after about 50.000 draws (see Figure 9 in Appendix A.2) and I therefore drop the first 50% of estimated values.

The posteriors of the shock processes are informative (see Appendix A.2). Persistence is relatively high for all shock processes with the exception of capital quality and bank net wealth shocks. The posterior mode for λ^{SB} is much higher than the prior mean and corresponding parameter for banks. This means *ceteris paribus* that shadow banks are less able to leverage since they can divert more funds than banks[6]. Matching elasticity ξ is relatively high, implying that 'unemployed' deposits are relatively abundant. This is mirrored in the household bargaining power ω^{HH}, which has a relatively low posterior mode at 0.02.

3.2 Response to a monetary policy shock

Figure 2 shows impulse response functions for key variables after unexpected monetary policy tightening for the case with only banks and the case with shadow banks present (as well as the 90% highest posterior density intervals based on the Bayesian estimation).

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[6]In steady state, shadow banks may still have higher leverage than banks because the marginal expected discounted values of assets and net wealth will be higher than the corresponding values for banks.

		Prior			Posterior	
Symbol	Name	Type	Mean	Std. Dev.	Mode	Std. Dev.
Structural						
s	Matching efficiency	Beta	3	1	4.6	0.06
ξ	Matching elasticity	Beta	0.5	0.2	0.87	0.08
ω^{HH}	Shadow Bank divertibility	Beta	0.5	0.2	0.02	0.01
χ^{SB}	Separation rate	Beta	0.05	0.02	0.10	0.02
λ^{SB}	Shadow Bank divertibility mean	Beta	0.381	0.1	0.73	0.03
Persistences						
ρ_A	TFP	Beta	0.5	0.2	0.78	0.05
ρ_ξ	Capital Quality	Beta	0.5	0.2	0.04	0.03
ρ_g	Government Spending	Beta	0.5	0.2	0.75	0.06
ρ_i	Monetary Policy	Beta	0.5	0.2	0.7	0.06
ρ_{Ne}	Bank Net Wealth	Beta	0.5	0.2	0.16	0.03
ρ_{FS}	Fund Share Redemption	Beta	0.5	0.2	0.76	0.05
$\rho_{\lambda Ne}$	Bank divertible share	Beta	0.5	0.2	0.61	0.28
$\rho_{\lambda FS}$	Shadow Bank divertible share	Beta	0.5	0.2	0.76	0.06
ρ_{IE}	Investment Efficiency	Beta	0.5	0.2	0.63	0.08
Std dev.						
e_A	TFP	Inverse Gamma	0.010	0.05	0.009	0.001
e_ξ	Capital Quality	Inverse Gamma	0.010	0.05	0.010	0.001
e_g	Government Spending	Inverse Gamma	0.010	0.05	0.008	0.001
e_i	Monetary Policy	Inverse Gamma	0.010	0.05	0.003	0.001
e_{Ne}	Bank Net Wealth	Inverse Gamma	0.010	0.05	0.047	0.003
e_{FS}	Fund Share Redemption	Inverse Gamma	0.010	0.05	0.076	0.012
$e_{\lambda Ne}$	Bank divertible share	Inverse Gamma	0.010	0.05	0.004	0.001
$e_{\lambda FS}$	Shadow Bank divertible share	Inverse Gamma	0.010	0.05	0.163	0.002
e_{IE}	Investment Efficiency	Inverse Gamma	0.010	0.05	0.009	0.001

Table 2: Priors and Posteriors of Estimated Parameters

First, consider the case with no shadow banks present in the economy (red, dashed line). After an unexpected monetary tightening of about 33 basis points, interest rates on government bonds increase. To encourage depositors to keep their savings with banks instead of shifting them into government bonds, banks need to raise interest on deposits. At the same time, an increase in interest rates reduces the net present value of future operations and therefore net worth of firms. This also reduces the value of collateral necessary to finance capital acquisitions. Unable to post collateral, the least productive firms leave the market, which decreases capital demand, reduces investment and also the price of capital. This drop in the price for capital further decreases firms' net worth, pushing up the external finance premium and decreasing capital demand even more. In addition, higher deposit interest rates increase savings and reduce consumption. The drop in demand reduces prices and makes goods production even less profitable, putting further downward pressure on capital demand for production. A negative financial accelerator results, as in Bernanke, Gertler and Gilchrist (1996) [3].

