Implications of Shadow Bank Regulation for Monetary Policy at the Zero Lower Bound

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Abstract

Counter to the credit channel of monetary transmission, monetary policy tightening induces a rise in lending by two different types of non-bank financial institutions (NBFI): shadow banks and investment funds. A monetary DSGE model is able to replicate the empirical facts when augmented with intermediaries that allow for regulatory arbitrage on the one hand, and household portfolio rebalancing on the other. Therefore NBFI reduce the effectiveness of the bank lending channel, which posits a decrease in bank lending following monetary tightening. Given the pending regulation of the financial system, I study how regulation of the shadow banking sector may affect the monetary transmission mechanism, especially during a zero lower bound (ZLB) episode. I find that bringing shadow banks back onto the balance sheets of commercial banks is beneficial for consumption smoothing. Alternatively, regulating them like investment funds results in a milder recession during, and a quicker escape from, the ZLB. This is because a large demand shock that moves the economy to the ZLB acts in a similar way to a monetary tightening due to the inability to lower the policy rate to the unconstrained level. Consequently, the bank lending channel becomes operational and its effectiveness can be reduced via less reliance on deposit funding.

Keywords: Shadow Banking, Zero Lower Bound, Monetary Policy, Bank Lending Channel, Bayesian Methods, Search Frictions

JEL Classification: E32, E44, E52, G11

1 Introduction

Monetary policy makers have been faced with a reduced ability to lower policy rates due to the Zero Lower bound (ZLB). At the same time, a regulatory overhaul is underway that is aimed at stabilizing the financial sector. One focus of regulation has been on the shadow banking sector[1], which has seen a reduction in credit intermediation by 50% since the financial crisis (see Figure 9 in Appendix C). The regulatory community is likely to regulate the financial system in a way that will make it less likely that shadow banks will play a crucial role going forward (Claessens et al., 2012). This paper analyzes which shadow banking regulations are most helpful at escaping the ZLB.

In this paper, I argue that a recession at the ZLB is milder and shorter lasting if the credit system is less bank based. This argument is based on the empirical observation that banks decrease lending in response to monetary tightening, while non-bank financial institutions (NBFI) increase lending. A monetary DSGE model with different financial intermediaries is able to replicate and explain these results. For banks, the lending channel becomes operational: monetary tightening results in an outflow of loanable funds, leading commercial banks to reduce lending. Shadow banks are used by commercial banks to circumvent capital restrictions and increase lending. Households substitute savings out of bank deposits and into higher yielding liabilities of investment funds[2], which will increase lending.[3]

I show that during a ZLB environment the bank lending channel is operational, because the lower bound on monetary policy prohibits short term rates from falling to the level that would be chosen with unconstrained monetary policy. The mechanics of the ZLB therefore resemble a monetary policy tightening: Households prefer higher yielding assets to deposits, which activates the bank lending channel. If the financial sector can substitute into non-deposit funding, the bank lending channel is weakened and credit tightening is dampened.

I take a standard monetary DSGE model and embed a financial sector that is able to replicate key empirical impulse response functions and aggregate business cycle statistics. I conduct counterfactual analyses in which shadow banks are eliminated from the model. Since the fundamentals of the real economy are not affected by the configuration of the financial system, credit demand from the real sector stays

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[1]Shadow banks are ABS Issuers, Financing Companies, Funding Corporations and Security Brokers and Dealers. Their fixed income private credit intermediation, which is defined as loans, bonds and commercial paper, totaled about 35% of all credit to the economy before the 2008 financial crisis. This group's common characteristic is that they occupy a central place in the internal functioning of financial markets between other financial institutions. Households typically do not fund shadow banks directly.

[2]Investment funds are mutual funds and money market funds. Although less visible than commercial banks, before the financial crisis these institutions channeled about 25% of private credit to the real sector, and they have grown since then. Investment funds are investment vehicles directly accessible to households and therefore feature in household savings decisions.

[3]Other sectors that hold large credit volumes are insurance and pension funds. These institutions fulfil different economic functions compared to pure lenders and would complicate the analysis, and therefore are not considered in this paper.

constant and will either be filled by commercial bank credit or investment fund credit. This discussion is crucial for regions currently assessing different regulatory systems, as for example in the European Union, where the Capital Markets Union proposal suggests a move away from a bank-dependent financial system to a more capital markets based system.

I contribute to the existing literature in the following three ways: i) by explaining and replicating the empirical behavior of NBFI to monetary policy in a monetary DSGE model; ii) by likening the behavior of economies at the ZLB to a response to monetary tightening; and iii) by analyzing the effects of financial regulations that are most helpful in escaping the ZLB on nominal interest rates. To do so, I develop a search and matching mechanism that allows households to make investment choices between debt and equity in a linear approximation.

There are a number of papers focusing on different aspects of shadow banking. Meeks et al. (2014) analyze financial stability and consider shadow banks as off-balance sheet vehicles of commercial banks to unload risky loans. Verona et al. (2013) 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. Moreira and Savov (2014) analyze the way in which shadow bank liability liquidity characteristics change over the business cycle. Goodhart et al. (2012) 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 commercial banking sector, comparable to off-balance sheet vehicles as in Meeks et al. Gertler et al. (2016) focus on the role of wholesale banking in transmitting crises to the real sector. I do not look at crisis periods and the accompanying effects of fire sales, bankruptcy and regime transition. Instead, I focus on business cycle consequences of different financial system configurations after they have been implemented.

In the next section, I describe the model with three types of intermediaries and the incorporation of a savings decision by households. Section 3 contains the model analysis, including calibration and Bayesian estimation, impulse response functions to monetary policy shocks and business cycle effects of eliminating shadow banking. Section 4 contains the ZLB analysis and reaction of the economy under different financial sector configurations, as well as the comparison of a demand shock at the ZLB to a monetary tightening. Section 5 concludes.

Related Literature

This paper contributes to four different strands of the literature. First, the paper relates to the credit channel of monetary policy. The credit channel posits that following monetary tightening the amount of credit in an economy is reduced, which amplifies traditional interest rate and asset price channels.[4] This channel is split up in the balance sheet channel and the bank lending channel.[5] The latter has often been

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[4]For a simple exposition in the IS/LM framework, see Bernanke and Blinder (1988).

[5]See Bernanke and Gertler (1995). The balance sheet channel is underlying the financial accelerator as developed in Bernanke et al. (1999)

3

challenged in light of banks' abilities to substitute to non-deposit funding.[6] However, there is a large empirical literature that finds evidence for the bank lending channel.[7] This paper introduces a mechanism that allows the financial sector to substitute into other sources of funding and therefore decrease the effectiveness of the bank lending channel.

The second strand of the literature analyzes monetary policy effectiveness. Over the past several decades unexpected monetary policy shocks appear to have had less and less of an influence on the real economy.[8] This is sometimes explained by developments in capital and financial markets.[9] This paper adds to the understanding of how the financial market structure, especially its funding via savers, influences the effectiveness of monetary policy.

Third, the paper adds to the understanding of economies that are constrained by a ZLB. Although the theoretical idea has existed for some time[10], empirical studies were limited to the Japanese experience. Since the financial crisis of 2008, several studies have focused on how an economy can escape the ZLB via fiscal policy or unconventional monetary policy.[11] This paper instead focuses on how the overall composition of the financial sector facilitates resilience to the negative consequences of the ZLB.

Lastly, the theoretical mechanism developed in this paper is related to the search and matching literature. The initial development focused on explaining the dynamics of the labor market and replicating key statistics.[12] It has since found applications to other markets, including money and credit relationships.[13] Following Wasmer and Weil (2004), I model funding market frictions analogously to those on the labor market because of their comparable characteristics of "moral hazard, heterogeneity and specificity". In contrast to Wasmer and Weil, in my model the amount of deposits changes endogenously.

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[6]Romer and Romer (1990) argue that bank loan supply is insulated from monetary policy if banks can frictionlessly find non-depository funding.

[7]Early support from aggregate data comes from Kashyap et al. (1993). Identification issues, however, necessitate more detailed data, which were advanced by Kashyap and Stein (1995).

[8]For an empirical exploration, see e.g., Primiceri (2005) and Boivin and Giannoni (2006). For a structural explanation, see Justiniano and Primiceri (2008).

[9]See Jermann and Quadrini (2006) and Dynan et al. (2006) as well as a critique by Haan and Sterk (2011).

[10]See Eggertsson and Woodford (2003) for a theoretical treatment before the US experience.

[11]Christiano et al. (2011) explain why government spending at the ZLB can generally be larger than 1, while Albertini and Poirier (2015) and Christiano et al. (2016) show potentially expansionary effects of unemployment benefits. Gambacorta et al. (2014) explore the effectiveness of unconventional monetary policy.

[12]The seminal paper is Mortensen and Pissarides (1994).

[13]See den Haan et al. (2003) and Wasmer and Weil (2004) for early contributions and Gu et al. (2016) and Beaubrun-Diant and Tripier (2015) for current applications.

2 The baseline model economy

Although the financial sector has been incorporated into DSGE models recently, it is still largely treated as a relatively homogeneous entity. However, empirical studies indicate that different financial institutions react differently to economic shocks: In Mazelis (2016), I find that two types of NBFI, shadow banks and investment funds, increase lending after monetary tightening, while banks decrease lending (see Figure 1).
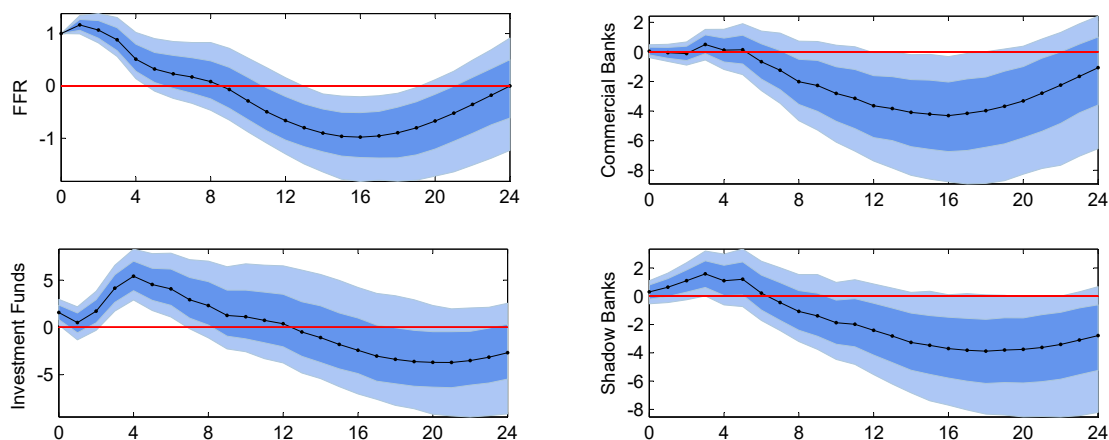

Figure 1: Responses of intermediaries to a contractionary monetary policy shock. Source: Mazelis (2016). *Note: Empirical impulse responses of the federal funds rate and credit by commercial banks, investment funds and shadow banks to an unanticipated 100 basis point increase in the federal funds rate. Data for the latter three are from the Financial Accounts of the United States, 1984I:2006IV. Commercial banks are US Depository Institutions and Credit Unions. Shadow banks are ABS Issuers, Security Brokers and Dealers, Financing Companies and Funding Corporations. Investment funds are Mutual Funds and Money Market Funds. As a measure of credit I include loans, bonds, and commercial paper. Identification of the shock follows the recursiveness assumption of Christiano et al. (1999) with slow moving variables ordered before the shock and credit after the shock. The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the unshocked path. Shaded regions are 32nd-68th and 5th-95th percentiles of 1000 draws. All variable responses are in Figure 10 in Appendix C.*

I follow the call by Woodford (2010) 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." I employ a monetary DSGE model with sluggish price setting to generate nominal frictions, as well as financial frictions. The structure of the shadow banking sector and its relationship to the rest of the financial sector is comparable to Meeks et al. (2014) and Gertler et al. (2016). Debt and equity financing are modeled using two different types of frictions. Debt financing via the moral hazard problem as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) guarantees that as long as the intermediary

does not exceed a maximum amount of leverage per intermediary value, creditors are indifferent towards the absolute amount of debt that they hold. Without explicitly modeling it, this can be understood as deposit insurance for commercial banks and pledged, or asset backed, debt for shadow banks.

Equity financing is risky. Since equity investors participate in the state-contingent returns of the intermediary, households are only willing to hold equity claims that have an underlying returns profile that fits into the individual household's portfolio. An equity return that is higher than the interest rate on debt captures this riskiness. Although not modeled explicitly, this heterogeneity on the micro level is captured via a search and matching mechanism: only a fraction of households agree to the terms of the potential intermediaries that they meet on the equity funding market. This allows me to solve the savings decision of households via a linear approximation.
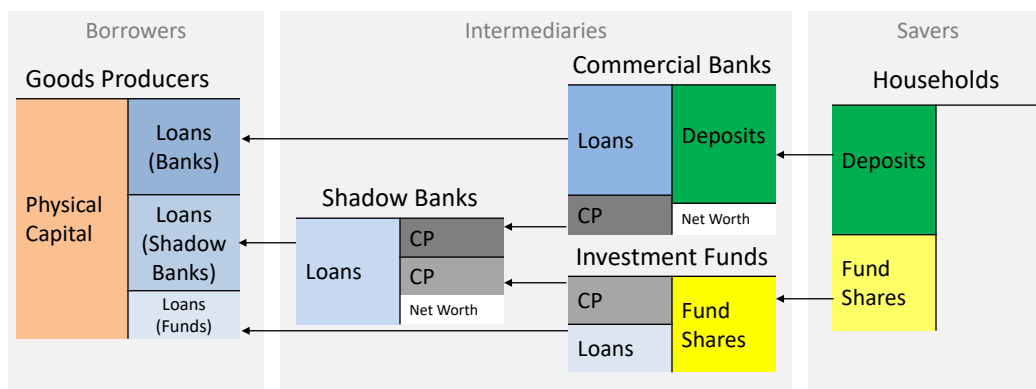

Figure 2: Balance sheets of key agents in the economy. *Note: In addition, the economy is populated by capital producers and monopolistically competitive retailers. A central bank is the source of monetary disturbances. CP = Commercial Paper.*

In addition to the five agents shown in Figure 2, the economy is populated by capital producers and monopolistically competitive retailers. A central bank conducting monetary policy is the source of monetary disturbances and completes the model.

