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Mortgage Debt and Shadow Banks*

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Abstract

Since the 1980s, the global banking sector has been characterized by three trends: i) a secular decline in interest rates, ii) a reallocation of bank investments from corporate loans towards mortgages and iii) the rise of shadow banking relative to regulated banking. This paper builds a general equilibrium framework that connects, analyzes and explains these trends in a causal way. In the model, exogenous downward pressure on real interest rates increases the share of mortgage investments. Consequently, the interbank market for mortgage securities becomes more liquid. This increases funding liquidity and shadow banks gain comparative advantage over regulated banks with respect to the supply of mortgage loans. In relative terms, the shadow banking sector grows. Meanwhile, the economy becomes more vulnerable to financial crises as shadow banks issue too many uninsured deposits. To enhance financial stability, I consider restrictions on admissible loan-to-value ratios for mortgage loans to reduce house price and mortgage supply fluctuation. Finally, I suggest to introduce interest-paying central bank deposits for households to raise the costs for banks to finance themselves with uninsured deposits.

Keywords: Shadow Banking, Regulated Banking, Financial Stability

JEL classification: E44, G10, G21, G23

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1 Introduction

Since the 1980s the banking sector has been characterized by three major trends. Perhaps the best documented trend is the secular decline in (real) interest rates, see Figure 1. In March 2005 former Fed chairman Bernanke emphasized the existence of a global savings glut, an increase in the global supply of savings, as the main source of this decline in interest rates.[1] An efficiently functioning banking sector allocates these savings to their most productive use. However, starting in the 1980s and up to the recent global financial crisis a second trend is observed. Banks increased the amount of loans secured by real estate, henceforth mortgages, much faster than the amount of commercial and industrial loans, henceforth corporate loans, see Figure 2. This reallocation of bank lending was accompanied by a third trend: a shift from regulated banking towards unregulated banking (henceforth: shadow banking), see Figure 3.

There is a clear correlation between the growth of shadow bank liabilities and the growth rate of mortgage loans, see Figure 4. However, no encompassing framework exists that describes a causal relationship in a general equilibrium context as these trends have, typically, not been considered together. Nevertheless, recent concerns regarding financial stability imply that such a framework is needed. These concerns arise because, on the one hand, a reallocation of lending towards housing investment rather than physical capital formation might harm the economy's production capacity, making it eventually harder to repay mortgage debt. A vastly growing shadow banking sector, on the other hand, might increase the likelihood of fire-sales and bank runs.[2] This paper builds a tractable model that shows how an exogenous inflow of deposits on bank balance sheets depresses real interest rates economy-wide and increases the share of mortgages on the aggregate bank balance sheet. This in turn fosters growth of, in particular, the shadow banking sector.[3] In doing so, we show that growth of the shadow banking sector reduces financial stability because shadow banks create more uninsured deposits than socially optimal.

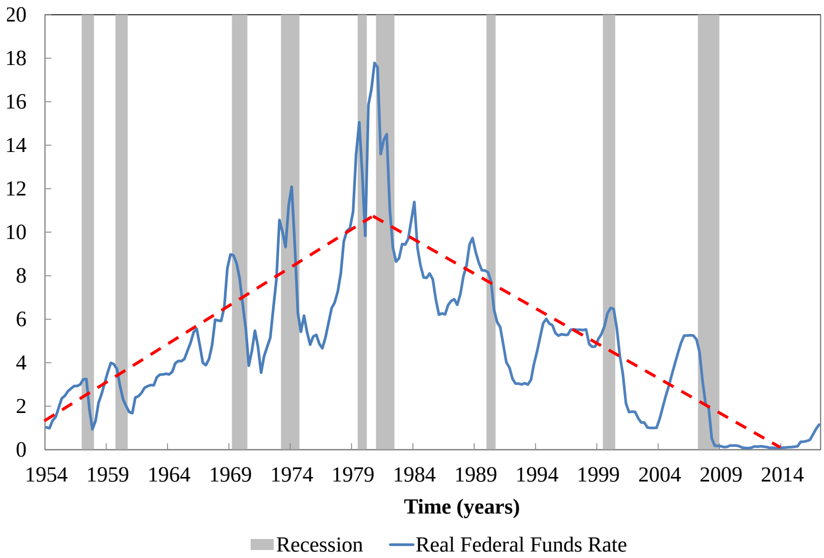
The intuition behind the relative reallocation of bank lending from corporate loans to

[1]Bernanke (2005) argues that developing countries increased their savings rate by decreasing their consumption. These savings were subsequently used to buy assets from developed countries which put downward pressure on their interest rates. See also Caballero et al. (2008) for a more detailed analysis of the decline in real interest rates.

[2]For example Bernanke (2005) argues that in the long run housing adds less to productivity growth than productive capital. Mian and Sufi (2014) and Mian et al. (2016) show that an increase in the household debt-to-GDP ratio predicts lower GDP growth and higher unemployment in the succeeding periods. Gennaioli et al. (2013) show how an exogenous increase in savings drives securitization, leverage and financial instability in the shadow banking sector. Moreira and Savov (2014) examine the interaction between shadow banks and the real economy and show how shadow banks can create liquidity via securitization but also additional instability.

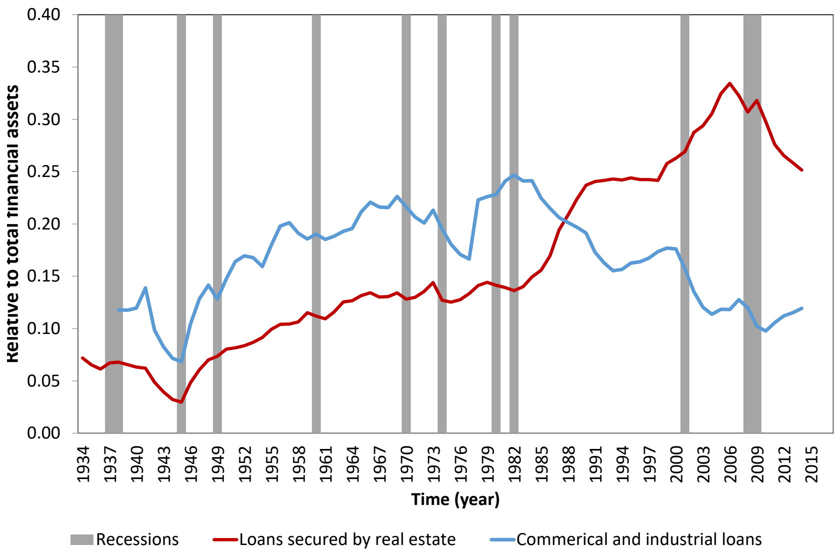
[3]Thereby the model also provides a theoretical explanation for the empirical findings of Jordà et al. (2015) who show that the rise in mortgage debt was closely associated with loose monetary policy.

Figure 1: Up and downward sloping trend in effective federal funds rate



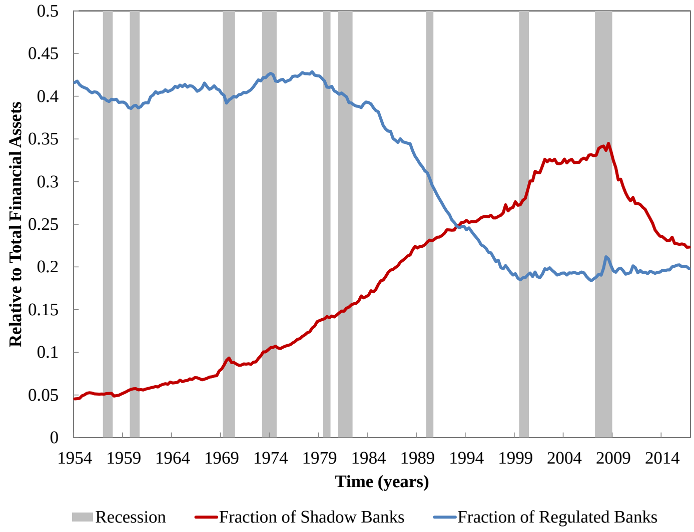
The effective federal funds rate is the interest rate at which depository institutions trade federal funds (balances held at Federal Reserve Banks) with each other overnight. Source: Federal Reserve Bank of St. Louis database (FRED Economic Data).

Figure 2: Real estate and corporate loans as share of U.S. financial sector



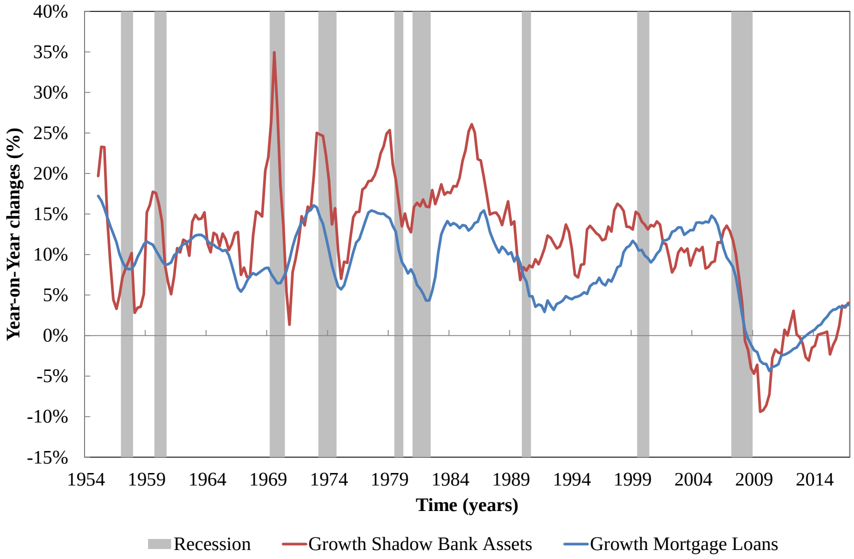
Notes: The blue line denotes loans secured by real estate (predominately mortgage loans). The red line denotes commercial and industrial loans (corporate loans). Both as a share of the total amount of financial assets of the domestic financial sector in the U.S. Source: Historical statistics on banking (Federal Deposit Insurance Corporation).