With shadow banks present (blue, solid line) the initial reaction is the same. Deposit rates rise and, to keep profit margins up, banks raise the borrowing rate. However, now the rise in interest rates on government bonds, bank deposits and bank loans has another effect. Shadow banks negotiate the fund rate over their expected profits and households' alternative savings. Both the borrowing rate and deposit rates rise, which increases the fund rate. Since the borrowing rate increases more than the funds rate, the interest rate differential that shadow banks earn increases and makes intermediation more profitable, raising fund advertisement expenditures. This increases new fund share sales and allows the shadow banks to offer more credit. Since many previously creditworthy borrowers were pushed out of the market, shadow bank loans now replace some of the lost credit. This has a dampening effect on the fall in investment, which strongly reduces capital
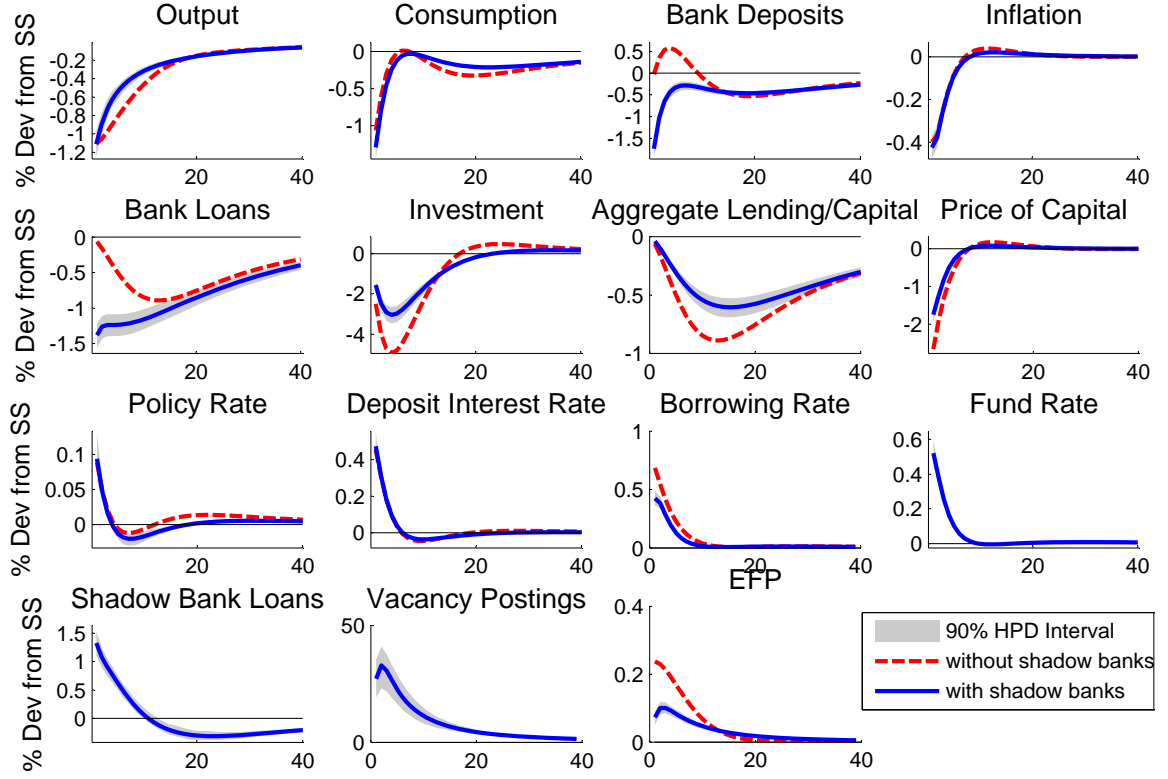
Figure 2: Impulse Responses to Monetary Policy Tightening

decumulation to about half the case without shadow banks present.