2.1   Households

A continuum of households of measure one exists that consume, save in a portfolio of assets and supply labor. They maximize discounted lifetime utility

$$\max_{\{C_t, L_t, D_t, N_t^{IF}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{i=0}^{t} \beta_i \right) \left[ln(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi} L_t^{1+\varphi} \right]$$

subject to the sequence of period budget constraints

$$C_t + D_t^e + N_t^{IF} = W_t L_t + \Pi_t + R_t D_{t-1}^e + R_t^{IF} N_{t-1}^{IF}.$$

Each unit of labor L_t earns the real wage W_t. Π_t are profits from ownership of capital producers, retailers and financial intermediaries. β_t is the time-varying

discount factor, h is the habit parameter, χ is the relative utility weight of labor and φ is the inverse Frisch elasticity of labor supply. The asset portfolio consists of deposits in commercial banks, D_t, and shares in investment funds, N_t^{IF}. On the micro level, when a household wants to invest into shares, it enters the funding market and randomly meets a potential investment fund. If the investment fund is a good fit regarding individual portfolio characteristics, they invest and form a match. On the macro level, this behavior is approximated by a search and matching mechanism. We only observe a fraction f_t of searching households establish a match. The end-of-period deposits that remain in the portfolio after investment into fund shares are then $D_t^e = D_t(1 - f_t)$. The fraction f_t is endogenously determined as explained in Section 2.2.2. Investment funds pay a state-contingent interest rate R_t^{IF}, which is above the risk-less real return R_t that banks pay on deposits. A fraction θ_{IF} of households withdraws their existing fund investments every period, resulting in a law of motion for fund shareholdings:

$$N_t^{IF} = \theta_{IF} N_{t-1}^{IF} \xi_t^{IF} + f_t D_t. \tag{1}$$

Reinvested fund shares might be affected by ξ_t^{IF}, an autoregressive shock process of order one and mean 1. With ϱ_t denoting marginal utility of consumption and μ_t denoting the additional value of being invested in fund shares, the first order conditions are given by

$$\text{Consumption } C_t: \quad \varrho_t = \frac{1}{C_t - hC_{t-1}} - \mathbb{E}_t \frac{\beta_{t+1}h}{C_{t+1} - hC_t}. \tag{2}$$

$$\text{Labor } L_t: \quad \chi L_t^\varphi = \varrho_t W_t. \tag{3}$$

$$\text{Deposits } D_t: \quad \varrho_t = (1 - f_t)\mathbb{E}_t\beta_{t+1}R_{t+1}\varrho_{t+1} + f_t(\mu_t + \varrho_t). \tag{4}$$

$$\text{Fund Shares } N_t^{IF}: \quad \mu_t + \varrho_t = \mathbb{E}_t\beta_{t+1}\left\{R_{t+1}^{IF}\varrho_{t+1} + \mu_{t+1}\theta_{IF}\xi_{t+1}^{IF}\right\}. \tag{5}$$

The first order conditions for consumption and labor are standard. Equation (4) reduces to the commonly known Euler condition in the case that fund investments do not exist or have no additional value[14], i.e., the household increases savings until the marginal utility of consumption today equals the discounted expected marginal utility of consumption tomorrow. If households can invest in fund shares, but their ability to find a match is constrained (i.e., $f_t < 1$), being invested in an investment fund is valuable (i.e., $\mu_t > 0$). The household therefore increases savings until the marginal utility of consumption today equals the *probability* of consuming tomorrow $(1 - f_t)$ times its value (the discounted expected marginal utility of consumption tomorrow) plus the *probability* of investing in fund shares f_t times that value.

The value of investing in fund shares is given by Equation (5). The right-hand side can be rewritten to yield $\mathbb{E}_t\beta_{t+1}\left\{r_{t+1}^{IF}\varrho_{t+1} + (1 - \theta_{IF})\varrho_{t+1} + \theta_{IF}(\varrho_{t+1} + \mu_{t+1})\right\}$. The first term denotes the per period net return r_{t+1}^{IF} from fund share investments that every investing household receives. The second term is the fraction of households that redeem their fund shares and use them for current period consumption. A fraction θ_{IF} of households stays invested in fund shares and will reap the value of being invested one period hence, expressed in the last term.

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[14]Iff $\mu_t = 0$, Equation (4) holds for all f_t.

2.2 Financial Intermediaries

There are three types of intermediaries: Commercial banks, investment funds and shadow banks. Commercial banks finance the real sector directly via loans and buy shadow bank commercial paper. Investment funds finance loans to the real sector and commercial paper in shadow banks via fund shares, which they sell to households. They are not able to leverage their operations with debt. Shadow banks use their funding to extend loans to the real sector.

2.2.1 Commercial Banks

There are infinitely many commercial banks in the economy, which are operated by members of households. Each commercial bank can make loans S_t^{CB} to the real sector that mature in one period and yield a return R_{t+1}^K. Every commercial bank can also extend credit to the shadow banking sector, which is called commercial paper. Commercial paper M_t^{CB} is different from regular loans, because it denotes a claim on a pool of loans managed by the shadow bank and yields a return R_{t+1}^{MCB}. The commercial bank funds these claims via net worth N_t^{CB} and deposits D_t that it receives from other households (excluding the household that it is managed by). The balance sheet of a commercial bank is then

$$Q_t S_t^{CB} + M_t^{CB} = N_t^{CB} + D_t \tag{6}$$

where Q_t denotes the price of physical capital. The commercial bank accumulates earnings net of the interest R_t that it pays out to depositors one period hence:

$$N_t^{CB} = R_{t+1}^K Q_t S_t^{CB} + R_{t+1}^{MCB} M_t^{CB} - R_{t+1} D_t. \tag{7}$$

Each commercial bank has a finite life time and exits the market with a probability θ_{CB} each period. Once the commercial bank exits, it pays out accumulated lifetime earnings to the household whose member was its manager. The commercial bank therefore maximizes its expected terminal net worth V_t^{CB} by picking its loan portfolio and funding according to

$$V_t^{CB} = \max_{\{S_t^{CB}, M_t^{CB}, D_t\}_{t=0}^\infty} \mathbb{E}_0 \sum_{\tau=0}^\infty \left(\prod_{i=0}^\tau \beta_i \right) (1 - \theta_{CB}) \theta_{CB}^\tau \Lambda_{t,t+\tau} N_{t+\tau}^{CB}, \tag{8}$$

where the stochastic discount factor of the household is given by the marginal rate of substitution between consumption today and tomorrow $\Lambda_{t,t+1}$ and the discount factor β_t. Since deposits only pay the risk free rate, a commercial bank has an incentive to keep leveraging up as long as it earns more than R_t on its credit claims. To motivate leverage endogenously, I introduce the incentive constraint by Gertler and Karadi (2011) (GK11 from here on): Every period, a commercial bank can divert a fraction λ^{CB} of its credit claims, which leads to the termination of the commercial bank. Since in such a case depositors would lose their claims on the commercial bank, they force the commercial bank to limit its leverage in such a way that motivates the commercial bank to continue operations. A commercial bank is required to always

maintain a value from continuing operations that is at least as high as the value it would gain from defaulting:

$$V_t^{CB} \geq \lambda^{CB}[Q_t S_t^{CB} + (1 - \lambda^{ABS})M_t^{CB}]. \tag{9}$$

A commercial bank can divert a larger fraction of its real sector loans, which are non-standardized, than of the commercial paper. Because commercial paper is a claim on a broad pool of loans, its standardization makes it more pledgeable. This is captured in the factor $(1 - \lambda^{ABS})$. As λ^{ABS} approaches 1, a commercial bank can reduce its funding constraint by shifting from outright lending to commercial paper, thereby evading leverage restrictions. This captures the regulatory arbitrage motive of off-balance sheet vehicles.

The solution to the commercial bank's problem is derived in Appendix A.1 and yields the balance sheet relation

$$Q_t S_t^{CB} + M_t^{CB}(1 - \lambda^{ABS}) = N_t^{CB}\phi_t^{CB} \tag{10}$$

with endogenous leverage ϕ_t^{CB}.

Since a constant fraction θ_{CB} of commercial banks exit each period, the remaining commercial banks have a net worth of

$$N_{et}^{CB} = \theta_{CB}(R_t^K Q_{t-1} S_{t-1}^{CB} + R_t^{MCB} M_{t-1}^{CB} - R_t D_{t-1}). \tag{11}$$

To make up for the outflow , households establish new commercial banks according to

$$N_{nt}^{CB} = \omega^{CB}(Q_t S_{t-1}^{CB} + M_{t-1}^{CB}) \tag{12}$$

with ω^{CB} calibrated to pin down the steady state. The law of motion for commercial bank net worth is the combination of both existing and new net worth $N_t^{CB} = N_{et}^{CB}\xi_t^{CB} + N_{nt}^{CB}$. Existing commercial bank net worth may be affected by ξ_t^{CB}, an autoregressive shock process of order one and mean 1.

2.2.2 Investment Funds

In addition to commercial bank deposits, households may save in fund shares. Fund shares offer higher returns on average in order to attract investments, but are state-contingent, since they are equity instruments. Infinitely many investment funds offer fund shares that differ on the micro level with regards to characteristics like investment style and fund management. Similarly, individual household preferences differ on the micro level with regard to the profile of an investment fund and individual portfolio preferences. Because of these idiosyncratic differences, households need to find a suitable fund, which takes time. Individual households and investment funds meet on the funding market at random and evaluate the potential for a match in isolation. I abstract from the mechanics on the micro level and approximate the behavior on the macro level via search and matching: in aggregate a fraction q_t of all investment funds searching for funding will find an investing household. In order to participate in the funding market, investment funds need to advertise their operations at a cost κ per advertisement v_t. After forming a match, an investment fund

is able to invest into either loans to the real sector S_t^{IF} or the commercial paper of shadow banks M_t^{IF}.

In contrast to commercial banks, investment funds do not face the incentive constraint problem, since they do not leverage their operations with debt or deposits. They lend out all acquired funding either to shadow banks or to the real economy. Given their funding, they maximize returns subject to constraints that prohibit them from investing more than a share ψ^{IF} of assets into commercial paper. Since commercial paper from shadow banks pays a higher return than loans to the real sector (see Equation (23)), investment funds generally invest into commercial paper up to their constraint ψ^{IF}.

Each period, investment funds pay out a return R_t^{IF} to their investing household. Some households will want to withdraw funding for consumption or alternative savings, while a fraction θ_{IF} keeps their existing fund shares. The value of an investment fund that has formed a match is

$$V_t^{IF,M} = -R_t^{IF} + \psi^{IF} R_t^{MIF} + (1 - \psi^{IF})R_t^K + \theta_{IF}\mathbb{E}_t\beta_{t+1}\Lambda_{t,t+1}V_{t+1}^{IF,M}, \qquad (13)$$

where R_t^{MIF} is the return on commercial paper holdings of investment funds. Investment funds searching for funding have a value

$$V_t^{IF,S} = -\kappa + q_t\mathbb{E}_t\beta_{t+1}\Lambda_{t,t+1}V_{t+1}^{IF,M}. \qquad (14)$$

Since operating an established investment fund is profitable, the value of operating an investment fund searching for funding may generally be profitable if the second term in Equation (14) is larger than the search cost κ. Additional potential investment funds searching for funding will therefore enter the funding market, which depresses the average fund filling rate q_t, until the value of a searching investment fund is zero. A Euler condition for the number of fund advertisements can be derived:

$$\frac{\kappa}{q_t} = \mathbb{E}_t\beta_{t+1}\Lambda_{t,t+1}\left\{-R_t^{IF} + \psi^{IF} R_t^{MIF} + (1 - \psi^{IF})R_t^K + \frac{\kappa}{q_{t+1}}\theta_{IF}\right\}. \qquad (15)$$

New fund advertisements are posted until the cost of establishing an investment fund is equal to the return, which consists of the difference in interest income and expenses, as well as the value from not having to look for funding in the next period. The probability of finding a match is the number of realized matches m_t per advertisement[15],

$$q_t = \frac{m_t}{v_t}. \qquad (16)$$

The number of matches is determined by the number of fund advertisements as well as the amounts households want to save. Since investment funds offer a higher return than deposits pay, households always prefer to hold fund shares.[16] The number

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[15]The rate at which households find a suitable investment is the investment finding rate $f_t = m_t/D_t$.

[16]The investment fund return is solved via Nash Bargaining and is derived in Appendix A.4.

of matches therefore rises with the amount of household deposits and is determined via a Cobb-Douglas matching function

$$m_t = sD_t^\xi v_t^{1-\xi} \tag{17}$$

with matching efficiency s and matching elasticity ξ.

2.2.3 Shadow Banks

Shadow banks are financial intermediaries that channel funding from commercial banks and investment funds to the real sector. Commercial banks invest into shadow banks via commercial paper M_t^{CB}, which is standardized and therefore more pledgeable to the commercial bank creditors. Investment funds invest into the commercial paper of shadow banks M_t^{IF} because they offer a high return. Accumulated earnings in net worth N_t^{SB} retain the 'first loss' of securitized assets. The amount of real sector lending S_t^{SB} is

$$Q_t S_t^{SB} = M_t^{CB} + M_t^{IF} + N_t^{SB}. \tag{18}$$

Since they are leveraged, shadow banks maximize terminal expected net worth by choosing lending and funding sources according to

$$V_t^{SB} = \max_{\{S_t^{SB}, M_t^{CB}, M_t^{IF}\}_{t=0}^\infty} \mathbb{E}_0 \sum_{\tau=0}^\infty \left(\prod_{i=0}^\tau \beta_i \right) (1-\theta_{SB})\theta_{SB}^\tau \Lambda_{t,t+\tau} N_{t+\tau}^{SB}. \tag{19}$$

Retained earnings N_{t+1}^{SB} in a shadow bank are made up of the interest rate difference that they make on loans and what they pay on commercial paper by commercial banks and investment funds:

$$N_t^{SB} = R_t^K Q_t S_t^{SB} - R_t^{MIF} M_t^{IF} - R_t^{MCB} M_t^{CB}. \tag{20}$$

As in Meeks et al. (2014), shadow banks structure some of their liabilities to be extra safe, i.e., they pool their loans and attribute the safest returns to certain creditors. These creditors are commercial banks, which need pledgeable securities to circumvent their regulatory capital constraints. Only a fraction ψ^{CB} of all loans that shadow banks grant meet this standard. The amount of loans that can be financed via commercial paper held by commercial banks is therefore

$$M_t^{CB} \le \psi^{CB} Q_t S_t^{SB}. \tag{21}$$

The solution to the shadow banks' problem is derived in Appendix A.2 and yields the balance sheet relation

$$Q_t S_t^{SB} = \frac{N_t^{SB} + M_t^{IF}}{1 - \psi^{CB}}. \tag{22}$$

Since some loans remain unsecuritized and non-pledgeable, a portion of the shadow bank balance sheets can not be funded by commercial bank holdings of commercial paper. Demand by investment funds for commercial paper therefore increases the lending operations of shadow banks. In order to incentivize investment

11

funds to hold commercial paper rather than grant loans themselves, shadow banks share the profit they receive from additional lending via Nash bargaining according to

$$R_t^{MIF} = R_t^K + \zeta^{IF} \frac{\psi^{CB}}{1 - \psi^{CB}} (R_t^K - R_t^{MCB}), \tag{23}$$

where ζ^{IF} is the bargaining power of the investment fund. Just like commercial banks and investment funds, a constant fraction θ_{SB} of shadow banks exit each period. The remaining shadow banks have a net worth of

$$N_{et}^{SB} = \theta_{SB}(R_t^K Q_t S_t^{SB} - R_t^{MIF} M_t^{IF} - R_t^{MCB} M_t^{CB}). \tag{24}$$

To make up for the outflow, new shadow banks are established according to

$$N_{nt}^{SB} = \omega^{SB} Q_t S_{t-1}^{SB} \tag{25}$$

with ω^{SB} calibrated to pin down the steady state. The law of motion for shadow bank net worth is the combination of both existing and new net worth $N_t^{SB} = N_{et}^{SB} \xi_t^{SB} + N_{nt}^{SB}$. Existing shadow bank net worth may be affected by ξ_t^{SB}, an autoregressive shock process of order one and mean 1.