Figure 3: Total assets regulated banks and shadow banks as fraction of the total financial sector U.S.



Notes: The blue line shows the total liabilities of private depository institutions (regulated regulated banks). The red line shows other financial intermediaries except insurance companies and pension funds (unregulated shadow banks). Both as a share of the total amount of financial assets of the domestic financial sector in the U.S. Source: Flow of funds accounts of the United States (FRB).

Figure 4: Growth of mortgage loans and shadow bank liabilities U.S.



Notes: the red lines shows the growth rate of other financial intermediaries (unregulated shadow banks). The blue line shows the growth rate mortgage loans. Correlation 0.69. Source: Author's own calculations using data from the Flow of funds accounts of the United States and Federal Reserve Bank of St. Louis database.

mortgage loans is as follows. The model distinguishes two assets that can serve as collateral for bank loans: residential houses for mortgages and physical capital for corporate loans. By assumption the assets differ with respect to their supply elasticity; on average the supply of physical capital is more elastic than the supply of houses. An exogenous inflow of deposits on bank balance sheets depresses interest rates and induces impatient households to demand more credit for both houses and physical capital. Inelastic housing supply relative to the supply of physical capital causes house prices to rise relative to the price of physical capital. The value of collateral for mortgage loans increases relative to the value of collateral for corporate loans. Consequently, banks increase mortgage lending relative to corporate lending. Hence, collateral with a low supply elasticity shows more price and credit supply fluctuations than collateral with a high supply elasticity.

After having established a relationship between an inflow of deposits and a relative increase in mortgage lending, we show how this relationship can foster growth of, in particular, the shadow banking sector. In the model, both regulated and shadow banks can create safe money-like claims—deposits—which allows them to extract a rent from households, see, e.g., Gorton and Pennacchi (1990), Stein (2012) and Krishnamurthy and Vissing-Jorgensen (2015). To keep deposits perfectly safe and liquid in any state of the world, regulated banks are compelled to buy deposit insurance. As in Stein (2012) and Hanson et al. (2015), shadow banks are not compelled to participate in the deposit insurance scheme. To create ex-ante equally safe and liquid deposits, shadow banks offer depositors an early liquidation option. Consequently, shadow banks have lower funding costs (regulatory arbitrage), but are exposed to liquidity risk and prefer to hold highly liquid assets.

In the model, all banks trade in the interbank market (e.g., to construct diversified portfolios or because they face idiosyncratic liquidity shocks). Consequently, when the aggregate banking sector grows, interbank trading increases, the interbank market appears deeper and market liquidity—the ease to sell an asset close to its fundamental value—increases, see also Hanson et al. (2015). As the inflow of deposits fosters growth of mortgage loans, the interbank market for mortgage loans becomes deeper and the expected liquidation value of selling mortgage loans increases. Since the expected liquidation value of shadow bank assets increases, their funding liquidity increases. Shadow banks face less liquidity risk and can exploit their regulatory arbitrage with respect to the supply of mortgage loans. As a result, the shadow banking sector grows relative to the regulated banking sector because the mortgage loan market grows relative to the corporate loan market.

The growing shadow banking sector leaves the economy excessively vulnerable to financial crises because the shadow banking sector creates too many uninsured deposits compared to the social optimum. As in Brunnermeier and Pedersen (2009) and Stein (2012), when intermediaries do not internalize the costs of fire-sales, unregulated private money creation is typically sub-optimal. In this paper, we utilize the general equilibrium structure of the model to show why banks do not internalize this price effect. A growing shadow banking sector increases the risk that a significant share of the banking sector must liquidate its assets which reduces liquidity in the interbank market. Consequently, shadow banks that create more uninsured deposits increase the banking system's reliance on liquidity support by the central bank. However, the expected costs of liquidity support by the central bank are not affected by the size of the shadow banking sector. As a result, the increase in liquidity risk is not fully reflected in the expected liquidation price of shadow banks' assets and they issue too many uninsured deposits.[4]

The results presented in this paper relate to a growing literature emphasizing the risks for financial and economic stability of household debt. First, an inflow of deposits might harm production when mortgage loan supply crowds out corporate loan supply as investment in physical capital is more productive than investment in housing, see Benigno and Fornaro (2014), Bernanke (2005) and Borio et al. (2016). In the model, the total stock of houses is fixed.[5] Hence, the increase in mortgage lending is collateralized by the increase in the price of the underlying asset rather than by an increase in the total amount of underlying assets. That is, the economy is increasingly Ponzi-financed (Minsky, 1986). The increase in mortgage loans supported solely by an increase in house prices does not improve the economy's production capacity and leaves the economy vulnerable to future house price declines.[6] Empirical evidence reported by Mian and Sufi (2014) and Mian et al. (2016) shows indeed that household debt, predominantly mortgage loans, is an important determinant of business cycle fluctuations.

Prudential authorities in some countries introduced restrictions on admissible loan-to-value (LTV) ratios to create a precautionary buffer against house price fluctuations. Here we show two additional potential benefits from these LTV limits. First, they mitigate house price and thereby mortgage supply fluctuations when shocks hit the economy. Hence, LTV limits do not only provide a larger buffer to protect borrowers against house price fluctuations but, also simultaneously attenuate fluctuations in house prices and mortgage supply. These results are in line with the findings of Wong et al. (2011) which

[4]Mink (2016) and DeAngelo and Stulz (2015) show that banks having access to a very liquid interbank market in which systemic risk is insured by a lender of last resort leads to excessive liquidity creation and high bank leverage.

[5]Green et al. (2005) argue that housing supply responds relatively inelastic to increases in housing demand in the short-run. Saiz (2010) shows that most areas in which housing supply is regarded as inelastic are constrained by the amount of available land related to the geography of the area.

[6]Glaeser et al. (2008) show indeed that places with more elastic housing supply have fewer and shorter house price bubbles.

emphasize the importance of LTV caps in reducing systemic risk originating from the boom-and-bust cycle of housing markets. Second, LTV limits reallocate bank lending from mortgage loans to corporate loans, not only in steady state but also when interest rates fall and credit supply increases. As a result, a larger share of the increase in credit supply is allocated to firms investing in physical capital which benefits the economy's production capacity. These results emphasize the importance of macroprudential tools like LTV limits in safeguarding financial and economic stability.

This paper is also related to a growing literature on financial stability. Absent a deposit guarantee system, a large shadow banking sector undermines financial and economic stability. As described by Diamond and Dybvig (1983), the liquid character of bank liabilities and the illiquid character of bank assets make these banks intrinsically prone to runs. Brunnermeier (2009), Brunnermeier and Pedersen (2009) and Brunnermeier and Sannikov (2014) describe how banks that fund themselves with liquid short-term deposits to finance illiquid long-term investments are more vulnerable to liquidity risk. Pozsar et al. (2010) and Adrian and Ashcraft (2012) argue that deposit insurance and a liquidity backstop provided by the central bank are key to keep consumers calm and their claims liquid. However, by providing liquidity insurance to banks that is not actuarially fair priced, banks have a competitive advantage in creating risk free and liquid claims. It is, precisely this free liquidity insurance that induces shadow banks to issue too many deposits rather than raising equity, leaving the financial sector vulnerable to liquidity crises.[7]

In theory this externality and thereby the consequences for financial stability could be regulated by means of a Pigouvian tax. In practice, however, it is hard to determine the optimal level of this tax. Stein (2012) suggests therefore that the regulator should supply tradable permits that allow banks to create deposits. The market price of these tradable permits helps to identify the externality. Nevertheless, the optimal amount of permits remains a guess and, if anything, the system increases regulatory arbitrage between regulated and unregulated banks. Here, we propose a more direct approach that does not rely on unobservables and affects shadow banks and regulated banks equally as it works through market prices. The central bank should provide households access to interest-paying central bank deposits. In doing so, the opportunity costs for households of holding bank deposits, as opposed to interest bearing central bank deposits, increases. This means that banks have to offer a higher interest rate on deposits to persuade households not to convert their deposits into central bank deposits. If the interest rate on central bank deposits is sufficiently high, the central bank eliminates the incentive for

[7]In this paper we use a macro-perspective to motivate the externality. Stein (2012), Greenwood et al. (2015) and Greenwood et al. (2016) motivate a similar externality from the perspective of an individual bank and also argue that in its presence banks create too many uninsured deposits.

both regulated and shadow banks to finance themselves with deposits rather than equity.

The rest of the paper is organized as follows. Section 2 describes the correlation presented in Figure 4 in more detail. Section 3 presents the model. Section 4 presents the simulation results. Section 5 discusses the policy implications and Section 6 concludes.

2 Stylized facts extended

In this section we examine more carefully which factors drive the correlation presented in Figure 4. Specifically, we control for real business cycle activity to ensure that the correlation in Figure 4 is not driven by an omitted variable or underlying trend. Also, Gertler et al. (2016) suggest that financial innovation (mostly securitization of mortgages) was the main driver of shadow bank growth which led to more leverage capacity at shadow banks, a decrease in lending rates and more mortgage lending. First, we control for financial innovation by including the growth rate of the asset backed securities and mortgage backed securities markets. Second, we estimate a vector autoregression in an attempt to control for reverse causality. Finally, the correlation in Figure 4 is biased when the growth rate of mortgage loans is by definition equal to the growth rate of the shadow bank balance sheet. Although we will argue that this form of simultaneity is unlikely, we replace the growth rate of mortgage loans by the growth rate of mortgage loans supplied by private depository institutions only. This growth rate is less likely to by determined simultaneously with the growth rate of shadow bank assets.

2.1 Linear regression model

To examine more carefully whether the correlation is caused by any of these factors, we estimate the following linear regression model for the U.S. banking sector:

$$\Delta \ln (Y_t^b) = \alpha_0 + \alpha_1 \Delta \ln (M_t^{total}) + \alpha_2 \Delta \ln (C_t^{total}) + \beta B_t^{real} + \gamma Z_t^{total} + \varepsilon_t \qquad (1)$$

where Y_t^b denotes either the total amount of regulated (rb) or shadow bank (sb) financial assets, $b \in (sb, rb)$, M_t^{total} denotes the total amount of mortgage loans and C_t^{total} denotes the total amount of corporate loans in the U.S., B_t^{real} controls for real business cycle activity (real GDP growth, the Federal Funds rate and CPI inflation) and Z_t^{total} controls for financial innovation and includes both the growth rate of the total asset backed securities (ABS) and mortgage backed securities (MBS) markets in the U.S., see Tables 3 and 4 in Appendix A for details.[8]

[8] All variables are stationary at the 5% significance level.