The behavior of shadow bank lending following a monetary policy tightening is consistent with empirical studies of the shadow banking system (see Figure 1 and Altunbas, Gambacrota and Marques-Ibanez (2009) [1]; Den Haan and Sterk (2010) [13]; Igan et al. (2013) [15]). Igan et al show that some shadow banks increase lending after monetary policy tightening, while banks reduce lending. Den Haan and Sterk show that both mortgages and consumption credit increase following an increase in the monetary policy rate. Finally, Altunbas et al show that European banks with more securitization activities reduce their lending by less than non-securitizing banks after monetary tightening. Given the European characteristic of universal banks that house both banking and shadow banking activities within the same group structure, this finding is in line with understanding securitizing banks to be less affected by monetary shocks because they house a larger shadow banking entity within their group structure, which insulates group lending behavior by increasing lending following monetary policy tightening.

3.3 Shadow Bank Contributions to the Business Cycle

Shadow banks change the way shocks propagate through the economy. Comparing variance decompositions of the GK11 economy with and without shadow banks shows that certain shocks are amplified while others are reduced, see Table 3. The contribution of technology shocks, both neutral and investment-specific, increases because shadow banks behave comparably to banks when real sector variables are affected. Shocks emanating from the banking sector are less pronounced, because the shadow banking sector offsets those developments. Contribution of shadow bank redemption rate shocks increases because the shadow banking sector has a bigger share of aggregate credit. Monetary policy shocks are an in-between case: their contribution to real variable variance decreases, while it increases for financial variables.

Series \shock	TFP	Mon Pol	Govt	Inv	Cap Quality	Bank NW	SB NW	Bank leverage	SB leverage
Output	17% / 21%	8% / 5%	0% / 0%	11% / 28%	16% / 14%	46% / 28%	2% / 3%	0% / 0%	0% / 0%
Hours	6% / 7%	5% / 5%	0% / 0%	3% / 7%	47% / 51%	38% / 31%	1% / 0%	0% / 0%	0% / 0%
Investment	15% / 23%	9% / 4%	1% / 1%	20% / 41%	5% / 10%	47% / 14%	2% / 7%	0% / 0%	0% / 0%
Consumption	12% / 15%	9% / 7%	0% / 0%	12% / 32%	6% / 3%	58% / 41%	3% / 2%	0% / 0%	0% / 0%
Borrowing rate	11% / 12%	5% / 4%	0% / 0%	3% / 5%	46% / 49%	34% / 28%	1% / 1%	0% / 0%	0% / 0%
Deposit rate	15% / 19%	16% / 15%	0% / 0%	28% / 46%	3% / 0%	36% / 14%	1% / 6%	1% / 1%	0% / 0%
Bank Leverage	17% / 20%	7% / 8%	0% / 0%	4% / 7%	41% / 44%	31% / 20%	1% / 1%	0% / 0%	0% / 0%
Inflation	13% / 13%	26% / 28%	0% / 0%	8% / 11%	31% / 34%	20% / 7%	0% / 6%	2% / 1%	0% / 0%
Bank Loans	11% / 14%	60% / 64%	0% / 0%	8% / 11%	1% / 1%	18% / 9%	1% / 1%	0% / 0%	0% / 0%

Table 3: Variance decomposition of key variables without / with shadow banking

Given the changed nature of shock propagation, it follows that macroeconomic fluctuations may be attributed to different developments. To shed light on past business cycles, I perform a historical shock decomposition of the dynamics of key variables. Parameters are fixed at the posterior mode and the Kalman smoother is used to identify shock timelines that best explain the data. Figure 3 shows the HP-trend deviation of GDP, bank loans and shadow bank loans from Q1 1990 to Q4 2008.