2.3 Goods Producers

The intermediaries are not productive by themselves and only derive profits from the return on loans to goods producers. Perfectly competitive goods producers manufacture intermediate goods and sell them to retailers at the relative intermediate output price P_{mt}. After production, non-depreciated capital is sold to capital producers and refurbished.[17] Labor and capital for past production are remunerated and decisions for new production are taken: The firm maximizes profits by solving

$$\max_{\{K_{t+1}, L_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{\tau=0}^{\infty} \left(\prod_{i=0}^{\tau} \beta_i \right) \Lambda_{t,t+\tau} \left[P_{m\tau} Y_\tau + (Q_\tau - \delta)\xi_\tau^K K_\tau - W_\tau L_\tau - R_{k\tau} K_\tau Q_{\tau-1} \right]$$

with production output given by

$$Y_t = A_t (\xi_t^K K_t)^\alpha L_t^{1-\alpha} \tag{26}$$

where α is the capital share, Q_t is the real price of capital, δ is the depreciation rate, W_t are wages, A_t is a total factor productivity shock and ξ_t^K is a capital quality shock. The first-order conditions are

$$R_t^K Q_t = P_{mt}\alpha \frac{Y_t}{K_t} + (Q_t - \delta)\xi_t^K \tag{27}$$

$$P_{mt}(1-\alpha)\frac{Y_t}{L_t} = W_t. \tag{28}$$

Firms pay out ex post returns to capital as interest payments, resulting in no profits state by state. Since they pay the same interest rate R_t^K to all creditors, loans by different intermediaries are perfect substitutes and do not enter the maximization problem of the firm:

$$K_{t+1} = S_t^{CB} + S_t^{IF} + S_t^{SB}. \tag{29}$$

[17]Capital producer and retailer programs are discussed in Appendix A.3.

2.4 Market Clearing, Resources and Policy

The aggregate resource constraint is given by consumption, investment and adjustment costs

$$Y_t = C_t + I_t + f\left(\frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}}\right)(I_{nt} + I_{SS}). \tag{30}$$

Capital evolves according to

$$K_{t+1} = \xi_t^K K_t + I_{nt}, \tag{31}$$

i.e., an autoregressive capital quality shock ξ_t^K of order one captures the variability of capital productivity inherent in fixed capital. Following the literature on the importance of marginal efficiency of investment (Justiniano et al., 2010), investment specific shocks ι_t affect the transformation of gross investment into net investment. Gross investment I_{nt} is

$$I_{nt} \equiv I_t \iota_t - \delta \xi_t K_t. \tag{32}$$

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 steady state value of output given by Y_{SS}, an interest rate smoothing parameter ρ_i, the inflation coefficient κ_π and the output gap coefficient κ_y:

$$i_t = i_{t-1}^{\rho_i}\left[i_{SS}(\pi_t)^{\kappa_\pi}\left(\frac{Y_t}{Y_{SS}}\right)^{\kappa_y}\right]^{1-\rho_i}\epsilon_t \tag{33}$$

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

$$1 + i_t = R_{t+1}E_t(1 + \pi_{t+1}), \tag{34}$$

where $E_t \pi_{t+1}$ is expected future net inflation.

3 Model specification and analysis

In this section, I first pin down the model parameterization via calibration and Bayesian estimation. Because I want to assess the model's ability to replicate business cycle statistics, I use a Bayesian estimation instead of minimizing the distance between empirical and theoretical IRFs as in Christiano et al. (2005). Distance minimization would be possible if empirical IRFs by the different intermediaries for other key macroeconomic disturbances were available. A Bayesian estimation allows a complementary analysis without these results and can be understood as a cross validation for my empirical results: the model IRFs to monetary disturbances from the estimated parameters are comparable to the empirical IRFs in Mazelis (2016).

Next, I analyze how monetary policy shocks propagate through the economy for four different compositions of the financial system. Since only the financial sector is reconfigured, but fundamentals of the model economy are unaffected, real sector

credit demand is unchanged. The baseline case is the financial system with commercial banks, shadow banks and investment funds, corresponding to the situation before the financial crisis of 2008. Since then, shadow bank lending has declined and been replaced by commercial bank and investment fund lending, which is attributable to consolidation in the industry and new regulations. To show the effects of different financial sector compositions, I consider three cases, one in which shadow bank lending has been taken up by commercial banks, an alternative in which investment funds have taken up the credit demand, and one in which both sectors share previously intermediated credit by shadow banks. The different relative sizes of commercial banks to investment funds are due to changes in parameter values. The affected parameter values are the proportional transfer to the entering bankers ω^{CB}, the proportional transfer to the entering shadow bankers ω^{SB}, the fund's survival rate θ^{IF}, the fund advertising cost κ, and the household bargaining power w.r.t. funds ζ^{HH}. The model is solved via first order perturbation around the deterministic steady state.

3.1 Parameterization

Several newly introduced parameters are calibrated to pre-crisis steady state values or directly follow from their economic counterparts. Parameters that govern the stochastic process as well as those that are not pinned down by steady state values and that do not have a direct economic counterpart are estimated. Most of the structural parameters present in GK11 are adopted here.

The pre-crisis economy includes a fully active shadow banking sector with a share of lending of approximately 35%, while commercial banks lent 40%, and investment funds lent the remaining 25% of credit.

The risk-free rate as measured by Shiller (1992) with updated values from his website is 3 percentage points per year. This translates into a quarterly risk-free rate of 75 basis points, i.e., $i_{SS} = .0075$ assuming zero inflation in steady state. In models featuring a conventional Euler equation this implies a higher discount factor than $\beta = 0.99$, which is used in this calibration. However, note that if the additional value from being invested in investment funds, μ_t, is positive, and if search frictions guarantee that the finding rate $f_t \in (0, 1)$, then over-saving will result in a risk-free rate that is lower than β^{-1}.

The fraction of commercial bank assets invested in commercial paper by shadow banks is set at 30%, as indicated in bank call report data reported in Meeks et al. (2014). The corresponding fraction for investment fund assets is 40% pre-crisis as indicated by Flows of Funds data.

Remaining model parameters are chosen to imply a spread for the borrowing rate $R_k - R_t$ of 79 bp, equal to the bank prime loan rate spread over the 3-month Treasury Bill rate between 2001 and 2004. A spread of 109 bp as proxied by Moody's Seasoned Aaa Corporate Bond Yield is chosen for the commercial paper rate that shadow banks pay to investment funds. I assume that shadow banks belong to

Symbol	Value	Description	Source
Households			
β	0.99	Steady state discount rate	Gertler and Karadi (2011)
h	0.815	Habit parameter	Gertler and Karadi (2011)
χ	3.409	Relative utility weight of labor	Gertler and Karadi (2011)
φ	0.276	Inverse Frisch elasticity of labor supply	Gertler and Karadi (2011)
Financial Sectors			
i_{SS}	0.0075	Quarterly nominal rate	Shiller (1992)
ψ^{CB}	0.3	Fraction of commercial bank assets invested in commercial paper	Meeks et al. (2014)
ψ^{IF}	0.4	Fraction of investment fund assets invested in commercial paper	Flows of Funds
λ^{ABS}	1	Relative divertibility of ABS	Steady state
ζ^{IF}	0.88	Fund bargaining power re shadow banks	Steady state
ζ^{HH}	0.86	Household bargaining power w.r.t. funds	Steady state
ω^{CB}	0.15	Proportional transfer to the entering bankers	Steady state
ω^{SB}	0.04	Proportional transfer to the entering shadow bankers	Steady state
s	.32	Matching efficiency	Steady state
κ	.0007	Search cost	Steady state
Goods Producers			
α	0.33	Effective capital share	Gertler and Karadi (2011)
δ	0.025	Depreciation rate	Gertler and Karadi (2011)
Retail Firms			
ϵ	4.167	Elasticity of substitution	Gertler and Karadi (2011)
γ	0.779	Probability of keeping prices fixed	Gertler and Karadi (2011)
γ_p	0.241	Price indexation	Gertler and Karadi (2011)
Government			
κ_π	1.5	Inflation coefficient of Taylor rule	Gertler and Karadi (2011)
κ_y	0.125	Output gap coefficient of Taylor rule	Gertler and Karadi (2011)

Table 1: Calibrated parameter values. *Note: 'steady state' refers to parameter values that directly follow from assumed steady state values. The steady state values are either the relative share of the financial sector or interest rate differentials.*

commercial banks and therefore do not pay a higher interest rate R_t^{MCB} than R_t. This results in commercial paper held by commercial banks to be pledgable with a $\lambda^{ABS} = 1$, i.e., commercial banks can not divert these assets. It follows from the steady state and parameter values that the bargaining power of investment funds vis-a-vis shadow banks ζ^{IF} is then .88, since shadow banks need a buyer of remaining loan pools. The fraction of new equity that has to be injected into commercial bank and shadow bank equity, respectively, is $\omega^{CB} = .15$ and $\omega^{SB} = .04$. The matching efficiency s, search costs κ and household bargaining power ζ^{HH} follows from the steady state and parameter values. Table 1 shows the fixed structural parameter values and their source.

The remaining parameters, including those governing the shock processes, are estimated using Bayesian methods. Commercial banks, investment funds and shadow banks are defined as in Mazelis (2016): Commercial banks are US Depository Institutions and Credit Unions. Shadow banks are ABS Issuers, Security Brokers and Dealers, Financing Companies and Funding Corporations. Investment funds are Mutual Funds and Money Market Funds. As a measure of credit I include loans, bonds, and commercial paper. The macroeconomic time series underlying the data for observables are: real GDP, the consumer price index, the federal funds rate, fixed capital, household consumption, and credit by commercial banks, investment funds and shadow banks (see Table 5 in Appendix C for details on the data sources). Since the model is expressed in log-deviations from steady state, for estimation purposes

		Prior			Posterior		
Symbol	Name	Type	Mean	Std. Dev.	Mean	L.B.	U.B.
Structural							
ξ	Matching elasticity	Beta	0.5	0.2	0.74	0.66	0.84
λ^{CB}	Commercial bank's divertible share	Beta	0.381	0.05	0.48	0.46	0.49
θ_{CB}	Commercial bank's survival rate	Beta	0.75	0.05	0.63	0.57	0.68
θ_{IF}	Investment fund's survival rate	Beta	0.75	0.05	0.74	0.68	0.80
θ_{SB}	Shadow banker's survival rate	Beta	0.75	0.05	0.74	0.66	0.84
Persistence parameters							
ρ_A	TFP	Beta	0.5	0.2	0.68	0.54	0.85
ρ_i	Monetary Policy	Beta	0.5	0.2	0.61	0.55	0.68
ρ_ξ	Capital Quality	Beta	0.5	0.2	0.19	0.09	0.30
ρ_{IS}	Investment Efficiency	Beta	0.5	0.2	0.993	0.990	.998
ρ_β	Demand	Beta	0.5	0.2	0.84	0.77	0.90
ρ_{CB}	Commercial bank equity	Beta	0.5	0.2	0.25	0.11	0.37
ρ_{IF}	Investment fund equity	Beta	0.5	0.2	0.74	0.68	0.80
ρ_{SB}	Shadow bank equity	Beta	0.5	0.2	0.78	0.71	0.84
Std dev.							
e_A	TFP	Inverse Gamma	0.010	0.05	0.012	0.007	0.017
e_i	Monetary Policy	Inverse Gamma	0.010	0.05	0.003	0.002	0.004
e_ξ	Capital Quality	Inverse Gamma	0.010	0.05	0.012	0.011	0.014
e_{IS}	Investment Efficiency	Inverse Gamma	0.010	0.05	0.013	0.011	0.015
e_β	Demand	Inverse Gamma	0.010	0.05	0.004	0.003	0.006
e_{CB}	Commercial bank equity	Inverse Gamma	0.010	0.05	0.043	0.036	0.048
e_{IF}	Investment fund equity	Inverse Gamma	0.010	0.05	0.054	0.040	0.067
e_{SB}	Shadow bank equity	Inverse Gamma	0.010	0.05	0.200	0.166	0.226

Table 2: Priors and posteriors of estimated parameters. *Note: L.B. is the lower bound of the 90% highest posterior density interval. U.B. is the upper bound of the 90% highest posterior density interval.*

I take the log difference from the one-sided HP filtered trend (smoothing parameter is set to 1600) for all variables except inflation and the federal funds rate, which are depicted in Figure 12 in Appendix C.3. The data have a quarterly frequency and range from 1984:I to 2006:IV.