The coefficients in Equation (1) are subject to a simultaneity bias when the growth rate of mortgage loans and the growth rate of corporate loans determine, to a large extent, the growth rate of the bank balance sheet Y_t^b. However, as shadow banks and regulated banks only constitute a relatively small share of the total U.S. financial sector, this bias is arguably small. These shares for shadow banks and regulated banks range from 5 and 42 percent in 1954 to 22 and 18 percent in 2017, respectively (see also Figure 3). In addition, mortgage loans account for (on average) 22 percent of the total amount of financial assets in the U.S while corporate loans account for only 6 percent of the total amount of financial assets. About half of these mortgage loans (48 percent) are supplied by private depository institutions, i.e., regulated banks. To estimate whether a simultaneity bias is driving our results, we also estimate Equation (1) for shadow banks and replace the growth rate of the total amount of mortgage loans, by the growth rate of mortgage loans supplied by private depository institutions only.

We estimate Equation (1) with Ordinary Least Squares. The results are presented in Table 1. Columns (1) and (2) present the estimation results for the growth rate of regulated bank assets. All regressors are significant and have the expected sign. The coefficients on mortgage loan growth (α_1) and corporate loan growth (α_2) are not significantly different from each other. These results suggest that both types of assets are equally important for the growth rate of regulated banks. The growth rate of the ABS and MBS markets ($\gamma = 0.089$) correlates significantly with the growth rate of regulated banks. The coefficient is, however, relatively small and suggests that growth of the ABS and MBS markets is not an important factor for the growth rate of the regulated banking sector.

The results for shadow banks are presented in columns (3) and (4) of Table 1. Shadow bank growth correlates strongly with the growth rate of mortgage loans ($\alpha_1 = 0.646$). Also the growth rate of corporate loans is significantly correlated with the growth rate of shadow banks. However, it appears that for shadow banks the growth rate of corporate loans is less important. The size of the coefficient on corporate loan growth $\alpha_2 = 0.176$, which is about one-fourth of the size of the coefficient on mortgage loan growth α_1. These results suggest that the growth rate of the mortgage loan market is much more important for shadow bank growth than the growth rate of the corporate loan market.

The growth rate of the market for ABS and MBS also significantly correlates with the growth rate of the shadow banking sector. However, the coefficient $\gamma = 0.068$ is again small. These results suggest that shadow bank growth is not strongly correlated with the expansion of the ABS and MBS market.

Finally, columns (5) and (6) present the results for shadow banks were we have replaced the growth rate of mortgage loans by the growth rate of mortgage loans supplied

Table 1: Estimation results Equation (1)

	Regulated banks		Shadow banks		Shadow banks	
Variables	Coefficients (1)	Prob. (2)	Coefficients (3)	Prob. (4)	Coefficients (5)	Prob. (6)
Growth of mortgages loans (α_1)	0.279	0.000	0.646	0.000		
	(0.044)		(0.073)			
Growth of mortgages loans PDI only (α_1)					0.378	0.000
					(0.065)	
Growth corporate loans (α_2)	0.215	0.000	0.176	0.000	0.175	0.001
	(0.026)		(0.044)		(0.053)	
GDP Growth (β_1)	0.153	0.000	-0.093	0.180	-0.079	0.302
	(0.042)		(0.070)		(0.076)	
Federal Funds Rate (β_2)	-0.328	0.000	0.852	0.000	1.087	0.000
	(0.072)		(0.119)		(0.132)	
Inflation (CPI) (β_3)	0.358	0.000	-0.324	0.018	-0.352	0.018
	(0.082)		(0.135)		(0.147)	
Growth ABS & MBS assets (γ)	0.089	0.000	0.058	0.035	0.082	0.005
	(0.016)		(0.027)		(0.029)	
Constant (α_0)	2.086	0.000	1.016	0.068	1.934	0.001
	(0.334)		(0.554)		(0.576)	

Notes: Estimation period $1955Q3 - 2017Q2$. Standard errors in parentheses Adjusted R-squared: 0.604 for the growth rate of regulated banks and 0.705 and 0.705 for the growth rate of shadow banks. Abbreviation: Private Depository Institutions (PDI). Source: Author's own calculations using data from the Flow of funds accounts of the United States and Federal Reserve Bank of St. Louis database.

by private depository institutions only. Although this variable does not capture the full dynamics of the mortgage loan market, the coefficients are no longer subject to a simultaneity bias. The coefficient on mortgage loan growth drops from 0.646 tot 0.378, which is still significantly larger than the growth rate on corporate loan growth which is 0.175. These results suggest that an increase in the amount of mortgage loans supplied by private depository institutions also correlates significantly with the growth rate of shadow bank assets.

2.2 Multivariate regression model

For shadow banks, the coefficients in Table 1 on the real economic control variables $(\beta_1, \beta_2, \beta_3)$ are either insignificant or have an unexpected sign. These coefficients can be biased due to reverse causality when the growth rate of the shadow banking sector also affects the growth rate of GDP, the inflation rate and the Federal Funds rate. In an attempt to control for this reverse causality we estimate the following vector autoregression:[9]

$$X_t = \alpha_0 + \Phi(L)X_{t-1} + \varepsilon_t, \tag{2}$$

[9]The series do show some signs of co-integration. For this reason we also estimated a Vector Error Correction model. The results, which are not presented here, are similar to the impulse response functions of the Structural Vector Autoregression.

where $\Phi(L) \equiv \Phi_0 + \Phi_1 L^1 + ... + \Phi_p L^p$ is a lag polynomial and X_t is a stacked vector containing the same observed variables as in (1). We identify the VAR by using a Cholesky decomposition. The ordering is as follows: $X_t = [Y_t^b, M_t^{total}, C_t^{total}, B_t^{real}, Z_t^{total}]$ and we include 4 lags. Results are robust to different lag lengths. Also the ordering of the VAR does not affect the results. Figure 7 in Appendix A shows the results for a different ordering: $X_t = [M_t^{total}, C_t^{total}, Y_t^b, B_t^{real}, Z_t^{total}]$, i.e., we allow the growth rate of the shadow banking sector to affect the growth rate of the mortgage loan market and the corporate loan market contemporaneously. Results are very similar. The results are also robust to placing the real economic variables B_t^{real} and/or the growth rate of the ABS and MBS markets Z_t^{total} first in order.

Figure 5 shows the impulse response functions for regulated banks. For brevity we omitted the impulse response functions for the other variables included in Equation (2). The graphs shown in the first column show the response of mortgage loan growth and corporate loan growth to an unexpected increase in the growth rate of the regulated banking sector. The growth rate of both assets increases when the regulated banking sectors grows. The growth rate of corporate loans responds stronger than the growth rate of mortgage loans to an increase in the growth rate of regulated banks. The results suggest that a one percentage point increase in regulated bank growth is related to a 1 percentage point increase in corporate loan growth, and only to a 0.5 percentage point increase in mortgage loan growth.

The first graphs in the second and third column show the response of the growth rate of the regulated banking sector to a shock in the growth rate of mortgage loans and corporate loans, respectively. Both impulse responses are insignificant suggesting that the growth rate of regulated banks is not affected by unexpected increases in the growth rates of these assets. That is, we cannot find evidence that an increase in the markets for corporate loans or mortgage loans affects the growth rate of the regulated banking sector.

Figure 6 shows similar impulse response functions as in Figure 5, but replaces the growth rate of the regulated banking sector with the growth rate of the shadow banking sector. It turns out that the results for shadow banks are different than those for regulated banks. Shadow bank growth appears to respond positively to a shock in the mortgage growth rate (first graph in the second column). In contrast, shadow bank growth is unaffected by an increase in the growth rate of corporate loans (first graph in the third column). Furthermore, an increase in the growth rate of shadow banks has no effect on the growth rate of either mortgage loans or corporate loans.

Figure 7 shows similar impulse response functions as in Figure 6, but replaces the growth rate of mortgage loans with the growth rate of mortgage loans supplied by private

Figure 5: VAR estimation results of Equation (2) for regulated banks

Notes: estimation period 1955Q3–2017Q2, time (quarters) horizontal axis, percentage point deviation on the vertical axis. The titles explain the response of one of the variables included to a shock of any of the variables included. Dotted red lines denote confidence intervals at 95% significance level.

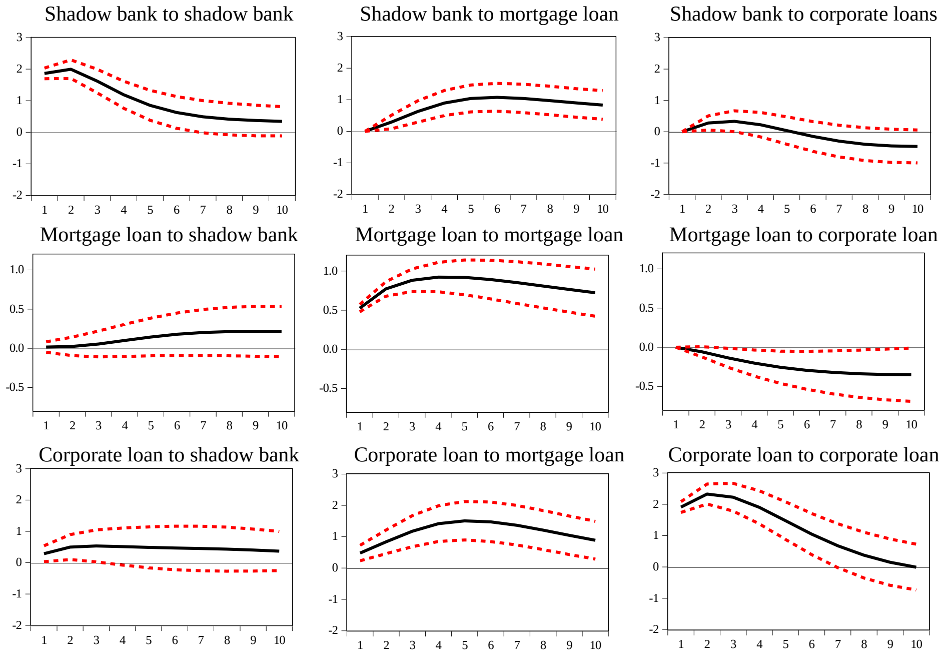
depository institutions. Results are very similar to the results presented in Figure 6: a shock to the growth rate of mortgage loans affects the growth rate of the shadow banking sector, whereas an increase in the shadow bank growth rate does not affect the growth rate of mortgage loans. Moreover, replacing the the growth rate of mortgage loans with the growth rate of mortgage loans supplied by private depository institutions in reduced the size of the coefficient significantly in Table 1. In contrast, the results in 7 are not affected by this change and appear robust.