Focusing on the lead up to the financial crisis, the model interprets GDP growth from 2004 to 2007 as having been caused by a mix of positive shocks to bank and shadow bank net wealth and neutral technology shocks as well as unexpected contractionary monetary policy and investment specific shocks. In contrast to some voices (e.g. Taylor 2007 [26]), the model does not interpret monetary policy to have been artificially low and thereby contributing to the housing boom. The positive financial shocks can be interpreted as the loosening of credit standards that lead to the housing boom, as is evident from the decompositions of loans by banks and shadow banks. Policy makers started to change gear in late 2007 when they started easing, which supported GDP but was not sufficient to avert a crisis. Negative financial shocks in the form of equity withdrawals and discontinuation of repo agreements led to a reduction of lending and the downturn.

In general, the insulation of the balance sheet channel from the lending channel can be seen in the influence of monetary policy on bank and shadow bank lending: most of the time, monetary policy affects the variables broadly in opposite directions. Focusing on only bank lending and the balance sheet channel may therefore result in the appearance of large policy mistakes. However, the effects of monetary policy decisions on shadow banks and the lending channel are likely to change this assessment. Since the Federal Open Market Committee considers a number of developments in real and financial sectors, the inclusion of the shadow banking sector is a convenient extension that allows a more comprehensible assessment of policy makers' decisions.
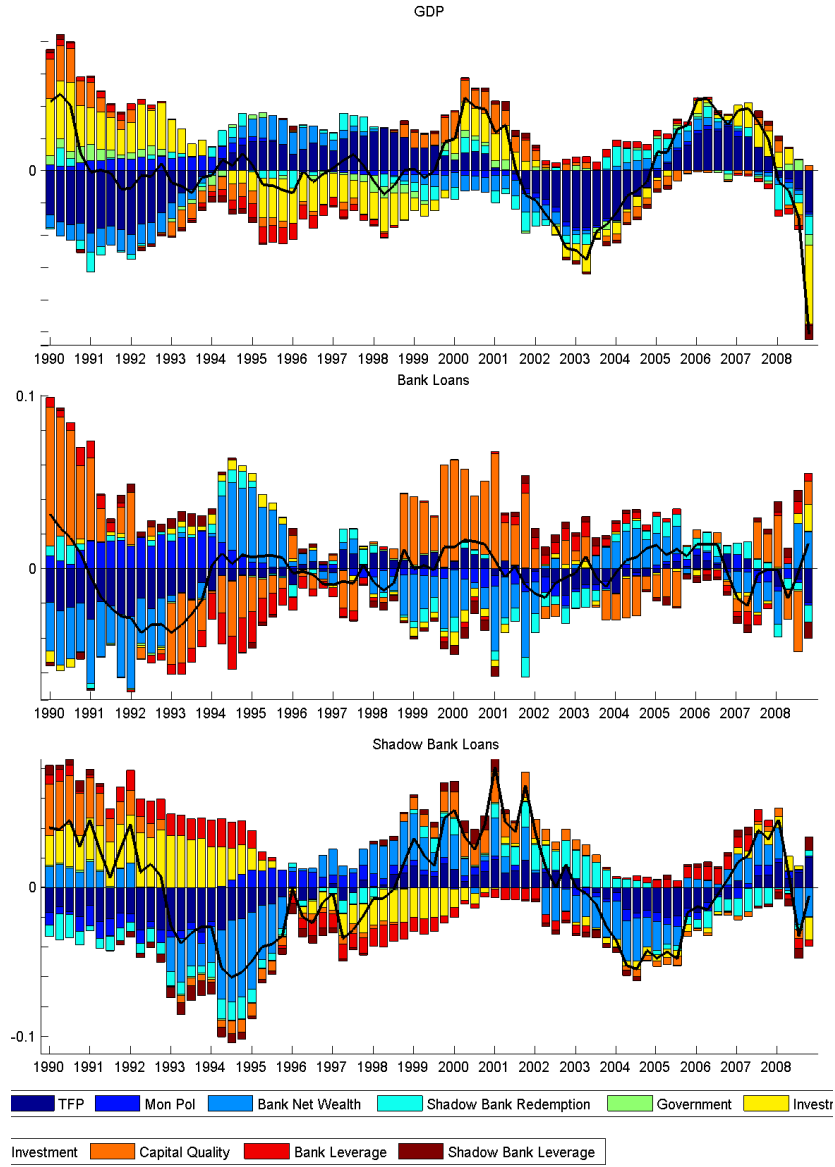
Figure 3: Historical Shock Decomposition of Key Variables, 1990:Q1 - 2008:Q4