The priors for all persistence parameters are relatively uninformative 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 0.01 standard deviations of 0.05. The shock processes are a priori independent. The prior distributions for the structural parameters are beta distributions. The interval for the matching elasticity allows all parameters between 0 and 1. The commercial bank's divertible share λ^{CB} is centered on the GK11 value of 0.381 and bound from below and bound from above to limit commercial bank leverage. The intervals for survival rates are between $(0.5, 1.0)$.

I run 2 Monte Carlo Markov Chains with 100.000 draws each over the full sample period. Convergence is reached after about 20.000 draws and I drop the first 50% of estimated values. Table 2 shows the results. The posteriors of the shock processes are informative (see Appendix C.3). In order to illuminate the dynamics of the matching friction, I do a robustness analysis of the matching elasticity ξ in Appendix B.

3.2 Response to a monetary policy shock

Figure 3 shows impulse response functions for key variables after unexpected monetary policy tightening for the case of i) the original GK11 economy, ii) the baseline case with investment funds and shadow banks, iii) the loans previously held by shadow banks now intermediated by commercial banks (bank dependent), and iv) the shadow bank loans intermediated by funds (fund dependent). The third case corresponds to commercial banks granting 75% of all loans to the real economy, while the last case has commercial banks intermediating a total of 40% of credit. Investment funds intermediate the remaining share in the latter two cases.

First, consider the original GK11 economy. After an unexpected monetary tightening of about 100 basis points in the first period, interest rates on commercial bank deposits increase to encourage depositors to keep their savings with commercial banks instead of shifting them into other assets. Because households have a higher incentive to save, consumption drops. The reduction in consumption demand translates into lower output and a reduction in the demand for physical capital by firms, which also lowers the price for physical capital. Lower output and capital prices initially diminish the return on capital for the firm, see Equation (27). Since firms pass this return on as the borrowing cost to the intermediary, existing commercial bank profits are hit. In the second period, the borrowing rate increases, because the price for physical capital slowly rises from its initial low. Since the risk-free rate does not increase by as much as the borrowing rate, the external finance premium (EFP) rises. Equation (A.2) increases as the EFP rises, indicating gains from expanding assets for commercial banks. This means that the reduction in lending is not just due to the balance sheet channel, which would necessitate a drop in credit demand. Banks are unable to quickly raise equity and soliciting more deposits from households would cut into their margin. Credit to the real sector therefore drops.

The baseline case features shadow banks and investment funds. After a monetary policy increase, the initial reaction in the economy is the same. However, commercial banks now have the ability to leverage up on their existing net wealth by increasing their investments into shadow banks, which lend on their behalf. At the same time, commercial banks face competition from investment funds, which increase the fund rate more aggressively than commercial banks increase the deposit rate. Households therefore substitute away from commercial bank deposits and into investment fund shares, which is consistent with empirical findings (Drechsler et al., 2016). Since many previously creditworthy borrowers were pushed out of the market, investment fund and shadow bank loans now replace some of the lost commercial bank credit. The bank lending channel is therefore reduced, because the financial sector substitutes away from bank deposits and into other funding options. This has a dampening effect on the fall in physical capital, which is reduced two thirds less compared to the GK11 economy with only commercial banks. The effect of the mitigated credit crunch is a less pronounced recession.

Two additional cases describe what happens after elimination of the shadow banking system. If the credit previously intermediated by shadow banks is now granted by commercial banks (the 'bank dependent' scenario), there is no room for outright

regulatory capital arbitrage by commercial banks anymore. Commercial banks therefore cut back on credit after monetary policy tightening, opening up the possibility for investment funds to fill the excess credit demand. Investment funds do so by raising funding from households. Although investment funds increase lending by more than 3%, the decrease in commercial bank borrowing is hardly offset, resulting in a decrease in physical capital that is about twice as large as in the baseline case.

If instead investment funds intermediate the credit that was previously held by shadow banks (the 'fund dependent' scenario), capital reduction is comparable to the bank dependent scenario. The behavior is the result of different mechanisms, however. Shadow banks allow commercial banks to circumvent capital requirements and raise more deposits than households would be willing to lend to commercial banks themselves. In the case of large investment funds instead of shadow banks, any losses are passed on to the households owning the fund shares. New investments in investment funds still take place as households decrease consumption and allocate their resources to savings, especially fund shares.
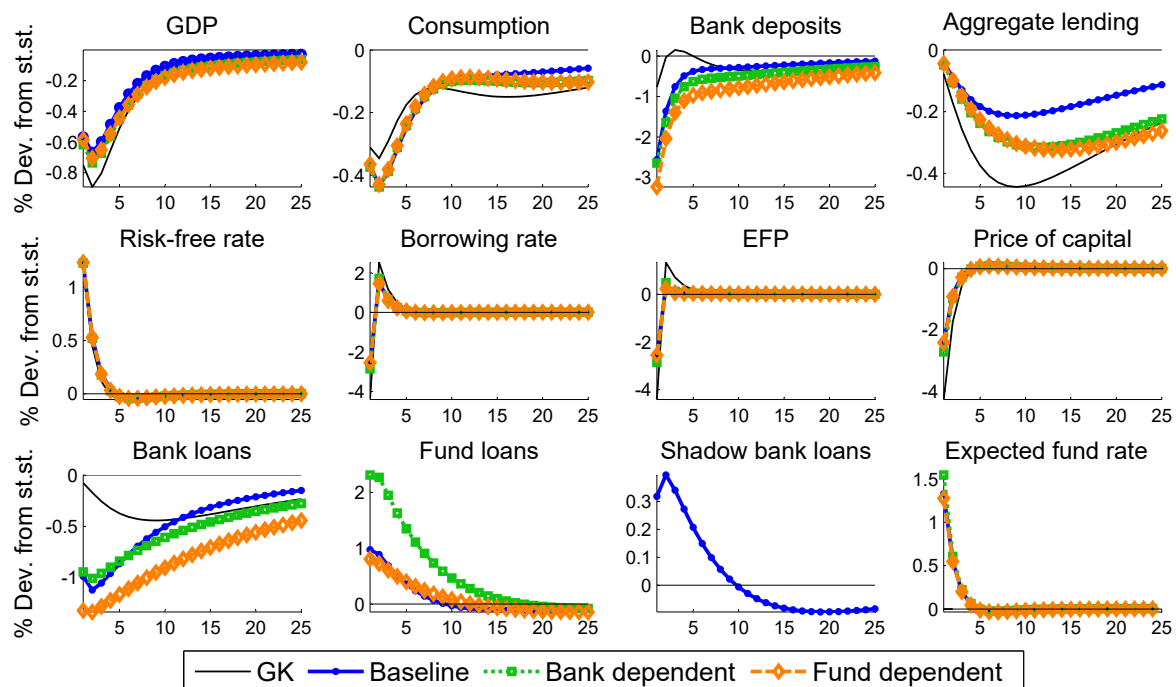
Figure 3: Model IRFs to monetary policy tightening of 100 basis points. *Note: The black, solid lines report the IRFs from the model without NBFI, which is the basic GK model. The blue, solid lines report IRFs from the full model including NBFI. The green, dotted lines with cubes are responses for the baseline model without shadow banks where commercial banks assume the excess credit demand. The orange, dashed lines with diamonds are responses for the baseline model without shadow banks where funds assume the excess credit demand. The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the steady state (except for the interest rates and the EFP, which are reported in percentage points).*

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The behavior of shadow bank lending following a monetary policy tightening is consistent with the literature. A monetary tightening in the model induces a drop in commercial bank lending. In the BVAR in Mazelis (2016), commercial bank lending contracts in a hump shaped fashion over six years. The increase in investment fund and shadow bank loans in the empirical results are mirrored in the model reaction. A resulting negative 0.6% in GDP in the BVAR is exactly reached in the model. The difference is in timing. While the model reacts within the first couple of periods, the empirical IRFs have a longer transmission period. For the sake of tractability, I refrain from using any modeling devices that replicate empirical IRFs more closely.

Pescatori and Sole (2016), Nelson et al. (2015) and Igan et al. (2013) all show empirically that some shadow banks increase lending after monetary policy tightening, while commercial banks reduce lending. Haan and Sterk (2011) show that both mortgages and consumption credit by shadow banks increase following an increase in the monetary policy rate. Finally, Altunbas et al. (2009) show that European banks with more securitization activities reduce their lending by less than non-securitizing banks after monetary tightening. European universal banks house both commercial 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 their shadow banking operations are larger, which insulates aggregate group lending behavior by increasing shadow bank lending following monetary policy tightening.

3.3 Business Cycle Effects

The benchmark economy with shadow banks compares well to second moments of some key variables in the data. Table 3 shows a close fit for GDP and intermediary credit standard deviations. Fixed capital is not as volatile as in the data, which might be due to labor being fully flexible and absorbing volatility in the production process. This might be fixed with model features like variable capital utilization and either monopolistically competitive labor unions or a search and matching process between firms and workers.

If shadow banks are eliminated, the volatility of aggregate variables necessarily decreases because the stochastic process affecting shadow bank equity is eliminated. The three counterfactual scenarios can therefore be compared among each other but not to the baseline scenario. GDP and consumption are more volatile in fund-heavy economies because households earn a state-contingent return on fund shares instead of a non-contingent return on commercial bank deposits. Although this makes consumption smoothing more difficult, it insulates the financial sector from assuming losses. Passing on variable profits may increase financial stability by having the ultimate equity holders help absorb fundamental shocks.

Apart from a change in second moments, variable means may also change.[18] Since the fundamentals in the economy are not affected by the composition of the

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[18]Deterministic steady states are studied, which ignore precautionary savings, to guarantee comparability among model variants.

			Shadow bank loans held by		
Variable	Data	Baseline	Banks	Split 50/50	Funds
GDP	1.26	1.45	1.21	1.25	1.33
Inflation	.79	.56	.44	.44	.48
Consumption	.73	1.09	.91	.92	.95
Physical capital	4.28	2.57	2.32	2.36	2.42
Commercial bank loans	5.76	5.51	6.65	6.60	7.11
Investment fund loans	7.44	7.28	15.46	8.39	5.16
Shadow bank loans	5.86	5.72	–	–	–

Table 3: Second moments of data and model variants (all numbers in %). *Note: Second moments for the data are calculated from cyclical variations around the one-sided HP filtered log data from 1984:I to 2006:IV. Second moments for the model variants are based on shock processes as estimated in Section 3.1.*

financial system, real economy variable means are unchanged. Instead, funding of the financial sector moves into the spotlight. In a more bank-dependent economy, commercial banks have to increase their deposit base by about 25%. This benefits households by increasing their total return from deposits by about 35%. Without shadow banks, however, regulatory arbitrage is not possible and commercial banks have to increase their equity holdings by about 80%. This increase in equity is arguably better for the stability of the financial sector, but it does beg the question whether commercial banks would be able to raise the required capital following a financial crisis.

In the case that the economy becomes more fund-dependent, commercial bank deposits diminish. Instead, fund share holdings are increased by about 40%, while commercial bank equity stays the same. This increases total fund returns to households, while decreasing total returns to deposits. The net result is a slightly higher total return for households from financial assets compared to the baseline case, and a 5 percentage point increase above the bank-dependent scenario. The reason for this is that fund returns are stochastic and therefore have to remunerate the investor for uncertainty.

4   Shadow bank regulation at the zero lower bound

Before the financial crisis, the shadow banking system contributed about 35% of credit to the real economy. This share has dropped significantly since 2007 (see Figure 9 in Appendix C). The shadow banking system has been the explicit focus of financial regulation in many countries around the world, see Financial Stability Board (2013) for an overview. Although no consensus has emerged, the dominant principle has been to bring credit intermediation out of the shadows. This means that shadow banks would either be differently regulated, or that they cease to exist and that the credit demand they previously intermediated would be assumed by

other institutions. In effect, the options then are to regulate this credit demand like commercial bank credit, like investment funds, or a combination of those. At the same time, many of those same economies have been plagued by the ZLB on nominal interest rates. Central banks and governments are actively trying to escape the ZLB with different measures and varying success. This section studies how an economy behaves under different financial intermediary regimes during a prolonged time at the ZLB.

4.1 Technical specifications

A ZLB on nominal interest rates means that the central bank cannot set the net monetary policy rate below 0, which amounts to an occasionally binding constraint. Formally, this changes the Taylor rule, equation (33), to

$$
i_t =
\begin{cases}
i_{t-1}^{\rho_i} \left[i_{SS}(\pi_t)^{\kappa_\pi} \left(\frac{Y_t}{Y_{SS}} \right)^{\kappa_y} \right]^{1-\rho_i} \epsilon_t & , \text{if} \quad i_t > 0 \\
0 & , \text{otherwise.}
\end{cases}
\tag{35}
$$

Since this induces non-linearities in the policy functions of economic agents, I use the method developed by Guerrieri and Iacoviello (2015) to find an approximated solution. The utilized "OccBin" toolbox considers an economy with two regimes, the "reference" regime in which the monetary policy rate follows a linearized Taylor rule and the "alternative" regime in which it is constant at zero. A piecewise-linear solution is then found by considering the reference regime where the constraint is slack until the monetary policy rate reaches its lower bound. Once the lower bound is reached, the regime switches to the alternative where the constraint is binding until the reference regime indicates a move away from the constraint.
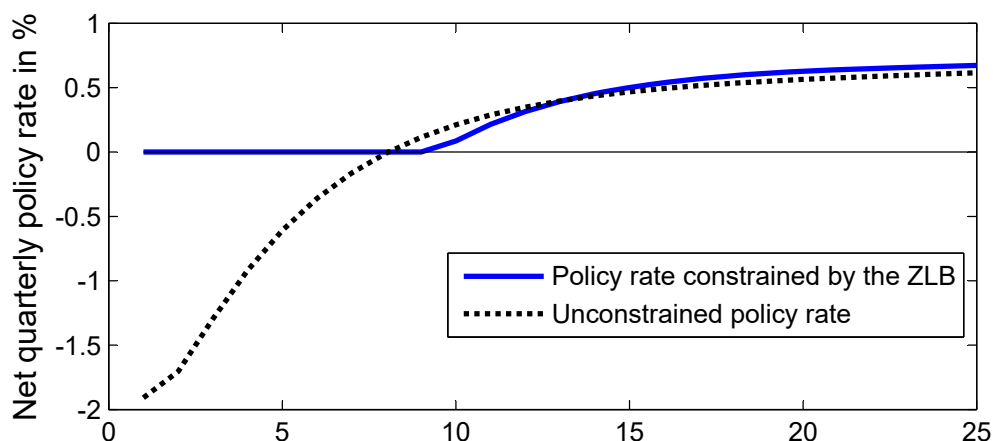
Figure 4: Monetary policy path after negative demand shocks. *Note: The blue, solid line refers to an economy constrained by the zero lower bound on monetary policy. The black, dotted line represents the case for the same economy unconstrained. The horizontal axis shows periods in quarters. The vertical axis is the net policy rate in annualized percentage points.*

A common way of analyzing the ZLB in theoretical models is to assume preference shocks[19] that elicit households to forego consumption today, see also Christiano et al. (2011) and Fernndez-Villaverde et al. (2015). Following this literature, I turn monetary policy smoothing off ($\rho_i = 0$). In addition, I increase price rigidity to $\gamma = 0.9$ and the Taylor rule coefficient for inflation to $\kappa_\pi = 2.5$ as in Guerrieri and Iacoviello (2015). These changes limit the use of disinflation in order to escape the ZLB, which is in line with the current ZLB experience. Following the drop in demand, output and inflation fall. This prompts the monetary authority to lower the policy rate until it reaches zero.