Evidently these results are not conclusive. They do suggest, however, that mortgage growth appears to affect shadow bank growth, while we cannot find strong evidence that shadow bank growth is driving the growth rate of the mortgage loan market. In the next section we present a model that is able to explain this apparent causality in more detail.

3 The model

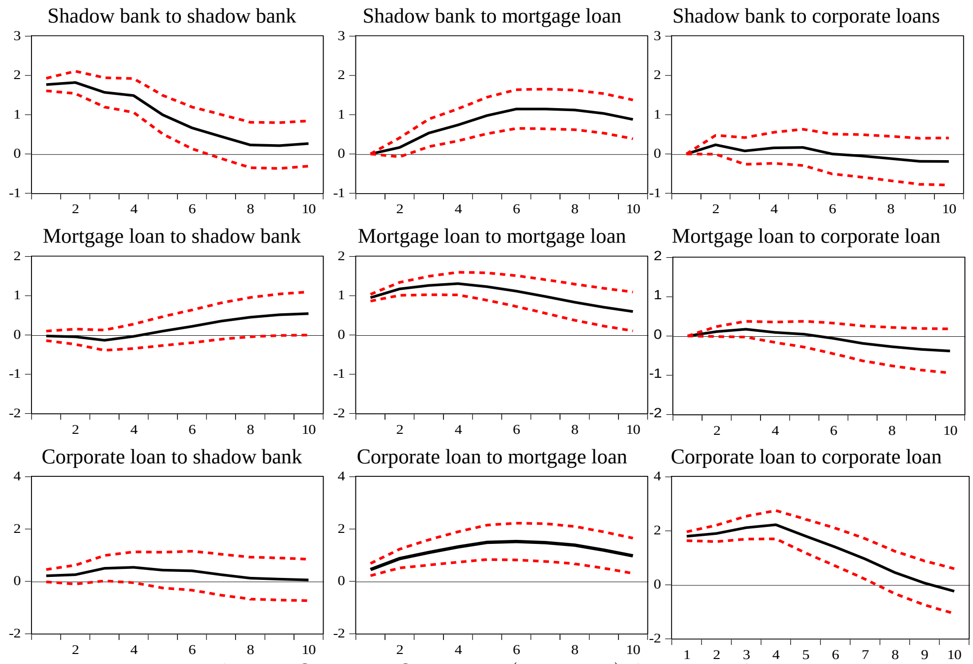
The model embeds elements of the financial structure developed in Stein (2012), Gennaioli et al. (2013) and Hanson et al. (2015) in a general equilibrium context. Specifically, regulated banks are regulated while shadow banks are not. Since households value deposits for their safety and liquidity, the deposit rate trades at a discount vis-à-vis the rate on bank equity. Consequently, absent regulation, both shadow banks and regulated

Figure 6: VAR estimation results of Equation (2) for shadow banks



Notes: estimation period 1955Q3–2017Q2, time (quarters) horizontal axis, percentage point deviation on the vertical axis. The titles explain the response of one of the variables included to a shock of any of the variables included. Dotted red lines denote confidence intervals at 95% significance level.

Figure 7: VAR estimation results of Equation (2) for shadow banks and PDI mortgage loan growth



Notes: estimation period 1955Q3–2017Q2, time (quarters) horizontal axis, percentage point deviation on the vertical axis. The titles explain the response of one of the variables included to a shock of any of the variables included. Dotted red lines denote confidence intervals at 95% significance level.

banks prefer to finance their lending with deposits rather than equity as the latter is more expensive. Both banking types can fund mortgages and corporate loans. In this paper, corporate loans are used by firms to buy physical capital and mortgage loans are used by impatient households to fund a house.

Aggregate productivity risk is introduced to create scope for deposit insurance and liquidity risk. Aggregate risk cannot be diversified and poses a potential threat to the risk-free claim of depositors. The central bank requires regulated banks to insure all downside aggregate risk in the deposit guarantee scheme (DGS). Shadow banks are unregulated and offer households an early liquidation option to create risk-free claims (Stein 2012 and Hanson et al. 2015). For shadow banks the early liquidation option is less costly, but offering this option creates additional liquidity risk. Unregulated shadow banks cannot borrow directly from the central bank. Consequently, if a pessimistic signal about the future state of the world occurs, shadow banks must sell their assets in the interbank market to regulated banks in order to remunerate their depositors. The expected liquidation value of shadow bank assets is key and determines the shadow banks' comparative advantage vis-à-vis regulated banks. If the expected liquidation value is low, shadow banks have no comparative advantage and only regulated banks exist. If the expected liquidation value is high, shadow banks have a comparative advantage and can exploit any regulatory arbitrage.

The model describes three sources of heterogeneity: patient (p) and impatient (i) consumers denoted by the superscript $j \in \{p, i\}$, regulated banks (rb) and shadow banks (sb) denoted by the superscript $b \in \{rb, sb\}$, and mortgages (f) and corporate loans (e) denoted by the superscript $\iota \in \{f, e\}$. Impatient consumers discount the future more heavily than patient consumers. As a consequence, the latter will prefer to save while impatient consumers will prefer to borrow. Both households may hold central bank money (henceforth: cash) which does not pay interest or buy risk-free money-like claims (henceforth: deposits) from risk neutral banks because both are necessary to consume. Thus, indirectly, consumption is subject to a cash-in-advance constraint. Patient households might also buy equity of both banking types in order to save part of their income.

3.1 Aggregate risk

The return on bank assets (corporate loans and mortgages) π_s depends on the state of the world $s \in S$. At time t all banks assume that state $s \in S$ materializes with probability $\varrho_s > 0$ where $\sum_s \varrho_s = 1$. For reasons of tractability, we assume that at each point in time banks expect only 3 different states: $S = \{g, b, d\}$ referring to a *good*, *bad* and *disaster* state, respectively. Accordingly, $\pi_g(\cdot) > \pi_b(\cdot) > \pi_d(\cdot)$ denote the return on bank assets in the respective states. Between time t and $t+1$ we assume that some information about the future economic state can be observed $S^{'} = \{H, L\}$, which can be either optimistic (H) or pessimistic (L). $P(u)$ denotes the probability of an upturn and $P(d)$ denotes the probability of a downturn. If an optimistic signal is observed, agents know with certainty that the disaster state will not occur. If a pessimistic signal is observed, all three states can occur.[10] The probability tree in Figure 8 formalizes the discussion.

The following notation is introduced for brevity purposes:

$$E_t(\pi_s) \equiv P(u)E_{t|S'=H}(\pi_s) + P(d)E_{t|S'=L}(\pi_s) = 1, \tag{3}$$

$$E_{t|S'=H}(\pi_s) \equiv P(u|H)\pi_g + P(d|H)\pi_b, \tag{4}$$

$$E_{t|S'=L}(\pi_s) \equiv P(u|L)\pi_g + (1 - P(u|L) - P(d|L))\pi_b + P(d|L)\pi_d, \tag{5}$$

where $E_t(\pi_s)$ is the expected return at time t before the signal occurs which we normalize to unity and $E_{t|S'=H}(\pi_s)$ and $E_{t|S'=L}(\pi_s)$ denote the expected return associated with an optimistic or a pessimistic signal, respectively.

3.2 Real economy: households and firms

The economy consists of two types of infinitely lived households, the only difference being that the impatient household has a lower discount factor than the patient household $\beta^i < \beta^p$. Consequently, in equilibrium patient households save, while impatient households borrow. The economy occupies a continuum of households with their mass normalized to unity. Households derive utility from consumption C_t^j, holding deposits or cash M_t^j, leisure $(1 - L_t^j)$ and owning a house H_t^j.[11] The corresponding household utility function takes the following functional form:

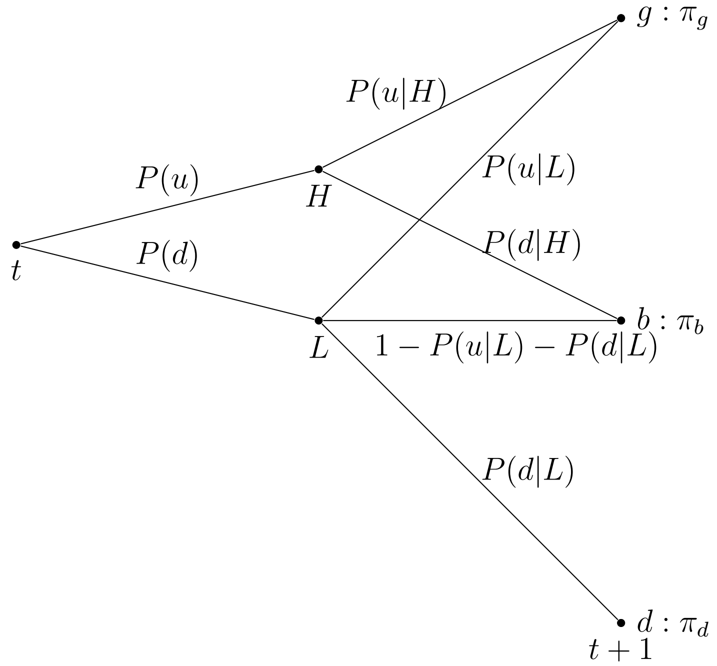
$$U_t^j = E_t \sum_{t=0}^{\infty} (\beta^j)^t \left(\frac{\left[(C_t^j)^\eta (H_t^j)^{1-\eta}\right]^{1-\sigma^c}}{1-\sigma^c} + \frac{\gamma_m (M_t^j)^{1-\sigma^m}}{1-\sigma^m} - \frac{\gamma_l^j (L_t^j)^{1+\sigma^l}}{1+\sigma^l} \right), \tag{6}$$

where deposits M_t^j can be supplied by regulated banks $M_t^{j,rb}$ and shadow banks $M_t^{j,sb}$ or by the central bank $M_t^{j,cb}$ in the form of cash, E_t is an expectation operator, $1-\eta$ denotes

[10]These assumptions can easily be generalized. In particular, S could include a continuous set of states s and a continuous set of signals might be observed that are consistent with the results presented below. Crucial, however, is that a set of signals can be observed with probabilities of a disaster states that are negligibly small (or absent) to keep depositors calm while pessimistic signals result in depositors withdrawing their shadow bank deposits.