3.4 Differentiating the Balance Sheet Channel from the Lending Channel

Monetary policy affects bank and shadow bank lending differently. The reason for this is that different constraints bind their behavior. Banks concentrate on the spread that they can earn on

lending. As long as a borrower is likely to be able to pay a high enough interest rate at a given risk, a bank will be willing to extend credit. Banks can afford this focus on the interest rate spread because they are not necessarily bound by available funds (Bennett, 2002, [2]). In the model, this is reflected in the effective balance sheet composition of the bank, as in equation (8). The amount of lending depends on the leverage variable and the net worth of the bank. The latter two adjust endogenously to the productivity in the economy, which is captured by the firms' ability to borrow. This credit mechanism therefore corresponds to the balance sheet channel of monetary policy transmission.

On the other hand, shadow banks are constrained in their lending by the amount of deposits they are able to acquire. Because the deposit interest rate increases the outside option for households in interest rate bargaining with shadow banks, households increase their allocation of savings in fund shares, which increases shadow bank funding. Although this increases shadow banking costs, their revenue in the form of the borrowing rate is also increasing. Reinforcing this effect, the last term in equation (17) shows that the value of every established match increases in the arrival rate of fund matches. Because a separation rate $\chi^{SB} < 1$ implies that a shadow bank stands to gain from already established funding matched today, front-loading on advertisement will result in the amount of fund shares overshooting their equilibrium value (Pissarides, 2000 [23]). Since shadow bank lending is dependent on funding, this mechanism should be more closely identified with the lending channel.

In practice, the differentiation between the two channels based on entities is not so clear cut. Many shadow banks are subsidiaries of banks and are sponsored or funded by the corporate parent. If the shadow bank receives funding before being able to sell shares to savers, credit creation is taking place on the balance sheets of the bank and shadow bank in step. Only after the sale of fund shares and repayment of the parent by the subsidiary will the credit be solely attributable to the shadow banking sector.

Some of the financial products banks offer to their customers are comparable to a lending channel mechanism. Consider long-term savings deposits or any other product that is not immediately withdrawable by the saver and does not constitute a means of payment in the economy. In this case, credit creation by the bank backed by savings deposits can only take place after succesfully matching a savings account with a lender. In this case, bank credit creation may be more comparable to the lending channel and should be modeled with the proposed mechanism.

Similarly, some authors argue that endogeneous credit creation is taking place inside the shadow banking system as well (Pozsar, 2014 [24]). This activity is identified as repo creation and the mechanism is modeled in Section 2.8, which is representative of the balance sheet mechanism explained above. The difference between repo creation by shadow banks and credit creation by banks is that although repo creation endogeneously varies with the productivity in the economy, it is bound by the fund shares it has exchanged for deposits since "demand deposits are special [...] because of their unique role in forming the backbone of the payments system and facilitating the payments of all entities lower in the system-hierarchy" (Pozsar, 2014 [24]). Repo creation therefore still depends on the amount of shadow bank funding matched.

An unambiguous identification of the two mechanisms with respect to individual entities or sectors is difficult to attain. A better classification of institutions and activities with regards to their function should be possible in more detailed studies.

4 Conclusions

In this paper I have introduced non-bank financial intermediaries into a monetary financial DSGE model via the relatively parsimonious search and matching framework. Since banks create credit endogenously, funding supply is not a constraint on bank lending. Instead, their choice of lending depends on the productivity in the economy. Banks' response to shocks therefore more readily resembles the balance sheet channel of monetary policy transmission. Shadow banks have to raise funds in the form of deposits first to act as intermediaries. Their behavior is therefore dependent on the supply of funding and corresponds more accurately to the lending channel.

Differentiating banks and shadow banks according to their lending and funding constraints respectively results in impulse response functions suggested by empirical studies of the sector. Following monetary policy tightening, banks will decrease the amount of loans, while shadow banks will increase loans (Figure 1). As a consequence, shadow banks can significantly reduce the real effects of monetary policy shocks. At the same time, they amplify the reaction of key variables to real shocks.