The discount factor receives an innovation of $\epsilon_\beta = 0.06$, which decreases output by 4 percent in a ZLB environment, comparable to the drop in GDP in 2008, (see the cyclical variation in the GDP panel in 2009, Figure 12 in Appendix C.3). The monetary authority reacts by lowering the policy rate, see Figure 4. Without the ZLB (black, dotted line), the policy rate would drop below zero for 8 quarters. An unconstrained policy would stimulate investment by lowering borrowing costs, while also limiting household incentives to save. With a ZLB, the economy never receives this feedback and is instead stuck with a policy rate that is above its desired level.

		Commercial banks	Investment funds	Shadow banks
i)	Historical case	40%	25%	35%
ii)	Bank dependent case	75%	25%	–
iii)	Fund dependent case	40%	60%	–

Table 4: Loan shares under different regulatory scenarios. *Note: The historical case corresponds roughly to the shares of fixed income securities to the real sector in 2006. The bank dependent case refers to credit previously held by shadow banks to be intermediated by commercial banks. The fund dependent case assumes that all shadow bank credit is lent out by investment funds.*

4.2 Implications of different shadow bank regulations

As explained in Section 3.2, bank credit decreases in response to monetary policy tightening due to the bank lending channel. However, shadow banks and investment funds increase lending. This behavior suggests that a policy rate above its natural level is conducive for NBFI lending. Furthermore, it begs the question whether an economy with a larger share of aggregate credit coming from NBFI may be less affected by a policy rate above its natural level. To answer this question, I analyze the response of the economy under three different scenarios: i) the historical case with commercial banks, investment funds and shadow banks under the baseline parameterization; ii) the bank dependent case in which shadow banks are eliminated and the

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[19]Although the financial crisis of 2008 has its roots in the financial sector, a negative household demand shock captures the reaction to the destruction in household wealth that followed the drop in real estate values as well as the effects on household asset holdings in financial firms.

excess credit demand is taken up by commercial banks; and iii) the fund dependent case in which investment funds take on all of the loans previously intermediated by shadow banks. The first case is 'historical' in the sense that a large shadow banking system was intact prior to the crisis but has mostly evaporated since. Shadow banks are likely to be more heavily regulated going forward. The last case assumes that several regulatory proposals that favor the capital market based credit system over the bank based one are enacted. This approach is currently being taken in Europe with the Capital Markets Union expected to allow NBFI to increase their market share. Table 4 summarizes the loan shares for the three cases.

Figure 5 shows the evolution of key variables for the case in which the ZLB is binding (left hand side) and in which the policy rate is unconstrained (right hand side). Consider the historical case with a shadow banking system intact (blue, solid line) with an unconstrained monetary policy. An increase in the household discount factor induces households to consume less and save more. To counter this development, monetary policy is reduced, thereby lowering the real rate, which stimulates investments. The additional credit is supplied by banks, which face reduced financing costs via deposits. A deep recession can be avoided by quickly lowering the policy rate.

Next, consider the historical case under the ZLB (blue line in the left hand panels). While the economy suffers from inadequate demand, the policy rate is bound at zero. The real rate can therefore not fall enough to stimulate investment and in fact rises, since the drop in demand results in deflation. This causes commercial banks to decrease lending, because their supply of loanable funds decreases. As a result, only the most creditworthy firms (i.e., those with a high marginal return on capital) can keep borrowing. Although some credit is channeled via shadow banks, and investment funds receive an inflow in funding because they pay a higher expected return than deposits, credit does not increase enough to counter the drop in demand. A negative 4% drop in output follows, which is comparable to the recession following the recent financial crisis. This scenario is no longer applicable, since the financial crisis caused many shadow banks to go out of business, thereby eliminating the opportunity for commercial banks to channel funds off their own balance sheets.

Credit previously held by shadow banks is now taken on by commercial banks or investment funds. The bank dependent case (green, dotted line with squares) illustrates the first scenario. Since commercial banks' supply of loanable funds is decreasing, they are reluctant to grant credit and they cut back on lending. Investment funds receive an inflow in funding, as households earn more from fund shares than commercial bank deposits. Since investment funds pass on the lower profits from depressed borrowing rates, they still profit from additional lending and therefore increase credit intermediation. Although additional investment fund lending counteracts the reduction in commercial bank lending somewhat, it is not sufficient to generate enough investment to stop the recession. The economy unconstrained by a ZLB does not suffer such a sharp recession, as commercial banks do not scale back lending as much due to the cheap refinancing via negative real rates. Following the ZLB episode, commercial banks slowly reverse credit intermediation back to steady state levels. At the same time, investment funds reduce lending as the policy rate is
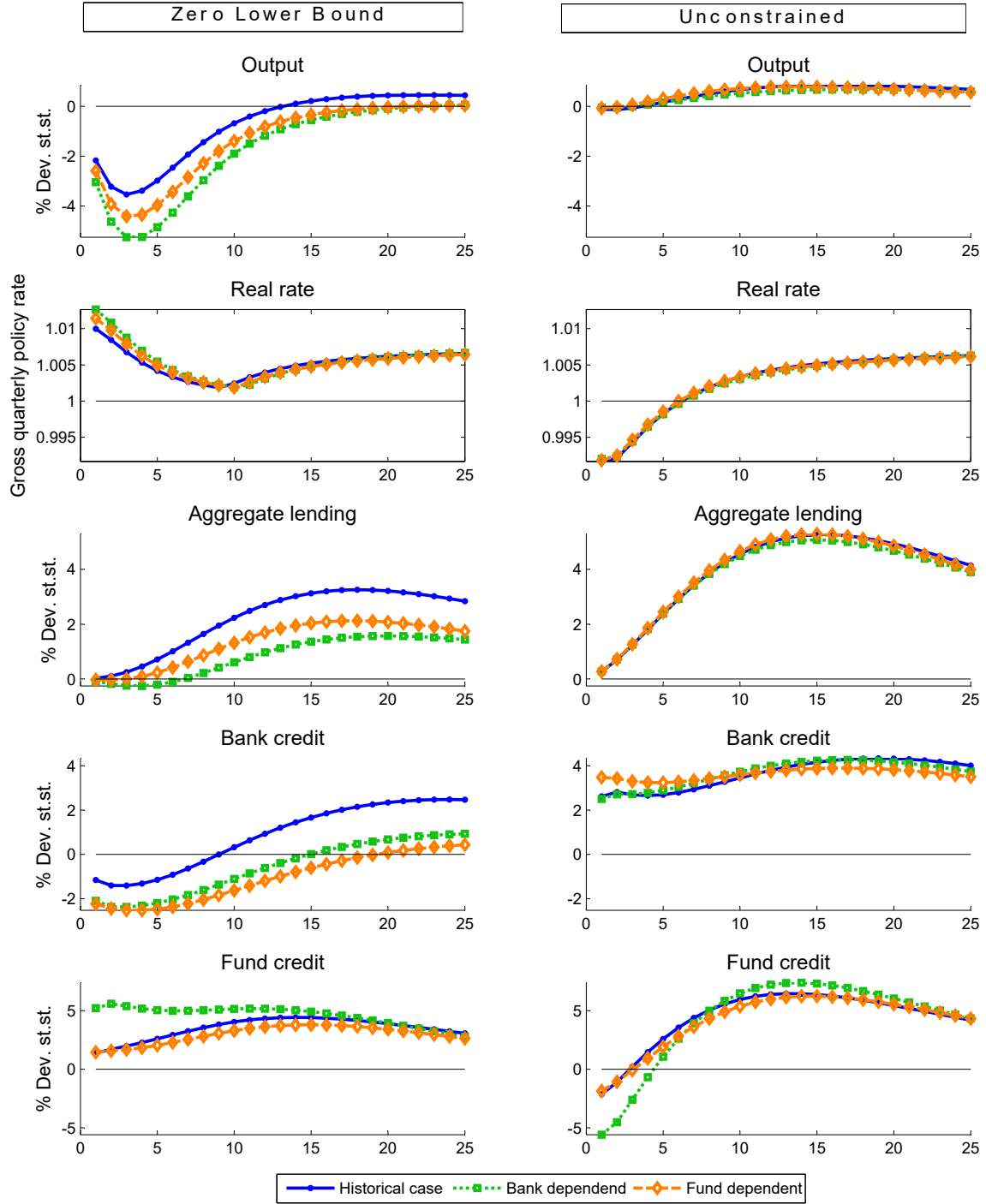
Figure 5: Paths of key variables after a prolonged time at the ZLB for different regulatory regimes. *Note: The left panels show paths for key variables under the ZLB constraint. The right hand panels show paths for unconstrained economies. Horizontal axes show periods in quarters, vertical axes are percentage deviations from steady state.*

back to its natural level.

Finally, consider the case in which investment funds provide the largest share of credit (orange, dashed line with diamonds). Again commercial bank lending is reduced, following a reduction in funding. However, lending by investment funds increases sufficiently to motivate enough investments for a prolonged period. The reason for this is that in steady state households are less invested in deposits and the rebalancing into fund shares is less pronounced. This reduces the impact of the lending channel and allows more firms to invest into capital. These investments keep GDP from dropping as much as in the bank dependent scenario and allow for a less severe recession compared to the bank dependent case.

4.3 A demand shock at the ZLB initiates the bank lending channel

The more favorable dynamics of a less bank-based credit system during a ZLB episode can be explained via the bank lending channel of monetary policy. In order to better understand this result, consider the Euler equation (4) with the value of fund investments, Equation (5), inserted in the last term on the right hand side:

$$\varrho_t = (1 - f_t)\mathbb{E}_t\beta_{t+1}R_{t+1}\varrho_{t+1} + f_t\mathbb{E}_t\beta_{t+1}\left\{R_{t+1}^{IF}\varrho_{t+1} + \mu_{t+1}\theta_{IF}\xi_{t+1}^{IF}\right\}. \tag{36}$$

The economic disturbance that hits the economy in this exploration is a large demand shock that increases the household discount factor. Households reduce current period consumption until the marginal utility of consumption rises to equal the right hand side of the Euler condition. To limit incentives for households to save, the monetary authority reduces the policy rate, lowering the real rate R_{t+1} in an economy unconstrained by the ZLB. This results in additional investments and, consequently, aggregate demand only suffers slightly. If the economy is constrained by the ZLB, the policy rate cannot counter the increase in the first term on the right hand side of the Euler condition. Current period consumption has to drop further to satisfy a higher marginal utility of consumption. The second component of aggregate demand, investment, does not rise enough to counter this development, since the real interest rate cannot fall to the unconstrained level. Because of deflation, the real rate even rises. A much more pronounced recession is the result.

The increase in the real rate is likewise the reason for the bank lending channel becoming operational in the case of a demand shock at the ZLB. This can be seen by taking the differences of the variable responses in case of the ZLB versus the unconstrained paths, which removes the effects purely due to the demand shock. Figure 6 shows these IRFs. The 'shock' in this diagram is due to the monetary authority's inability to lower the policy rate by an additional two percentage points after the demand shock hits. The reactions of most other variables are then similar to the case of monetary policy tightening in Section 3.2.

Now consider the second term in the right hand side of the Euler condition. If households can easily find investment funds as an alternative to deposits, the fund finding rate f_t is higher and the weight on the first term on the right hand side is
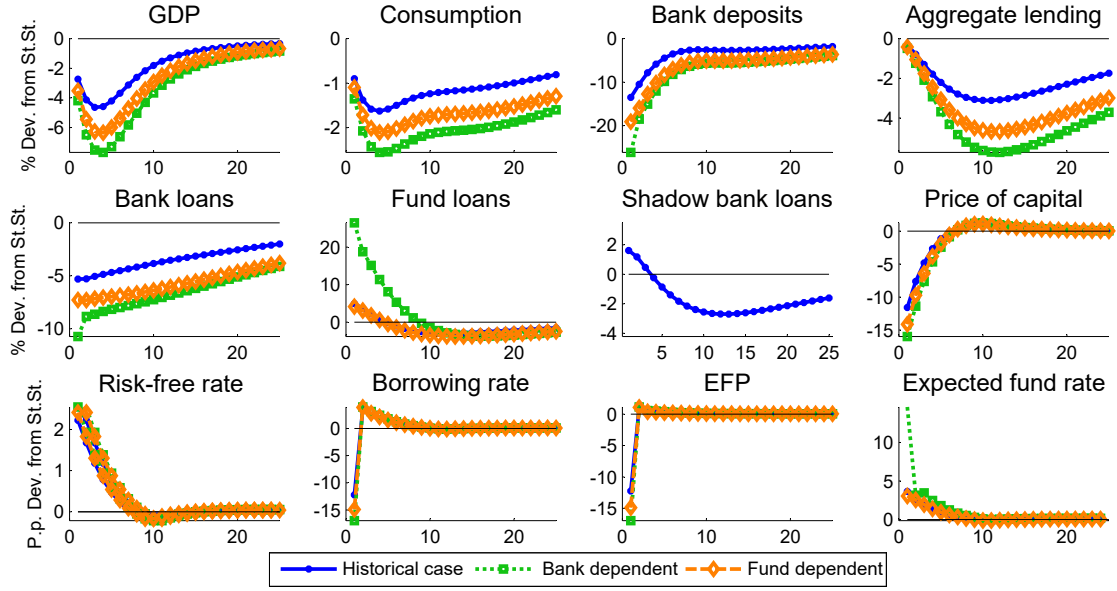
Figure 6: Differences in reactions of the ZLB and unconstrained models to a demand shock. *Note: The blue, solid lines report IRFs from the full model including NBFI. The green, dotted lines with cubes are responses for the baseline model without shadow banks where commercial banks assume the excess credit demand. The orange, dashed lines with diamonds are responses for the baseline model without shadow banks where funds assume the excess credit demand. The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the steady state (except for the interest rates and the EFP, which are reported in percentage point deviations).*

smaller. The inability of the monetary authority to lower the policy rate does not affect the economy as much. Instead, the focus shifts to the reaction of variables in the second term, the fund rate R_{t+1}^{IF} and the additional value from being invested in fund shares μ_{t+1}. In a bank-dependent credit economy, both variables increase strongly following the activation of the bank lending channel, because funds are able to strongly raise the fund rate they pay on shares. In a fund-dependent economy, there are already many funds in operation and many households invested in them. Therefore funds have a reduced incentive to increase the fund rate.[20]

The fund-based economy can be interpreted as one in which households have already exhausted most options for higher yielding, non-depository assets. The activation of the bank lending channel then has little effect on the funding supply of the economy. Alternatively, in a bank based economy, households rebalance their portfolios towards higher yielding assets, which increases the effectiveness of the bank lending channel. The reduction in credit is not desirable while the policy rate is at the ZLB. This can be countered by lowering the effectiveness of the bank lending channel through more non-depository sources of funding.