[11]Deposits in the utility function can be motivated by a cash-in-advance constraint as households need deposits to pay for consumption. While deposits can be used directly for payment, equity must first be converted into a liquid asset like deposits before a household can use it for payment. This liquidity difference motivates why, apart from safety reasons, both types of households value deposit holdings over equity when interest rates on both assets are the same.

Figure 8: Probability tree for the occurrence of a signal and the states of the world.



Notes: $P(u)$ denotes the probability for an up node and $P(d)$ denotes the probability of a down node. After the signal, the probabilities of an up node or down node are conditional on an optimistic (H) or pessimistic (L) signal. $\pi_g(\cdot) > \pi_b(\cdot) > \pi_d(\cdot)$ denote the productivity in the good, bad and disaster state, respectively.

the weight of housing, σ^c, σ^m and σ^l denote, respectively, the inverse of the elasticities with respect to consumption, deposits and work-effort, γ_m and γ_l^j denote the weights of deposits and labor relative to consumption in the utility function.

Residential houses play a key role in the model. In Equation (6) we assume that households consume a consumption bundle that contains regular consumption goods and their stock of houses. Consequently, if consumption increases, housing demand increases because consumers equate the marginal rate of substitution to the price differential between house prices (q_t^h) and consumer prices (in this model normalized to unity). However, as residential houses do not perish each period like consumption goods, owning a house also yields a potential capital gain $r_t^h \equiv q_t^h/q_{t-1}^h - 1$. Accordingly, both a decrease in the lending rate or an expected increase in house prices increase housing demand.

If households receive a pessimistic signal, they liquidate their deposits in the shadow banks and convert it in regulated bank deposits or cash. If the signal is optimistic, households remain calm and hold on to their deposits in the shadow banks. The option to liquidate at the intermediate stage makes the shadow bank deposits ex-ante perfectly safe and liquid. Regulated bank deposits are fully protected by the deposit guarantee system (DGS). Hence, in the steady state households do not hold cash because the central bank does not pay interest and cash is therefore inferior to deposits. Cash becomes attractive, however, when deposit interest rates fall sufficiently (below zero) or when the regulated banking sector is no longer able to create perfectly safe and liquid claims.

Households maximize their utility subject to their budget constraints. The patient household's budget constraint is represented by:

$$\begin{aligned} M_t^p + Q_t + q_t^h(H_t^p - H_{t-1}^p) = (1 + i_{t-1}^m)M_{t-1}^p - i_{t-1}^m M_{t-1}^{p,cb} + \\ (1 + i_{t-1}^q)Q_{t-1} + r_t^h H_{t-1}^p - C_t^p + W_t L_t^p + \theta(\Pi_t^b + \Pi_t^p) \end{aligned} \tag{7}$$

where $Q_t = Q_t^{rb} + Q_t^{sb}$ denotes the equity stakes of the patient households in the regulated and shadow banks respectively, i_t^m, either $i_t^{m,rb}$ or $i_t^{m,sb}$, denote the rates on regulated and shadow bank deposits respectively, and i_t^q, either $i_t^{q,rb}$ or $i_t^{q,sb}$, denotes the risky interest rates on regulated and shadow banking equity respectively.[12] The term W_t denotes the wage rate patient households receive for supplying labor to the firms and Π_t^p and Π_t^b denote firm profits and bank profits redistributed to households where θ denotes the share of patient households in the economy.[13] Finally, households own a housing stock H_t^j and realize a return on the house defined by r_t^h. We assume that a house is perfectly divisible. Each period, households can therefore buy or sell part of their house in line

[12]Note that $i_{t-1}^m M_{t-1}^{p,cb}$ in (7) accounts for the fact that cash does not pay interest.

[13]As the economy is fully flexible, firms profits are always zero, while bank profits flow to the bank equity holders.

with their demand for housing for a price q_t^h.

The impatient households have the same utility function as the patient households. They own, however, potentially different assets because they are the savers and therefore also the investors in the economy. Particularly, impatient households have two investment opportunities for which they can borrow: they can invest in physical capital K_t or in housing H_t. Physical capital has a cost r_t^e and yields a return r_t^k while housing costs r_t^f and yields a return r_t^h. The impatient household's budget constraint is represented by:

$$\begin{aligned}B_t^f + B_t^e - M_t^i =& q_t^h(H_t^i - H_{t-1}^i) + (1 + i_{t-1}^f)B_{t-1}^f + (1 + i_{t-1}^e)B_{t-1}^e - \\ & (1 + i_{t-1}^m)M_{t-1}^i + i_{t-1}^m M_{t-1}^{i,cb} - r_t^h H_{t-1}^i - W_t L_t^i - r_t^k K_{t-1} - \\ & (1 - \theta)(\Pi_t^b + \Pi_t^p) + C_t^i + I_t, \end{aligned} \tag{8}$$

where B_t^f denotes mortgages for the nominal value of the house $q_t^h H_t^i$ and B_t^e denotes corporate loans for the nominal value of physical capital $q_t^k K_{t-1}$, i_t^f denotes the gross lending rate for mortgages and i_t^e denotes the gross lending rate for physical capital. Impatient households rent out their physical capital stock to firms for a rental rate r_t^k. The physical capital stock accumulates according to:

$$K_{t+1} = K_t(1 - \delta) + I_t\left(1 - \frac{\phi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right), \tag{9}$$

where I_t denotes net investment in the physical capital stock and δ denotes the depreciation of the physical capital stock. The second term in round brackets in (9) denotes physical capital adjustment costs. The parameter ϕ which denotes the degree of adjustment costs, determines to some degree shifts in demand between physical capital and housing as it determines the elasticity of physical capital supply.

The loan (B_t^ι) cannot be larger than the real value of its collateral. Without this constraint, impatient consumers would like to borrow indefinitely to finance housing, physical capital, but also consumption. As the main purpose is to distinguish between investment in two types of assets, we restrict borrowing for consumption. For this reason, the following inequality constraints are postulated for impatient households, Appendix B presents a proof that (10) and (11) hold with equality:

$$q_t^h H_t^i \geq \zeta^f B_t^f, \tag{10}$$

$$q_t^k K_{t-1} \geq \zeta^e B_t^e, \tag{11}$$

where ζ^f is a cap on admissible loan-to-value ratios for mortgage loans and ζ^e is a cap on admissible loan-to-value ratios for corporate loans. Inequalities (10) and (11) state that the amount borrowed for housing B_t^f and physical capital B_t^e cannot be larger than the value of the underlying asset that serves as collateral $q_t^h H_t^i$ and $q_t^k K_{t-1}$ corrected for the loan-to-value limit.

Household preferences determine both the return on banking equity and the deposit rate. Intermediation adds value as households are willing to pay a premium for a safe and liquid asset that pays interest. Alternatively, households can hold cash supplied by the central bank, which is safe but does not pay interest. Hence, as long as banks create completely safe deposits and offer a positive return on deposits, households are willing to hold deposits rather than cash. Banks have access to deposit insurance and the interbank market to insure liquidity risk while households have no access to these institutions and as such cannot construct a diversified portfolio to eliminate credit and liquidity risk. For this reason, households do not want to invest their endowment directly in corporate loans or mortgages.

The option for households to convert deposits into cash is a source of aggregate liquidity risk in the banking sector. Households only convert their deposits into cash when regulated banks are no longer able to guarantee the safety and liquidity of their deposits. This might happen when the interbank market stops functioning properly, for example, because shadow banks trigger a loss spiral. Regulated banks use the interbank market to diversify their portfolio and insure idiosyncratic liquidity risk. Without interbank market regulated banks loose their ability to create safe and liquid deposits and the DGS buffers are not large enough to cover the increase in liquidity risk. Consequently, households are more likely to convert their deposits into cash which does not pay interest, but is completely safe and liquid. It is precisely this mechanism we will use later on to motivate the increase in aggregate liquidity risk when the shadow banking sector grows.

Patient households maximize (6) subject to (7) with respect to consumption, deposits, labor supply, housing accommodation and bank equity. Impatient households maximize (6) subject to (8), (9), (10) and (11) by choosing consumption, housing accommodation, deposits, labor supply, mortgages, corporate loans, physical capital and investment, see Appendix B for details. Consequently, and in contrast to Stein (2012), Gennaioli et al. (2013) and Hanson et al. (2015), depository funding, equity funding and household borrowing demand are all endogenously determined in the model. Additionally, we model an explicit outside option that enables households during financial stress to withdraw liquidity from the system by increasing their holdings of cash.

Firms rent their physical capital from the impatient households and hire labor from both types of households to minimize their production costs subject to the aggregate production technology:

$$Y_t = A_t(K_{t-1})^{1-\alpha}(L_t)^{\alpha}, \tag{12}$$

where Y_t denotes production, $L_t = L_t^p + L_t^i$ is the sum of patient and impatient household labor, A_t denotes an aggregate productivity index which follows a stochastic process $A_t = \exp(\eta_t^a)$, where $\eta_t^a = \rho^a \eta_{t-1}^a + \varepsilon_t^a$ and ε_t^a is an i.i.d. productivity shock $\sim (0, \sigma^a)$.