A historical shock decomposition shows that easing of credit standards for banks and shadow banks were important contributors to the run up to the financial crisis. Expansionary monetary policy does not seem to have played a major role, mainly because credit developments by banks and shadow banks are affected in different ways. Redemption of fund shares in shadow banks was a key contributor to the sharp drop in GDP in 2008.

The modification of impulse response functions in the face of different financial intermediaries suggests an impact on the welfare effects of business cycles in the tradition of Lucas (2003) [19]. The recognition of additional effects shadow banks introduce may impact results on both the optimal size of the financial sector as a whole, and the relative shares of its components.

Another important question is whether central bank policy reacts optimally to real and nominal shocks if it does not take the presence of shadow banks into account. Monetary policy as modeled by a Taylor rule may not anticipate dampened responses following the presence of shadow banks, and may therefore not react optimally. The recognition of shadow bank lending or a modified Taylor rule that includes data on money and credit as in Christiano, Motto and Rostagno (2007) [5] may generate further insights in another exploration.

In the model, shadow banks fund themselves through fund shares that are sold to households only. In reality, shadow banks are often debtors to banks. Additionally, before the crisis mostly US shadow banks contributed to the funding of mostly EU banks. These situations could be explored in both a national and international setting to understand the funding shocks more thoroughly. These analyses will also allow us to experiment with the re-regulation of the shadow banking sector.

In addition, household savings allocations are passively modeled in this version. The explicit microfoundation of savings decisions, together with the introduction of uncertain returns from the intermediary sector, will allow further realism and additional policy experiments.

A Appendix

A.1 Interest Rate Bargaining

The marginal surplus shadow banks stand to gain from making an additional loan is the difference between the value of an employed share $V^{SB,e}$ versus an unemployed share $V^{SB,u}$, with

$$V_t^{SB,e} = (R_{kt} - R_t^{SB}) + \beta\Lambda_{t,t+1}[(1-\chi)V_{t+1}^{SB,e} + \chi V_{t+1}^{SB,u}]$$
$$V_t^{SB,u} = -1 + \beta\Lambda_{t,t+1}[q_t V_{t+1}^{SB,e} + (1-q_t)V_{t+1}^{SB,u}].$$

If shadow banks find a fund share buyer, they earn the difference on the interest rates and will keep this surplus if the match is not separated. If they do not find a match, they have to advertise, incurring advertisement costs, which has a probability q_t of finding a match next period. In accordance with the free entry condition in the labor search literature, I assume that shadow banks advertise until the value of an unemployed share is zero, $V^{SB,u} = 0$. I can then express $\beta\Lambda_{t,t+1}V_{t+1}^{SB,e} = 1/q_t$. Inserting this above, the value of an employed share under free entry is then

$$V_t^{SB} = (R_{kt} - R_t^{SB}) + (1-\chi)\frac{1}{q_t}.$$

For a household the value of savings at shadow banks $V^{HH,e}$ versus savings at banks $V^{HH,u}$ is

$$V_t^{HH,e} = R_t^{SB} + \beta\Lambda_{t,t+1}[(1-\chi)V_{t+1}^{HH,e} + \chi V_{t+1}^{HH,u}]$$
$$V_t^{HH,u} = R_t + \beta\Lambda_{t,t+1}[f_t V_{t+1}^{HH,e} + (1-f_t)V_{t+1}^{HH,u}],$$

where $f_t \equiv m(v_t, B_{t+1}^u)/B_{t+1}^u$ is the probability of an unemployed deposit being intermediated through a shadow bank. The surplus from lending to a shadow bank is the difference they receive in interest rates together with the value they have from keeping that savings relationship,

$$V_t^{HH} = R_t^{SB} - R_t + \beta\Lambda_{t,t+1}(1-\chi-f_t)V_{t+1}^{HH}.$$

From the first-order condition for interest rate bargaining I know that

$$\frac{\omega^{HH}}{V_t^{HH}} = \frac{(1-\omega^{HH})}{V_t^{SB}}.$$

Solving this forward one period and inserting above, as well as inserting V_{t+1}^{SB}, I get for the households surplus