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[20]Additional households on the funding market are a positive externality for searching funds, but seen as congestion from the perspective of other searching households, see Petrongolo and Pissarides (2001).

5   Conclusions

The reactions of different financial intermediaries can be explained in a monetary DSGE model. Shadow banks are associated with commercial banks to circumvent regulatory restrictions and continue lending in otherwise unfavorable circumstances. Investment funds on the other hand experience funding inflows during contractionary episodes, because they raise their payouts in line with policy tightening. This also allows investment funds to increase lending overall. A subsequent counter factual analysis in the DSGE model shows that eliminating shadow banks has different effects, depending on how the remaining financial system is regulated. If commercial banks pick up the credit previously supplied by shadow banks, consumption volatility is reduced. However, large investments into commercial bank equity have to precede this option. If instead investment funds are taking up the additional credit demand, consumption is more volatile, resulting from the state-contingent return that fund investments pay out. Total returns from financial assets are also higher in this case, as households are compensated with a risk premium. Allocating losses to the ultimate equity holders instead of concentrating them in the financial sectors may have additional benefits for financial stability that go beyond the scope of this paper.

A key advantage of having a fund-dependent financial sector comes from the behavior at the ZLB. Because households decrease deposit holdings, banks cut lending, thereby starving the economy of necessary credit. Investment funds benefit from a higher real rate in contrast to commercial banks as they experience a funding inflow from savers. This inflow is translated into more loans that partially make up for the loss in commercial bank credit. The effectiveness of the bank lending channel is therefore reduced, which is beneficial during a ZLB episode. Although a recession cannot be avoided, the drop in GDP is not as deep, and the return to steady state levels occurs more quickly when the credit economy is funded less by deposits and more by fund shares.

The policy implications that follow from this analysis contribute towards the debate on the composition and size of the financial sector. Shadow banking in the sense of regulatory arbitrage as treated here will likely be strongly contained in the regulatory overhaul currently discussed in various countries. Since the void will have to be filled with credit coming from different sources, this paper suggests some business cycle implications for credit systems that are more bank based as compared to more fund based ones.

In order to escape the ZLB, this analysis favors a fund-dependent financial system, as the effectiveness of the bank lending channel is reduced. The paper therefore supports current plans in the European Union to increase the size of the market based financial system on the basis of an increased resilience to ZLB issues. However, in order to make more comprehensive suggestions, a detailed analysis based on European data and financial system configurations would need to follow.

The same argument that favors fund based credit systems during ZLB episodes might speak in favor of a bank based system outside the ZLB. The bank lending channel is more effective in a more deposit based credit system, i.e., credit will react more strongly to monetary policy. This may be desirable, if the monetary authority

wants to stave off a potential recession by lowering the policy rate and stimulating credit. Whether one credit system dominates the other therefore depends on the frequency at which monetary policy is constrained by the ZLB.

A Appendix: Model Derivation

A.1 Solution to the Commercial Bank's Problem

Substituting D_t in Equation (7) from Equation (6), the ongoing value of a commercial bank Equation (8) can be expressed recursively as

$$V_t^{CB} = \nu_t^{SB} Q_t S_t^{CB} + \nu_t^{MCB} M_t^{CB} + \eta_t^{CB} N_t^{CB} \tag{A.1}$$

with the marginal benefit from extending loans ν_t^{CB} given by

$$\nu_t^{CB} = \mathbb{E}_t\{(1-\theta_{CB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1}^K - R_{t+1}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{CB}x_{t+1}^{CB}\nu_{t+1}^{CB}\}, \tag{A.2}$$

where x_{t+1}^{CB} is the gross growth rate of assets $Q_{t+1}S_{t+1}^{CB}/Q_t S_t^{CB}$. Similarly, the marginal benefit from extending commercial paper ν_t^{MCB} given by

$$\nu_t^{MCB} = \mathbb{E}_t\{(1-\theta_{CB})\beta_{t+1}\Lambda_{t,t+1}(R_{Mt+1} - R_{t+1}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{CB}x_{t+1}^{MCB}\nu_{t+1}^{MCB}\}, \tag{A.3}$$

where x_{t+1}^{MCB} is the gross growth rate of commercial paper M_{t+1}^{CB}/M_t^{CB}. The marginal benefit from extending net worth η_t^{CB} is

$$\eta_t^{CB} = \mathbb{E}_t\{(1-\theta_{CB})\beta_{t+1}\Lambda_{t,t+1}R_{t+1} + \beta_{t+1}\Lambda_{t,t+1}\theta_{CB}z_{t+1}^{CB}\eta_{t+1}^{CB}, \tag{A.4}$$

and the gross growth rate of net worth $z_{t+1}^{CB} = N_t^{CB}/N_{t-1}^{CB}$.

Together with the incentive constraint in Equation (9), the Lagrangian can be written

$$\mathbb{L} = V_t^{CB} + \mu_t^{CB}[V_t^{CB} - \lambda^{CB}(Q_t S_t^{CB} + [1 - \lambda^{ABS}]M_t^{CB})]$$
$$= (1 + \mu_t^{CB})(\nu_t^{CB}Q_t S_t^{CB} + \nu_t^{MCB}M_t^{CB} + \eta_t^{CB}N_t^{CB}) - \mu_t^{CB}\lambda^{CB}(Q_t S_t^{CB} + [1 - \lambda^{ABS}]M_t^{CB}).$$

The first order conditions with respect to S_t^{CB}, M_t^{CB} and μ_t^{CB} are, respectively,

$$(1 + \mu_t^{CB})\nu_t^{CB} = \mu_t^{CB}\lambda^{CB} \tag{A.5}$$
$$(1 + \mu_t^{CB})\nu_t^{MCB} = \mu_t^{CB}\lambda^{CB}[1 - \lambda^{ABS}] \tag{A.6}$$
$$Q_t S_t^{CB}(\nu_t^{CB} - \lambda^{CB}) + M_t^{CB}(\nu_t^{MCB} - \lambda^{CB}[1 - \lambda^{ABS}]) + \eta_t^{CB}N_t^{CB} = 0. \tag{A.7}$$

Equations (A.5) and (A.6) result in $\nu_t^{MCB} = \nu_t^{CB}[1 - \lambda^{ABS}]$, which can be substituted into Equation (A.7) to yield

$$Q_t S_t^{CB} + M_t^{CB}(1 - \lambda^{ABS}) = N_t^{CB}\phi_t^{CB}, \tag{A.8}$$

with the endogenous leverage variable given by

$$\phi_t^{CB} = \frac{\eta_t^{CB}}{\lambda^{CB} - \nu_t^{CB}}. \tag{A.9}$$

A.2 Solution to the Shadow Bank's Problem

Substituting M_t^{CB} in Equation (20) from Equation (18), the ongoing value of a shadow bank Equation (19) can be expressed recursively as

$$V_t^{SB} = \nu_t^{SS}Q_tS_t^{SB} - \nu_t^{MF}M_t^{IF} + \eta_t^{SB}N_t^{SB} \tag{A.10}$$

with the marginal benefit from extending loans ν_t^{SB} given by

$$\nu_t^{SS} = \mathbb{E}_t\{(1-\theta_{SB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1}^K - R_{t+1}^{MCB}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{SB}x_{t+1}^{SS}\nu_{t+1}^{SS}\}, \tag{A.11}$$

where x_{t+1}^{SS} is the gross growth rate of assets $Q_{t+1}S_{t+1}^{SB}/Q_tS_t^{SB}$. Similarly, the marginal benefit from increasing funding by commercial paper held by investment funds is ν_t^{MF} given by

$$\nu_t^{MF} = \mathbb{E}_t\{(1-\theta_{SB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1}^{MIF} - R_{t+1}^{MCB}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{SB}x_{t+1}^{MF}\nu_{t+1}^{MF}\}, \tag{A.12}$$

where x_{t+1}^{MF} is the gross growth rate of commercial paper M_{t+1}^{IF}/M_t^{IF}. The marginal benefit from extending net worth η_t^{SB} is

$$\eta_t^{SB} = \mathbb{E}_t\{(1-\theta_{SB})\beta_{t+1}\Lambda_{t,t+1}R_{t+1}^{MCB} + \beta_{t+1}\Lambda_{t,t+1}\theta_{SB}z_{t+1}^{SB}\eta_{t+1}^{SB}, \tag{A.13}$$

and the gross growth rate of net worth $z_{t+1}^{SB} = N_{t+1}^{SB}/N_t^{SB}$.

Together with the incentive constraint in Equation (21), the Lagrangian can be written

$$\mathbb{L} = V_t^{SB} + \mu_t^{SB}[V_t^{SB} - \psi^{CB}(M_t^{IF} + [1-\lambda^{ABS}]M_t^{CB})]$$
$$= (1+\mu_t^{SB})(\nu_t^{SS}Q_tS_t^{SB} - \nu_t^{MF}M_t^{SB} + \eta_t^{SB}N_t^{SB}) - \mu_t^{SB}\psi^{CB}(Q_tS_t^{SB}[1-\lambda^{ABS}] + \lambda^{ABS}M_t^{IF}).$$

The first order conditions with respect to S_t^{SB}, M_t^{IF} and μ_t^{SB} are, respectively,

$$(1+\mu_t^{SB})\nu_t^{SS} = \mu_t^{SB}\psi^{CB}(1-\lambda^{ABS}) \tag{A.14}$$
$$(1+\mu_t^{SB})\nu_t^{MF} + \mu_t^{SB}\psi^{CB}\lambda^{ABS} = 0 \tag{A.15}$$
$$Q_tS_t^{SB}(\nu_t^{SS} - \psi^{CB}[1-\lambda^{ABS}]) - M_t^{IF}(\nu_t^{MF} + \psi^{CB}\lambda^{ABS}) + N_t^{SB}(\eta_t^{SB} + \psi^{CB}[1-\lambda^{ABS}] = 0. \tag{A.16}$$

Equations (A.14) and (A.15) result in $\nu_t^{MF} = -\nu_t^{SS}\frac{\lambda^{ABS}}{1-\lambda^{ABS}}$, which can be substituted into Equation (A.16) to yield

$$Q_tS_t^{SB} = N_t^{SB}\frac{\eta_t^{SB} + \psi^{CB}(1-\lambda^{ABS})}{\psi^{CB}(1-\lambda^{ABS}) - \nu^{SS}} - M_t^{IF}\frac{\lambda^{ABS}}{1-\lambda^{ABS}}. \tag{A.17}$$

A.3 Capital producers and retailers

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

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

with

$$I_{nt} \equiv I_t \iota_t - \delta \xi_t K_t. \tag{A.18}$$

Following the literature on the importance of marginal efficiency of investment (Justiniano et al., 2010), investment specific shocks ι_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

$$Q_t = 1 + f(.) + \frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}} f'(.) - E_t \beta_t \Lambda_{t,t+1} \left(\frac{I_{nt+1} + I_{SS}}{I_{nt} + I_{SS}}\right)^2 f'(.). \tag{A.19}$$

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

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

The first-order condition is given by

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta_t^i \Lambda_{t,t+1} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (1 + \pi_{t+k-1})^{\gamma_p} - \frac{\epsilon}{\epsilon - 1} P_{mt+i}\right] Y_{ft+i} = 0. \tag{A.20}$$

The evolution of the price level is given by

$$P_t = [(1 - \gamma)(P_t^*)^{1-\epsilon} + \gamma(\Pi_{t-1}^{\gamma_p} P_{t-1})^{1-\epsilon}]^{1/(1-\epsilon)}. \tag{A.21}$$

31

A.4 Interest Rate Bargaining

Households and investment funds share the joint value they derive from having established a match via Nash bargaining according to the household bargaining power ζ^{HH}. Interest rates are negotiated that maximize a convex combination of the surpluses,

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

The household value V_t^{HH} is made up of the value of owning a fund share $V^{HH,e}$ versus saving deposits at a commercial bank $V^{HH,u}$:

$$V_t^{HH,e} = R_t^{IF} + \mathbb{E}_t\beta_{t+1}\Lambda_{t,t+1}[\theta V_{t+1}^{HH,e} + (1 - \theta)V_{t+1}^{HH,u}]$$
$$V_t^{HH,u} = R_t + \mathbb{E}_t\beta_{t+1}\Lambda_{t,t+1}[f_t V_{t+1}^{HH,e} + (1 - f_t)V_{t+1}^{HH,u}].$$

Together they make up the household value

$$V_t^{HH} = R_t^{IF} - R_t + \mathbb{E}_t\beta_{t+1}\Lambda_{t,t+1}(\theta - f_t)V_{t+1}^{HH}. \tag{A.22}$$

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

$$\frac{\zeta^{HH}}{V_t^{HH}} = \frac{(1 - \zeta^{HH})}{V_t^{IF}}.$$

Solving this forward one period and substituting into Equation (A.22), as well as inserting $\mathbb{E}_t\beta_{t+}\Lambda_{t,t+1}V_{t+1}^{IF} = \kappa/q_t$ from Equation (14), I get for the return investment funds have to pay on their shares

$$R_t^{IF} = R_t + \zeta^{HH}\left\{\psi^{IF}R_t^{MIF} + (1 - \psi^{IF})R_t^K - R_t + \kappa\frac{f_t}{q_t}\right\}.$$

Note that investment funds can get away with paying only the risk-free deposit rate in case that they have all the bargaining power. The interest rate on investment shares rises with the bargaining power of households, guaranteeing at least the risk-free rate.