3.3 Regulated and shadow banks

In the model two types of banks exist: regulated banks that are regulated and shadow banks that are unregulated. Regulated regulated banks are obliged to insure their deposits in the DGS and have access to the central bank lending facility. Regulated banks pay an actuarially fair price for this deposit insurance that pays-off in the disaster state (Hanson et al., 2015). Households can convert their regulated bank deposits into cash because regulated banks can borrow from the central bank. Shadow banks do not participate in the deposit insurance scheme and cannot borrow from the central bank. Consequently, shadow bank deposits cannot be converted into cash, but only into regulated bank deposits. Therefore, if between t and $t+1$ a pessimistic signal about the future state of the world occurs, depositors liquidate their shadow bank deposits which are no longer risk-free. To repay their depositors, the shadow banks must liquidate their assets in the interbank market. The expected liquidation value determines how much safe and liquid deposits a shadow bank can issue ex-ante and thereby determines indirectly the shadow banks' funding cost.

In the main text, only fully diversified portfolios without idiosyncratic risk are considered. Appendix E shows that both regulated banks and shadow banks will always completely diversify their portfolio if diversification costs are reasonably low. For example, when the interbank market functions properly transaction costs are low and banks can easily trade assets to have diversified portfolios. We therefore assume that a properly functioning interbank market is a necessary condition for the banking sector to construct a fully diversified portfolio. Without a properly functioning interbank market, bank deposits are no longer perfectly safe and liquid, and households might convert deposits into cash.

Regulated and shadow banks, denoted by the superscript $b \in (sb, rb)$, respectively, have the same objective function except for the deposit insurance premium. Each period the banks issue M_t^b units of deposits and Q_t^b units of equity and promise to repay $(1 + i_t^{m,b})M_t^b$ and $(1 + i_t^{q,b})Q_t^b$ in the next period. These funds are used to lend mortgages $B_t^{f,b}$

and corporate loans $B_t^{e,b}$. The objective function for both banks can be described by:

$$\Pi_t^b = i_t^e B_t^{e,b} + i_t^f B_t^{f,b} - i_t^{m,b}(M_t^b + M_t^{b,x}) - i_t^{q,b} Q_t^b - \Xi^b - \xi D_t, \tag{13}$$

where i_t^f and i_t^e are the expected returns on investment in mortgages and corporate loans respectively, M_t^b is the sum of patient $M_t^{p,b}$ and impatient household deposits $M_t^{i,b}$, and $M_t^{b,x}$ denote foreign deposits for which demand is specified below. All off-steady state excess returns Π_t^{rb} and Π_t^{sb} accumulate to the equity holders. The term Ξ^b denotes fixed costs and ensures that excess returns are zero in equilibrium. Both the deposit rate and equity rate are in equilibrium pinned down by household preferences while loan supply is restricted by the collateral constraints. Accordingly, lending rates might differ from the banks' weighted average costs of funding which yields non-zero bank profits without the fixed costs term. The last term is the deposit guarantee premium D_t. For regulated banks $\xi = 1$ and for shadow banks $\xi = 0$. The ex-ante actuarially fairly priced deposit guarantee payment is expressed as:

$$D_t = \chi \left[(1 + i_t^f) B_t^{f,rb} + (1 + i_t^e) B_t^{e,rb} \right], \tag{14}$$

where $\chi = P(d)P(d|L)(\pi_b - \pi_d)$ denotes the DGS cost per unit of investment in the risky assets. The deposit insurance needs to cover only the difference between the bad and disaster state as regulated banks holds sufficient equity to remain solvent in the good and bad state. Both types of banks satisfy the same budget constraint:

$$B_t^{e,b} + B_t^{f,b} + \xi (D_t + R_t) \leq Q_t^b + M_t^b + M_t^{b,x}, \tag{15}$$

where R_t denotes deposits, or reserves, at the central bank. Only regulated banks have access to central bank deposits. By assumption central bank deposits do not pay interest and are completely safe. Moreover, regulated banks are not required to hold these central bank deposits which ensures that in equilibrium they will not lend from the central bank to hold central bank deposits.

The market also requires banks to hold sufficient equity. The equity buffer constraint states that in the worst possible state banks should be able to repay their risk-free deposits. Since both types of banks adopt a different business model with respect to the creation of risk free claims, the regulated bank equity buffer constraint is different from the shadow bank equity buffer constraint. The regulated bank equity buffer constraint is specified by:

$$R_t^{rb} + \pi_b \left[(1 + i_t^f) B_t^{f,rb} + (1 + i_t^e) B_t^{e,rb} \right] \geq (1 + i_t^{m,rb})(M_t^{rb} + M_t^{rb,x}). \tag{16}$$

The buffer constraint states that regulated banks should have sufficient equity to ensure that the return in the bad state of the world is sufficient to cover all risk-free deposits. Deposit insurance guarantees the repayment of deposits in the disaster state and is therefore not of interest to the market.

The shadow bank equity buffer constraint is specified by:

$$R_t^{sb} + \kappa_t^f(1+i_t^f)B_t^{f,sb} + \kappa_t^e(1+i_t^e)B_t^{e,sb} \geq (1+i_t^{m,sb})(M_t^{sb} + M_t^{sb,x}), \tag{17}$$

where $0 < \kappa_t^f, \kappa_t^e < 1$ specify the percentage of value that is retrieved when the shadow banks liquidate their assets in the interbank market. It is possible to read the participation constraint as a "worst case scenario outcome" which, for the shadow bank, is the realization of a pessimistic signal. In that case, households liquidate their deposits and shadow bank must sell their assets in the interbank market to remunerate the households.

In Appendix C we show that for both banks the budget and equity buffer constraints hold with equality. Hence, it is possible to substitute the constraints (15) and (16) in (13) to obtain the regulated bank maximization problem. Likewise, substituting the constraints (15) and (17) in (13) gives the shadow bank maximization problem. From these maximization problems we can induce that as long as the return on a loan is larger than the costs of funding and insurance, both banks will maximize asset holdings and minimize the amount of equity funding.

3.4 How do banks investment?

Regulated banks pay for deposit insurance costs summarized by the parameter χ which is assumed to be a fixed percentage of the total asset return. Shadow banks circumvent the deposit insurance costs but are limited in their creation of deposits by the expected liquidation value κ_t^ι. Equating the weighted average costs of funding of regulated banks and shadow banks, see Appendix D, we can distinguish three different scenarios depending on the relative weighted average costs of funding of regulated banks versus shadow banks. Proposition 3.1 summarizes the three scenarios:

Proposition 3.1

a) If $\kappa_t^e < \frac{\pi_b}{1+\chi i_t^e}$ and $\kappa_t^f < \frac{\pi_b}{1+\chi i_t^f}$, liquidity in the interbank market for both corporate loans and mortgages is too low for shadow banks to be able to compete with regulated banks. Regulated banks specialize in both mortgages and corporate loans.

b) If $\kappa_t^e < \frac{\pi_b}{1+\chi i_t^e}$ and $\frac{\pi_b}{1+\chi i_t^f} < \kappa_t^f$, the interbank market for mortgages is sufficiently liquid for shadow banks to overcome the expected liquidation cost disadvantage. Regulated banks specialize in corporate loans while shadow banks specialize in mortgages.

c) If $\kappa_t^e > \frac{\pi_b}{1+\chi i_t^e}$ and $\frac{\pi_b}{1+\chi i_t^f} > \kappa_t^f$, the interbank market for corporate loans is sufficiently liquid for shadow banks to overcome the expected liquidation cost disadvantage. Regulated banks specialize in mortgages while shadow banks specialize in corporate loans.

It is, of course, possible that shadow banks have a competitive advantage in supplying both mortgage loans and corporate loans. However, it is not possible for shadow banks to exist without regulated banks because the viability of the shadow bank business model depends on the existence of regulated banks that buy shadow bank assets in case of a liquidation. If shadow banks have lower costs in supplying both corporate loans and mortgages they specialize in the assets in which they have a comparative advantage which brings us back to either Proposition 3.1-b or c.

3.5 Expected liquidation value

Whether regulated banks or shadow banks have lower funding costs depends on the liquidation value κ_t^ι. We assume that the fundamental liquidation values are affected by the relative depth of the interbank market for mortgages or corporate loans and by aggregate liquidity risk which depends on the relative share of deposits that are uninsured, see Stein (2012) and Hanson et al. (2015) for a similar approach. Accordingly, the liquidation values per unit of investment are specified by:

$$\kappa_t^\iota = (1-\omega)\left(E_{t|S'=L}(\pi_s)\right)\varphi_1^\iota\left(\frac{B_t^\iota}{B_t}\right)\varphi_2^\iota\left(\frac{M_t^{sb}}{M_t}\right), \tag{18}$$

where $\omega = P(d|L)(\pi_b - \pi_d)$ denotes the deposit insurance costs regulated banks must pay when they buy shadow bank assets, $E_{t|S'=L}(\pi_s)$ denotes the fundamental price of the loan when a pessimistic signal occurs and $\varphi^\iota(\cdot)$ is a function that specifies the impact of a deeper interbank market for corporate loans and mortgages (B_t^ι) relative to the entire market (B_t) and more uninsured deposit creation (M_t^{sb}) relative to total bank deposits (M_t) on the liquidation value.

The intuition behind (18) is as follows. When regulated banks buy shadow bank loans, regulated banks must insure these loans in the deposit guarantee system. The term $(1-\omega)$ incorporates the insurance costs which only consist of the probability that a bad state of the world will occur conditional on the occurrence of a pessimistic signal. In Appendix E we show that when shadow banks diversify their asset portfolio, the liquidation costs decrease because idiosyncratic risk no longer needs to be insured. This provides an incentive for shadow banks to diversify their portfolio. In particular, if the diversification costs are sufficiently low, shadow banks will always completely diversify their portfolio because a diversified portfolio has a higher liquidation value.