$$V_t^{HH} = R_t^{SB} - R_t + (1-\chi-f_t)\beta\Lambda_{t,t+1}V_{t+1}^{SB}\frac{\omega^{HH}}{1-\omega^{HH}}.$$
$$= R_t^{SB} - R_t + (1-\chi-f_t)\frac{1}{q_{t+1}}\frac{\omega^{HH}}{(1-\omega^{HH})}.$$

Inserting the surpluses for shadow banks and households into the first-order condition and solving forward one period results in

$$\frac{\omega^{HH}}{\left\{(R_{t+1}^{SB} - R_{t+1}) + (1 - \chi - f_{t+1})\frac{1}{q_{t+1}}\frac{\omega^{HH}}{1-\omega^{HH}}\right\}} = \frac{(1 - \omega^{HH})}{\left\{(R_{kt+1} - R_{t+1}^{SB}) + \frac{(1-\chi)}{q_{t+1}}\right\}},$$

which can be solved for the interest rate shadow banks have to pay on their fund shares

$$R_{t+1}^{SB} = (1 - \omega^{HH})R_{t+1} + \omega^{HH}\left\{R_{kt+1} + \theta_{t+1}\right\}.$$

A.2   Bayesian Estimation
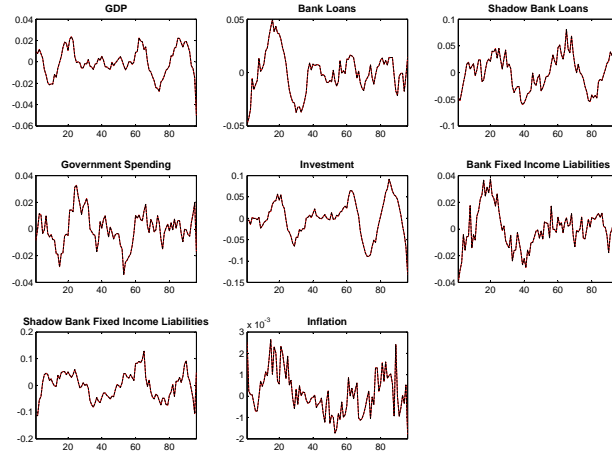
Figure 4: Data Series
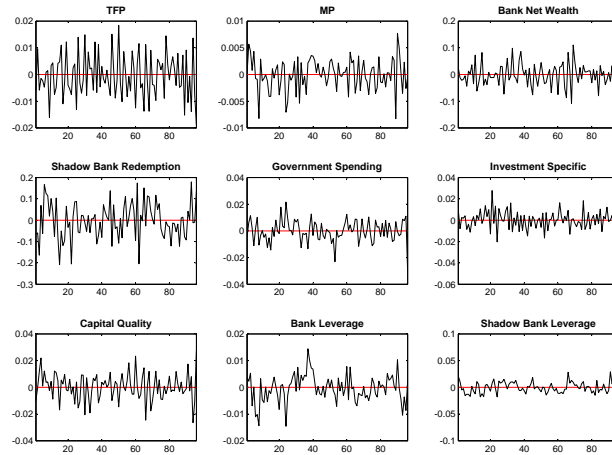
Figure 5: Shock Series
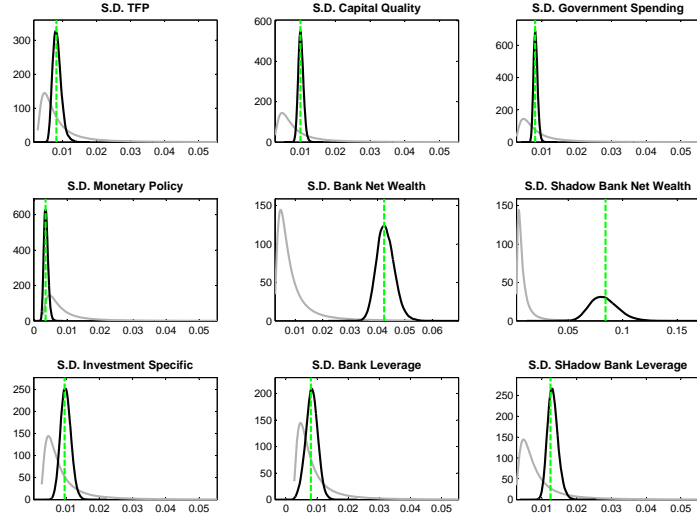
Figure 6: Priors and Posteriors 1/3
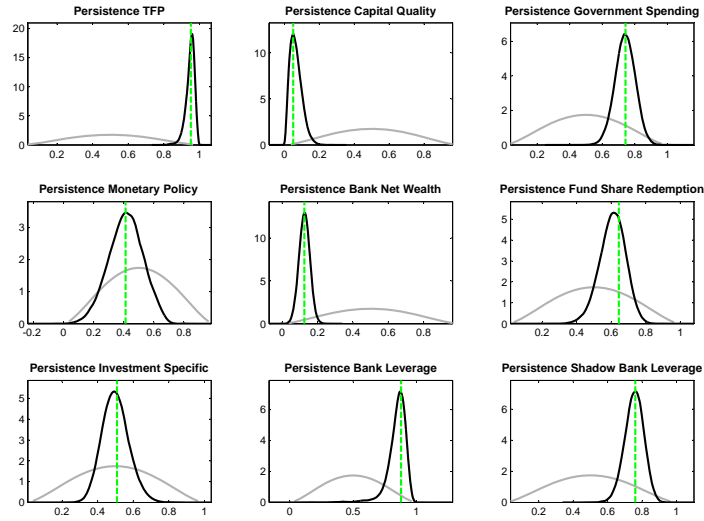
Figure 7: Priors and Posteriors 2/3