B Robustness Analysis

This section analyzes the robustness of the results of the paper with regard to key parameter values. All of the parameters either come from the literature, are calibrated to fit steady state values, or are estimated. However, the analysis of especially newly introduced parameters facilitates the understanding of the model extension.

B.1 Matching elasticity ξ

The parameter for matching elasticity ξ is important for the dynamics of the matching friction. The value is determined by the Bayesian estimation as 0.74 with relatively narrow posterior density intervals. However, there is no a priori reason why the value could not be lower. In order to test whether the results depend on the value of the matching elasticity, Figure 7 shows the response of the economy to the same monetary tightening as in Section 3.2 for the different configurations of the financial sector but a matching elasticity of $\xi = 0.2$. In this case, household savings play a larger part in establishing new matches.
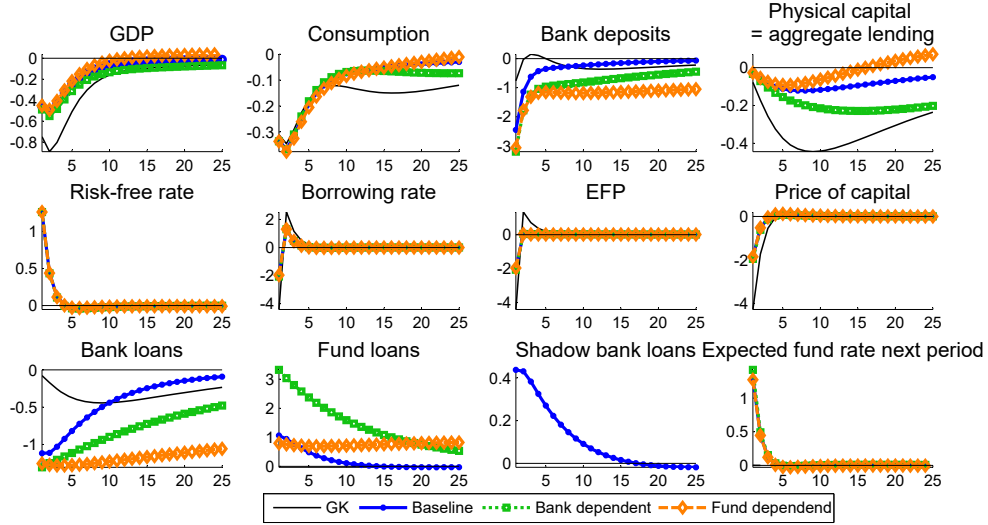
Figure 7: IRFs to a monetary tightening of 100bp and the matching elasticity $\xi = .2$.

The baseline scenario (blue, solid line) is almost unchanged, because investment funds only make up 25% of the credit economy. However, in the bank dependent scenario (green, dotted line), investment funds increase their intermediation by more than with a lower elasticity. This is so because households can more quickly substitute out of deposits and into higher yielding assets.

In the fund dependent case (orange line with diamonds), investment fund lending increases more persistently than with a higher elasticity. This leads to an even milder reduction in aggregate lending than in the baseline case. Remarkably, aggregate lending even turns positive after 15 periods.

In order to study the ZLB case, taking the differences of the responses to a demand shock for constrained and unconstrained monetary policy as in Section 4.3

leads to the reactions in Figure 8. The baseline case is not changed much, and the bank dependent case is qualitatively similar to a higher elasticity. However, the fund dependent case without shadow banks now shows a reaction that is as favorable as the baseline case with shadow banks.
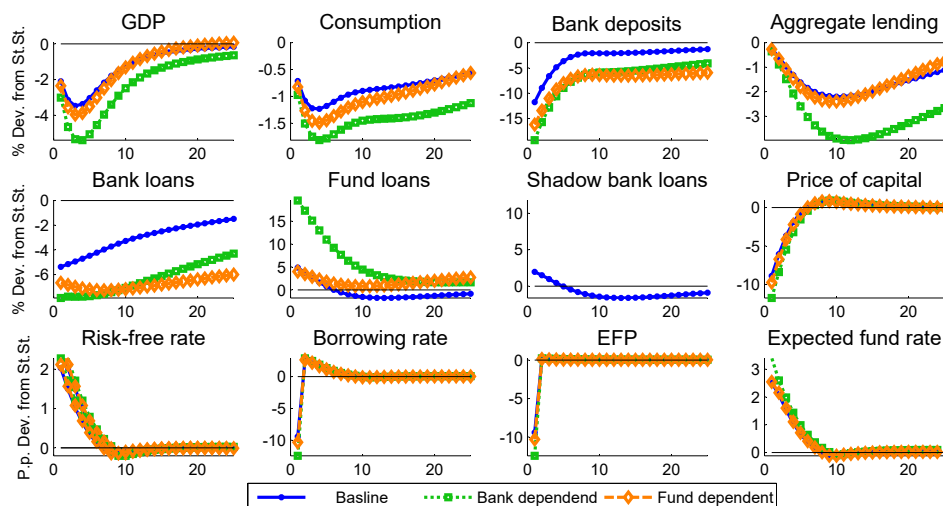
Figure 8: Difference of IRFs to demand shocks under the ZLB and unconstrained monetary policy. Matching elasticity $\xi = .2$.

The robustness analysis shows that the results in the main body of the text can be taken as a lower bound for the reaction of the fund dependent case, while there is not a lot of variation in the baseline and bank dependent cases. The Bayesian estimation provides a narrow standard deviation for the posterior of the matching elasticity. However a quantitative study (e.g., in the case of a welfare analysis) would benefit from further evidence for the exact matching parameter, as the results may change.

C Empirical Resources

C.1 Data Sources

Variables	Description	Source
Aggregate Output Y_t	Real Gross Domestic Product, USD, not s.a.	Stock and Watson (2012)
Consumption C_t	Real Personal Consumption Expenditures: Services and Nondurable Goods, USD, not s.a.	Stock and Watson (2012)
Physical Capital K_t	Real Private Fixed Investment, USD, not s.a.	Stock and Watson (2012)
M2 Money Supply	M2SL, USD, not s.a.	Stock and Watson (2012)
Total Reserves	TOTRES, USD, not s.a.	Stock and Watson (2012)
Non-borrowed Reserves	NBRES, USD, not s.a.	Stock and Watson (2012)
Inflation π_t	Consumer Price Index For All Urban Consumers: All Items	Stock and Watson (2012)
Index of sentitive materials prices		Stock and Watson (2012)
Federal Funds Rate i_t	Effective Federal Funds Rate	Stock and Watson (2012)
Commercial Bank Loans S_t	Fixed income credit to the real sector[21] of U.S.-chartered depository institutions and credit unions, USD, not s.a.	Financial accounts of the United States
Investment Fund Loans S_t^{IF}	Fixed income credit to the real sector of Money market funds, Mutual Funds, USD, not s.a.	Financial accounts of the United States
Shadow bank Loans S_t^{SB}	Fixed income credit to the real sector of ABS Issuers, Financing Companies, Funding Corporations, Security Brokers and Dealers, USD, not s.a.	Financial accounts of the United States

Table 5: Data sources and definitions
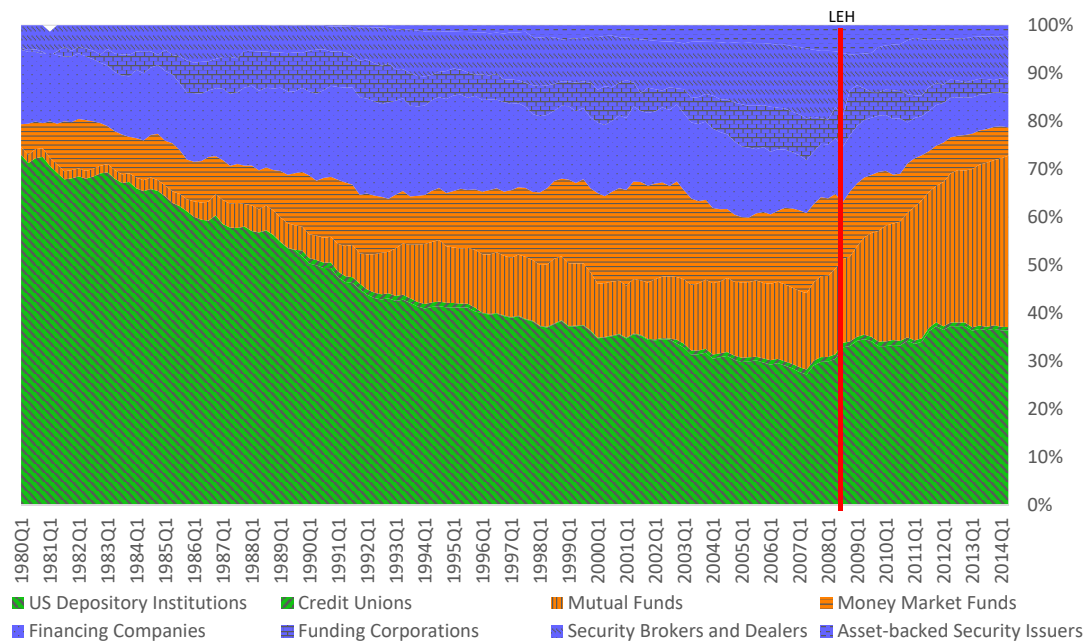
Figure 9: Timeline of credit intermediation share by the various components of the US financial system, 1980 to 2014. *Note: The red line titled 'LEH' indicates September 15, 2008. Source: Financial accounts of the United States.*
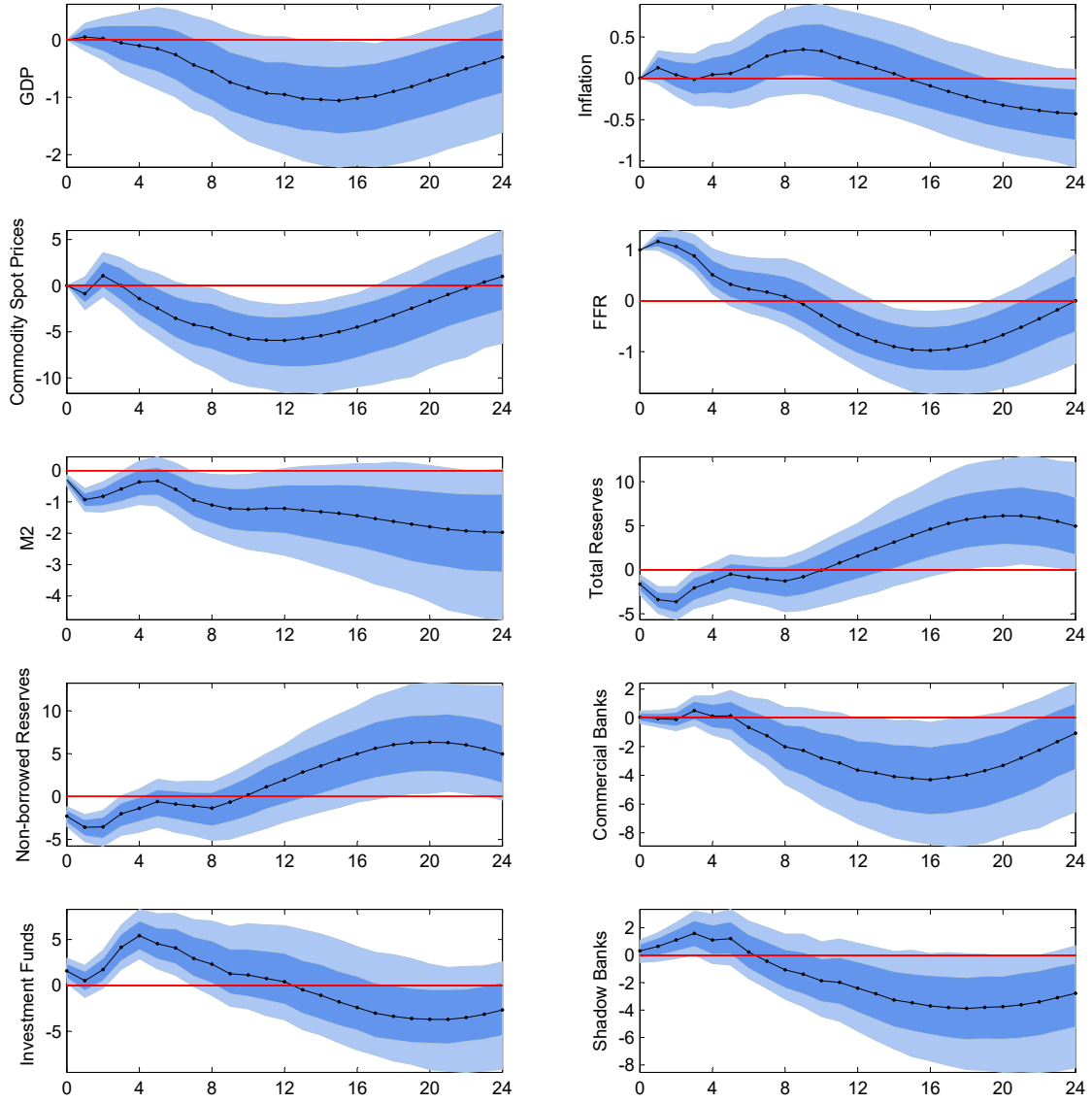
Figure 10: Response of all variables to a contractionary monetary policy shock. *Note: Empirical impulse responses of all variables to an unanticipated 100 basis point increase in the effective federal funds rate. The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the unshocked path. Shaded regions are 32nd-68th and 5th-95th percentiles of 1000 draws.*