In case a pessimistic signal about the future state of the world occurs ($S' = L$), the expected returns fall from $E_t(\pi_s)\{i^\iota_{t+1}\} = 1$ to $E_{t|S'=L}(\pi_s)\{i^\iota_{t+1}\} < 1$. The loan contracts, however, are predetermined at the beginning of period t under a condition of zero bank profits and therefore the lending rate equals the banks' funding costs (the net present value of a loan is zero). Consequently, the net present value of a bank loan becomes negative when a pessimistic signal occurs. The reverse holds when a signal about the future state of the world is positive. Regulated banks will therefore only buy shadow bank loans if the price of these loans falls sufficiently to compensate for the loss in value. The fundamental liquidation value after a pessimistic signal occurs therefore yields $E_{t|S'=L}(\pi_s)/E_t(\pi_s) < 1$ where $E_t(\pi_s) = 1$.

The function $\varphi^\iota(\cdot)$ consists of two terms that create a wedge between the fundamental liquidation value and the value in the interbank market. First, the depth of the interbank market positively affects the expected liquidation value as a deeper interbank market makes it easier to find a counterparty, $\partial\varphi^\iota(\cdot)/\partial B^\iota_t > 0$. We assume that the relative ease to find a counterparty depends on the size of the market for asset ι (B^ι_t) relative to the total size of the market (B_t). Motivated by the fact that individual banks trade in the interbank market, e.g., to construct diversified portfolios or because they face idiosyncratic liquidity shocks, a larger banking sector in terms of assets results in more interbank trading. In the limit, when the depth of the market goes to infinity, no liquidation discount is added and the expected liquidation price of the asset equals its fundamental value: $\lim_{(B^\iota_t/B_t)\to 0}\{\varphi^\iota(\cdot)\} = 1$. Without an interbank market for the asset, the asset can never be sold to another party and the liquidation price equals zero: $\lim_{(B^\iota_t/B_t)\to 1}\{\varphi^\iota(\cdot)\} = 0$.

Second, the creation of shadow bank deposits decreases the expected liquidation value, $\partial\varphi^\iota(\cdot)/\partial M^{sb}_t < 0$. In case a pessimistic signal occurs, more shadow bank deposits are withdrawn and more shadow bank assets are sold. Regulated banks buy shadow bank assets, but face aggregate liquidity risk as households might convert some of their deposits into cash. We assume that the ability of regulated banks to guarantee the safety and liquidity of their deposits depends on liquidity in the interbank market. The expected market liquidity therefore depends on the amount of shadow bank deposits (M^{sb}_t) relative to the total amount of deposits (M_t). In the limit, when all deposits are created by shadow banks, the expected liquidation value goes to zero because all shadow banks sell in case a pessimistic signal occurs and no regulated bank exists that buys, $\lim_{(M^{sb}_t/M_t)\to\infty}\{\varphi^\iota(\cdot)\} = 0$. The interbank market ceases to exist. Without shadow banks, no liquidation discount is added because no bank ever liquidizes its assets, $\lim_{(M^{sb}_t/M_t)\to 0}\{\varphi^\iota(\cdot)\} = 1$.

Brunnermeier and Pedersen (2009), Stein (2012) and others showed that the creation of uninsured deposits is associated with a negative externality. Banks do not take into account that selling an asset affects the price of the asset which leads to further losses.

Consequently, the initial decrease in the liquidation value is amplified and the ex-ante expected liquidation value differs from the ex-post realized liquidation value. In this paper we take the negative correlation between more shadow bank deposits and the expected liquidation value as given $\partial\kappa^{\iota}/\partial M_t^{sb} < 0$. Instead, we analyze why this negative externality is not priced by the market.

3.6 Externalities

At the aggregate level the depth of the interbank market and the amount of shadow bank deposits affect the expected liquidation value of shadow bank assets. If, however, shadow banks take the expected liquidation discount as given and do not include the incremental impact they have on its value, two externalities emerge. In this case, shadow banks maximize their profits (13) subject to the budget (15) and bank equity constraints (17). The FOCs w.r.t. loans and deposits yield:

$$i_t^{\iota} = i_t^{q,sb} - \mu_t^{sb}\kappa_t^{\iota}(1 + i_t^{\iota}), \tag{19}$$

$$i_t^{m,sb} = i_t^{q,sb} - \mu_t^{sb}(1 + i_t^{m,sb}), \tag{20}$$

where μ_t^{sb} denotes the shadow value of the bank equity buffer constraint and we use that the shadow value of the budget constraint equals the costs of bank equity, see Appendix C. In contrast, maximizing shadow bank profits w.r.t. loans and deposits taking into account the incremental impact shadow banks have on the liquidation parameter yields:

$$i_t^{\iota} = i_t^{q,sb} - \mu_t^{sb}(1 + i_t^{\iota})\left[k_t^{\iota} + \frac{\partial k_t^{\iota}}{\partial B_t^{\iota}}B_t^{\iota}\right], \tag{21}$$

$$i_t^{m,sb} = i_t^{q,sb} - \mu_t^{sb}\left((1 + i_t^{m,sb}) - \sum_{\iota}\left\{\frac{\partial k_t^{\iota}}{\partial M_t^{s}}(1 + i_t^{\iota})B_t^{\iota}\right\}\right). \tag{22}$$

The impact of ignoring the incremental impact of shadow banks on the liquidation parameter is twofold. First, an increase in credit supply for mortgages or corporate loans by shadow banks increases the depth of the market for mortgages and corporate loans. Consequently, the shadow bank equity buffer constraint relaxes because $\mu_t^{sb}(1 + i_t^{\iota})\partial\kappa_t^{\iota}/\partial B_t^{\iota} > 0$. Hence, if shadow banks neglect the incremental impact they have on the depth of the interbank market, they underestimate their marginal costs. Consequently, lending rates are higher and credit supply and shadow bank leverage are lower than their social optimal levels.

Second, from a funding perspective, if shadow banks issue deposits, market liquidity decrease. The shadow bank equity buffer constraint always binds and accordingly shadow bank deposit creation is at its maximum attainable level. If a shadow bank changes its capital structure by financing a larger share of its assets with deposits, it realizes a private benefit in the form of lower financing costs. However, the shadow bank also decreases the expected liquidation value of other shadow banks represented by a decrease in κ_t^ι because more shadow banks assets are sold when a pessimistic signal occurs, $\partial\kappa_t^\iota/\partial M_t^s < 0$. The equity buffer constraint of all other shadow banks tightens. Consequently, the deposit rate, shadow bank deposit creation and shadow bank leverage are above their socially optimal level. The following proposition summarizes the discussion:

Proposition 3.2

Let B^* and M^* denote the social optimal amounts of shadow bank loans and deposits and let $B^{'}$ and $M^{'}$ denote the optimal amount of shadow banks loans and deposits from the perspective of the shadow banks. Shadow banks supply too much credit, $B^* < B^{'}$, and create too many deposits, $M^* < M^{'}$, if $|\partial\kappa_t^\iota/\partial B_t^\iota| < |\partial\kappa_t^\iota/\partial M_t^s|$.

3.7 Closure

The real side of the model is closed by imposing the goods market equilibrium. Total production is equal to consumption, investment and lump-sum central bank consumption (which is equal to the deposit premium paid by regulated banks if not paid out):

$$Y_t = C_t^p + C_t^i + I_t + D_t. \tag{23}$$

We assume foreign deposit demand takes the same functional form as the domestic deposit demand equation for $\sigma^m = -1$. All endogenous variables affecting deposit demand (the foreign deposit, lending and bank equity rate, consumption and housing), except for the domestic deposit rate, are lumped in a fixed term $\bar{\vartheta}$. The domestic interest rate provides feedback as an increase in foreign deposit demand reduces the domestic interest rate which attenuates the increase in foreign deposit demand. The functional form is represented by:

$$M_t^{rb,x} = (\epsilon_t^m - 1)\bar{\vartheta}\log(1 + i_t^{m,i}), \tag{24}$$

where ϵ_t^m denotes a foreign deposit demand shock, i.e., a savings glut if $\epsilon_t^m > 1$, $\epsilon_t^m = \exp(\eta_t^m)$, where $\eta_t^m = \rho^m\eta_{t-1}^m + \varepsilon_t^m$ and ε_t^m is an i.i.d. error term $\sim (0, \sigma^m)$.

Housing supply is fixed at an arbitrarily level $\bar{H}$:

$$H_t^s = \bar{H}. \tag{25}$$

Prices are perfectly flexible and accordingly there is no role for conventional monetary policy to attenuate macroeconomic fluctuations by setting the policy rate. However, as Goodhart (1988) argues, the original motivation for creating most central banks was not maintaining price stability but, as in this paper, to provide financial stability. Here the central bank regulates the banks and fulfills the lender of last resort function when the banking sector has insufficient funding. Aggregate liquidity can only fall when aggregate demand for cash M_t^{cb} increases. In this case, the banking sector faces a funding shortfall and needs to borrow from the central bank. Bank borrowing from the central bank is denoted by B_t^{cb}. The central bank balance sheet is represented by:

$$B_t^x + B_t^{cb} = R_t + M_t^{cb}. \tag{26}$$

In normal times both non-interest paying deposits at the central bank R_t and household holdings of cash M_t^{cb} are zero such that borrowing from the central bank by banks, B_t^{cb}, is also zero. Moreover, B_t^x denotes borrowing from the central bank by non-domestic banks (denoted in the domestic currency). Borrowing by foreign banks is zero in equilibrium and increases when the aggregate foreign banking sector has insufficient funding.

The intuition behind the transmission of the shock ϵ_t^m is as follows. Foreign households withdraw their deposits at foreign banks and deposit these deposits at domestic banks. Foreign demand for domestic deposits, $M_t^{rb,x}$, increases. As foreign banks have a funding shortfall, they can either borrow from domestic banks or the central bank. We assume that the interbank market does not provide funding for these foreign funding shortfalls. Foreign banks therefore lend from the central bank, while domestic banks deposit their excess funds at the central bank. Both B_t^x and R_t increase. Central bank deposits do not pay any interest, while bank deposits do pay interest. Therefore the domestic banking sector decreases the deposit rate to reduce demand for its deposits. The decline in the deposit rate decreases domestic and foreign deposit demand and it increases borrowing by impatient households.