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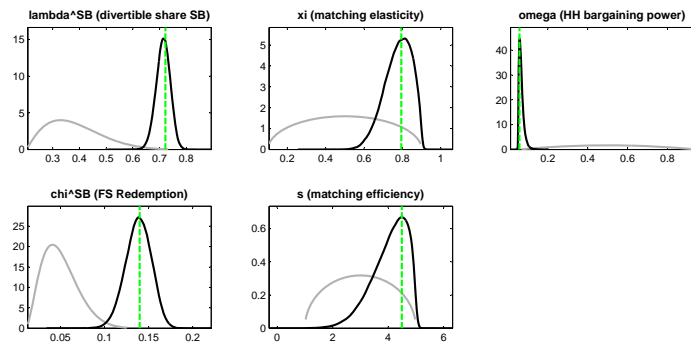
Figure 8: Priors and Posteriors 3/3
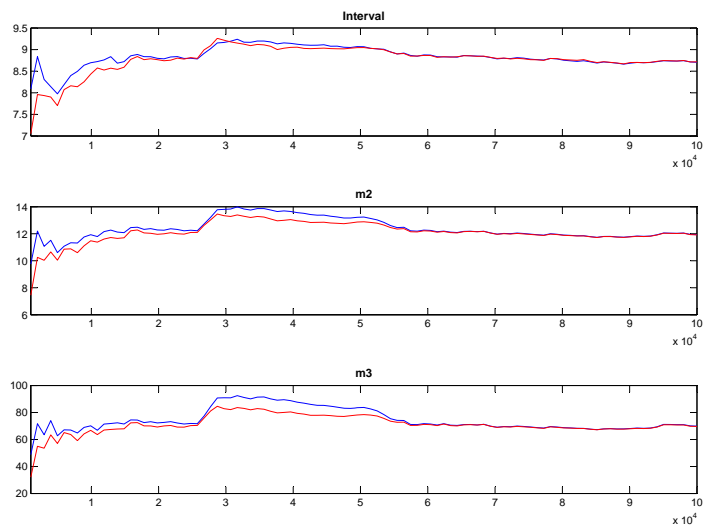
Figure 9: Multivariate Diagnostics

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