C.2 Full Bayesian VAR

C.3 Bayesian Estimation
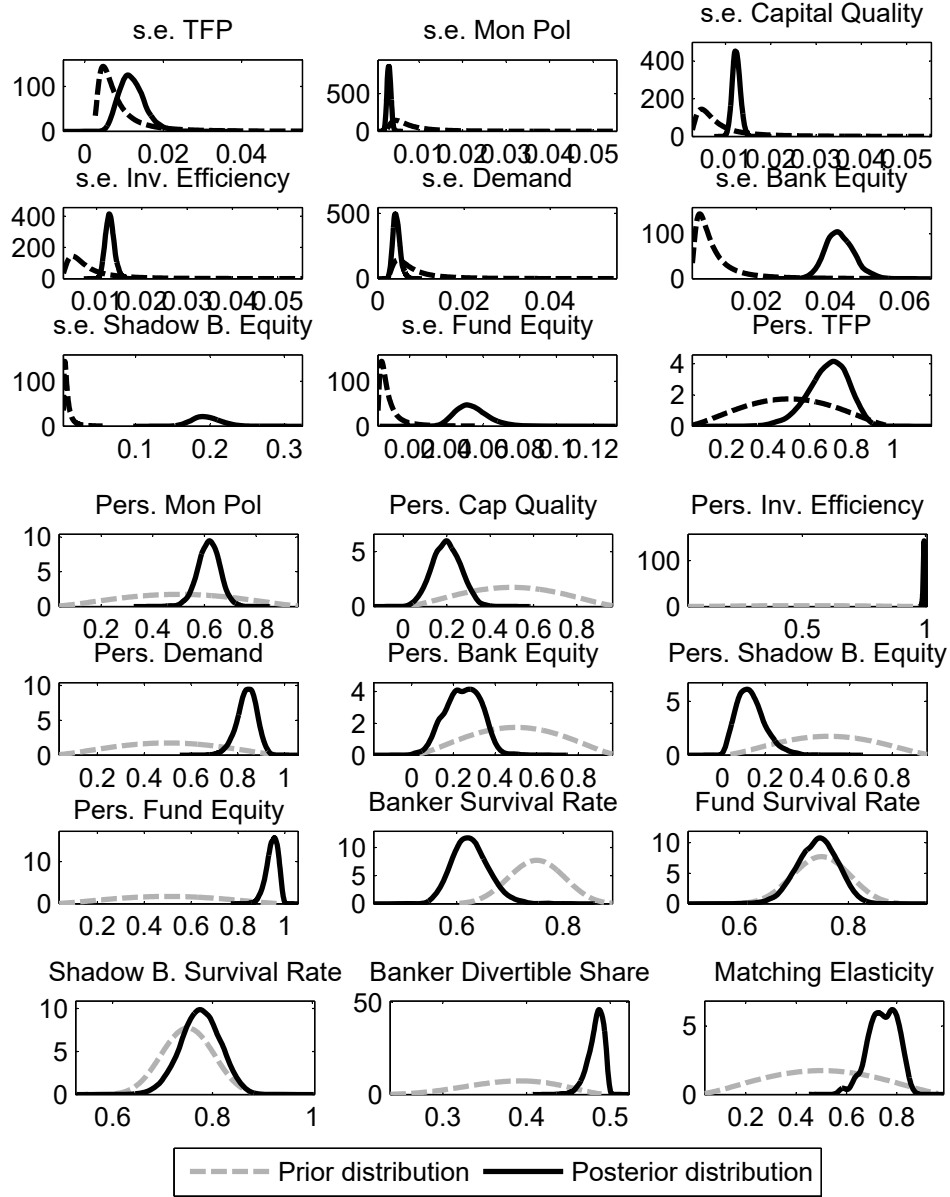
Figure 11: Posteriors for the standard deviations and persistances of shock processes, and structural parameters. *Note: Bayesian estimation with data from 1984:I to 2006:IV. Posteriors are based on 2 chains of 100.000 draws each. I drop the first 50.000 values of each chain.*
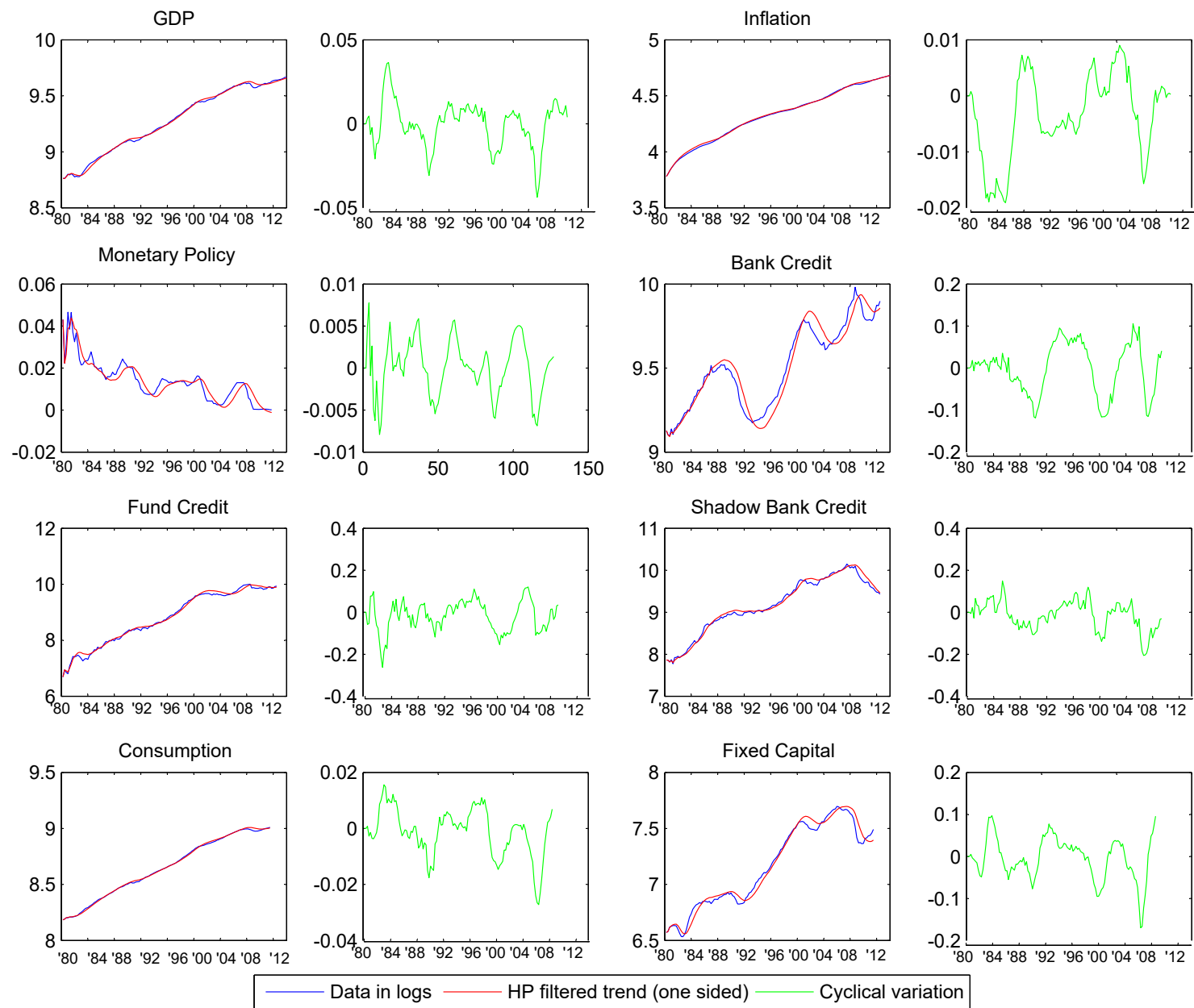
Figure 12: Data: Unfiltered, trend component (via one-sided HP filter), cyclical component. *Note: Vertical axes are pecentage points divided by 100 for cyclical variations and log data for data and trends.*

References

Albertini, J. and A. Poirier
   2015. Unemployment Benefit Extension at the Zero Lower Bound. *Review of Economic Dynamics*, 18(4):733–751.

Altunbas, Y., L. Gambacorta, and D. Marques-Ibanez
   2009. Securitisation and the bank lending channel. *European Economic Review*, 53(8):996–1009.

Beaubrun-Diant, K. E. and F. Tripier
   2015. Search frictions, credit market liquidity and net interest margin cyclicality. *Economica*, 82(325):79–102.

Bernanke, B. S. and A. S. Blinder
   1988. Credit, Money, and Aggregate Demand. *American Economic Review*, 78(2):435–39.

Bernanke, B. S. and M. Gertler
   1995. Inside the Black Box: The Credit Channel of Monetary Policy Transmission. *Journal of Economic Perspectives*, 9(4):27–48.

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

Boivin, J. and M. P. Giannoni
   2006. Has Monetary Policy Become More Effective? *The Review of Economics and Statistics*, 88(3):445–462.

Christiano, L., M. Eichenbaum, and S. Rebelo
   2011. When Is the Government Spending Multiplier Large? *Journal of Political Economy*, 119(1):78 – 121.

Christiano, L. J., M. Eichenbaum, and C. L. Evans
   1999. Monetary policy shocks: What have we learned and to what end? In *Handbook of Macroeconomics*, J. B. Taylor and M. Woodford, eds., volume 1 of *Handbook of Macroeconomics*, chapter 2, Pp. 65–148. Elsevier.

Christiano, L. J., M. Eichenbaum, and C. L. Evans
   2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*, 113(1):1–45.

Christiano, L. J., M. S. Eichenbaum, and M. Trabandt
   2016. Unemployment and business cycles. *Econometrica*, 84(4):1523–1569.

Claessens, S., Z. Pozsar, L. Ratnovski, and M. Singh
2012. Shadow Banking; Economics and Policy. IMF Staff Discussion Notes 12/12, International Monetary Fund.

den Haan, W. J., G. Ramey, and J. Watson
2003. Liquidity flows and fragility of business enterprises. *Journal of Monetary Economics*, 50(6):1215–1241.

Drechsler, I., A. Savov, and P. Schnabl
2016. The deposits channel of monetary policy. Working Paper 22152, National Bureau of Economic Research.

Dynan, K. E., D. W. Elmendorf, and D. E. Sichel
2006. Can financial innovation help to explain the reduced volatility of economic activity? *Journal of monetary Economics*, 53(1):123–150.

Eggertsson, G. B. and M. Woodford
2003. The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity*, 34(1):139–235.

Fernndez-Villaverde, J., G. Gordon, P. Guerrn-Quintana, and J. F. Rubio-Ramrez
2015. Nonlinear adventures at the zero lower bound. *Journal of Economic Dynamics and Control*, 57(C):182–204.

Financial Stability Board
2013. Strengthening oversight and regulation of shadow banking - an overview of policy recommendations. Technical report, Financial Stability Board.

Gambacorta, L., B. Hofmann, and G. Peersman
2014. The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A CrossCountry Analysis. *Journal of Money, Credit and Banking*, 46(4):615–642.

Gertler, M. and P. Karadi
2011. A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17–34.

Gertler, M. and N. Kiyotaki
2010. Financial Intermediation and Credit Policy in Business Cycle Analysis. In *Handbook of Monetary Economics*, B. M. Friedman and M. Woodford, eds., volume 3 of *Handbook of Monetary Economics*, chapter 11, Pp. 547–599. Elsevier.

Gertler, M., N. Kiyotaki, and A. Prestipino
2016. Wholesale Banking and Bank Runs in Macroeconomic Modelling of Financial Crises. NBER Working Papers 21892, National Bureau of Economic Research, Inc.

Goodhart, C. A., A. K. Kashyap, D. P. Tsomocos, and A. P. Vardoulakis
2012. Financial regulation in general equilibrium. Working Paper 17909, National Bureau of Economic Research.

Gu, C., F. Mattesini, and R. Wright
2016. Money and credit redux. *Econometrica*, 84(1):1–32.

Guerrieri, L. and M. Iacoviello
2015. OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70(C):22–38.

Haan, W. J. D. and V. Sterk
2011. The Myth of Financial Innovation and the Great Moderation. *Economic Journal*, 121(553):707–739.

Igan, D., A. N. Kabundi, F. N.-D. Simone, and N. T. Tamirisa
2013. Monetary Policy and Balance Sheets. IMF Working Papers 13/158, International Monetary Fund.

Jermann, U. and V. Quadrini
2006. Financial Innovations and Macroeconomic Volatility. NBER Working Papers 12308, National Bureau of Economic Research, Inc.

Justiniano, A. and G. E. Primiceri
2008. The Time-Varying Volatility of Macroeconomic Fluctuations. *American Economic Review*, 98(3):604–41.

Justiniano, A., G. E. Primiceri, and A. Tambalotti
2010. Investment shocks and business cycles. *Journal of Monetary Economics*, 57(2):132–145.

Kashyap, A. K. and J. C. Stein
1995. The impact of monetary policy on bank balance sheets. *Carnegie-Rochester Conference Series on Public Policy*, 42(1):151–195.

Kashyap, A. K., J. C. Stein, and D. W. Wilcox
1993. Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance. *American Economic Review*, 83(1):78–98.

Mazelis, F.
2016. Non-bank financial institutions and monetary policy. *working paper*.

Meeks, R., B. Nelson, and P. Alessandri
2014. Shadow banks and macroeconomic instability. Bank of England working papers 487, Bank of England.

Moreira, A. and A. Savov
2014. The macroeconomics of shadow banking. 2014 Meeting Papers 254, Society for Economic Dynamics.

Mortensen, D. T. and C. A. Pissarides
1994. Job creation and job destruction in the theory of unemployment. *The review of economic studies*, 61(3):397–415.

Nelson, B., G. Pinter, and K. Theodoridis
2015. Do contractionary monetary policy shocks expand shadow banking? Bank of England working papers 521, Bank of England.

Pescatori, A. and J. Sole
2016. Credit, Securitization and Monetary Policy: Watch Out for Unintended Consequences. IMF Working Papers 16/76, International Monetary Fund.

Petrongolo, B. and C. A. Pissarides
2001. Looking into the black box: A survey of the matching function. *Journal of Economic Literature*, 39(2):390–431.

Primiceri, G. E.
2005. Time Varying Structural Vector Autoregressions and Monetary Policy. *Review of Economic Studies*, 72(3):821–852.

Romer, C. D. and D. H. Romer
1990. New Evidence on the Monetary Transmission Mechanism. *Brookings Papers on Economic Activity*, 21(1):149–214.

Shiller, R. J.
1992. *Market volatility.* MIT press.

Verona, F., M. M. F. Martins, and I. Drumond
2013. (Un)anticipated Monetary Policy in a DSGE Model with a Shadow Banking System. *International Journal of Central Banking*, 9(3):78–124.

Wasmer, E. and P. Weil
2004. The Macroeconomics of Labor and Credit Market Imperfections. *American Economic Review*, 94(4):944–963.

Woodford, M.
2010. Financial Intermediation and Macroeconomic Analysis. *Journal of Economic Perspectives*, 24(4):21–44.

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