3.8 Calibration

Table 2 specifies the parameter settings. Patient and impatient consumers have a slightly different discount factor to ensure that impatient households borrow and that patient households save. The coefficient that determines the relative risk aversion of households—the substitution elasticity of consumption—σ_c is set at 1 ensuring log-utility and the inverse of the elasticity of work effort with respect to the wage rate $\sigma_l = 2$ are set at conventional values, see Christiano et al. (2005). The substitution elasticity of deposits σ_m is set at 1 which also ensures log-utility, but more importantly, a direct link with consumption. Moreover, we set the weight of housing in the consumption bundle $(1 - \eta)$

Table 2: Calibrated parameters

Parameters	Description	Value
β^p	Discount factor patient households	0.990
β^i	Discount factor impatient households	0.989
θ	Share of patient households	0.500
η	Share of housing in the consumption bundle	0.250
γ_l^p	Weight of leisure in utility function patient households	0.627
γ_l^i	Weight of leisure in utility function impatient households	1.920
γ_m	Weight of deposits in utility function	0.040
α	Share of labor in the production function	0.667
δ	Capital depreciation rate	0.025
ϕ	Capital adjustment costs	2.500
σ_c	Substitution elasticity consumption	1.000
σ_m	Substitution elasticity deposits holdings	1.000
σ_l	Substitution elasticity leisure	2.000
$\bar{H}$	Housing supply	1.000
$\bar{\vartheta}$	Exogenous foreign deposit demand	10.000
φ_1^ι	Market depth feedback parameter	0.200
φ_2^ι	Shadow bank deposits feedback parameter	0.200
π_g	Productivity good state	1.100
π_b	Productivity bad state	0.850
π_d	Productivity disaster state	0.100
$P(u)$	Probability good signal	0.750
$P(u\|H)$	Probability good state if good signal	0.950
$P(u\|L)$	Probability good state if bad signal	0.800
$P(d\|L)$	Probability disaster state if bad signal	0.100
ρ^m	Persistence parameter increase in deposits shock	0.900
μ^m	Mean increase in deposits shock	0.000
σ^m	S.D. savings glut shock	1.000

equal to 0.25 which entails that housing is 1/4 of total consumption expenses. The weights of labor and deposits γ^l and γ^m in the utility function are used to normalize labor supply in steady state of both representative households to unity and bank leverage in steady state equal to $Q/(Q+M) = 20\%$.

The physical capital adjustment cost parameter ϕ is set at 2.5, close to the value estimated by Christiano et al. (2005). The physical capital depreciation rate δ and the share of labor in the production function α take their standard values of 0.025 per quarter and 2/3, respectively. The loan-to-value parameters ζ^f and ζ^e are set equal to unity in the benchmark case. Housing supply $\bar{H}$ is fixed to unity. The supply elasticity of foreign deposit demand with respect to the domestic deposit rate $\bar{\vartheta}$ equals its domestic value in steady state.

The probabilities that a state of the world occurs and the corresponding productivities are set such that the ex-ante expected value of $E_t(\pi_s)$ equals 1. The expected productivity after the bad signal is equal to approximately 90% and the DGS costs are set to approximately 1% of the bank balance sheet.

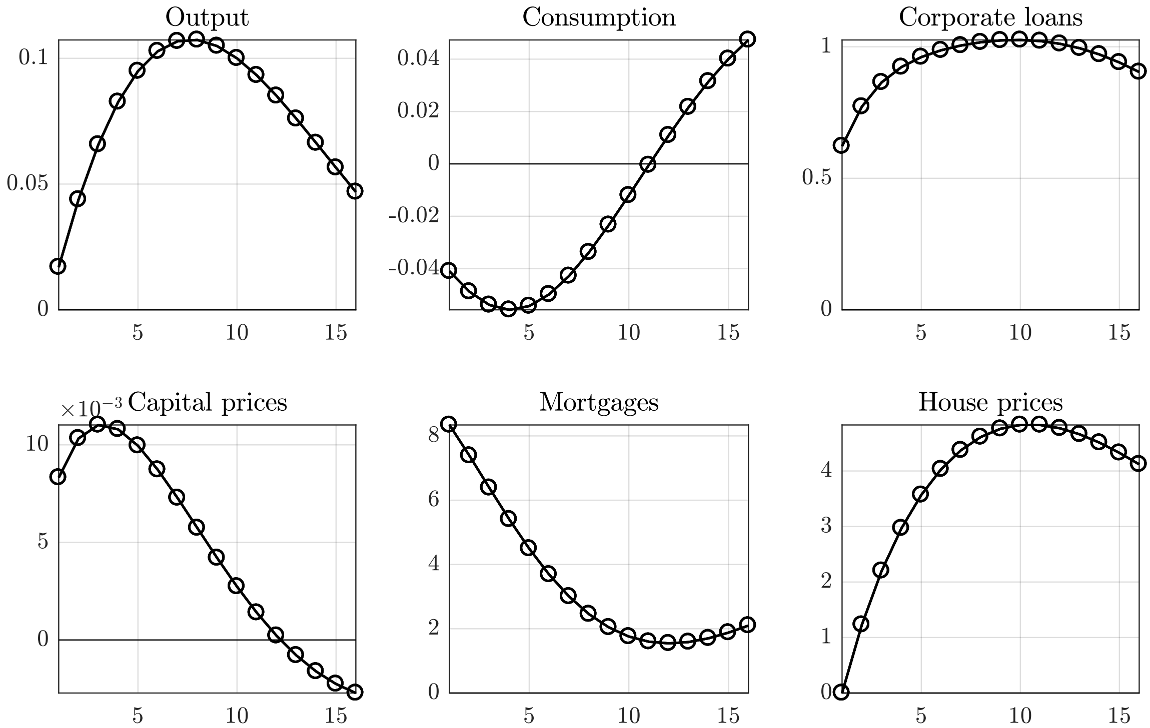
4 Results

4.1 Growth of mortgage loans

Figure 9 shows the effects of an exogenous increase in funding on the aggregate bank balance sheet. In this section, we set shadow banks' costs of funding equal to regulated banks' costs of funding by setting the liquidation value equal to a constant $\kappa^{\iota} = \pi_b/(1+\chi)i^{\iota *}$. The results for the three cases discussed in Proposition 3.1 are almost identical because the real side of the economy is similar. The banking structure, however, is slightly different which might give rise to a small difference. Specifically, regulated banks pay DGS costs which reduces the amount of funding that could be used for lending compared to the uninsured shadow banking sector. Second, the bank equity constraints of the two banking types are slightly different. This difference marginally impacts their financial structure and it therefore affects the amplification of fluctuations.

The increase in domestic bank deposits raises banks' holdings of central bank deposits contemporaneously. Although domestic banks could also lend to the foreign banks who face a shortfall, here we assume that domestic banks do not want to lend to foreign banks because, e.g., they consider foreign banks too risky. Banks lower the deposit rate because aggregate bank deposits increase, while the resulting central bank deposits do not generate any extra income. Both the mortgage rate and the corporate loan rate follow the reduction in bank funding costs because banks compete which eventually equalizes their

Figure 9: An increase in bank deposits and the real economy



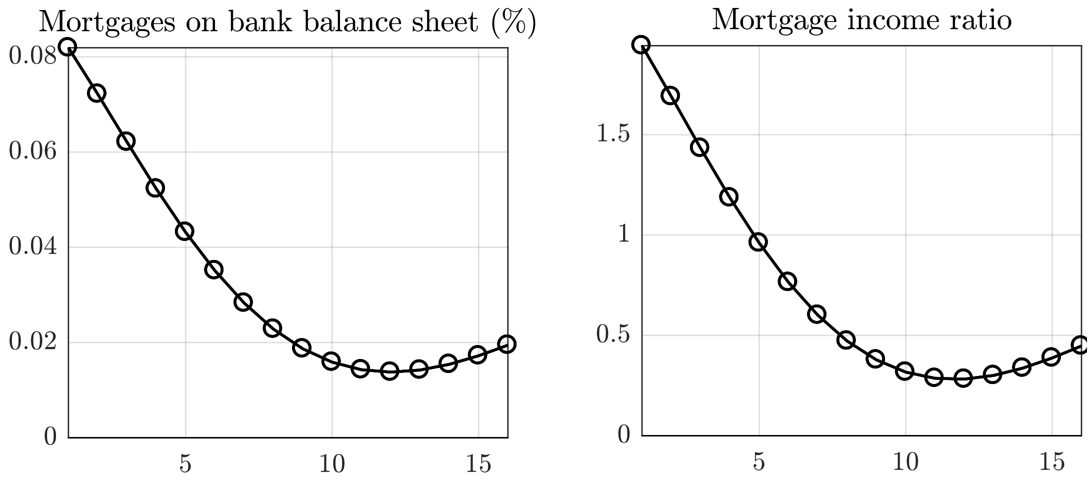
Notes: Impulse responses following an increase in bank deposits, that is, a positive shock to ϵ_t^m while the expected asset liquidation values (κ_t^e and κ_t^f) remain constant. The increase in deposits equals 3% of total domestic deposits M_t. Horizontal axis shows quarters. Vertical axis shows deviations from steady state.

lending rate to their weighted average costs of funding. Hence, arbitrage and competition ensure that both lending rates fall and borrowing increases.

Patient and impatient households hold different asset portfolios. Patient households hold bank deposits, bank equity and houses while impatient households hold bank deposits, houses and physical capital. The return on these assets changes which provides an incentive for both types of households to rebalance their portfolio. The inflow of deposits raises bank leverage and therefore the required return on bank equity increases. As the leverage constraint is binding, banks induce patient households to rebalance their portfolio from deposits and housing towards bank equity. This implies that the return on bank equity increases relative to the expected return on housing and deposits. Patient households therefore reduce savings, sell part of their housing stock to the impatient households and convert the proceeds and some of their deposits into bank equity.

Impatient households do not own—and do not wish to own—bank equity and are therefore unaffected by changes in the return on bank equity. That is, the return on bank equity is still below the required return of impatient households to due their high discount

Figure 10: An increase in bank deposits and the share of mortgages (% balance sheet)

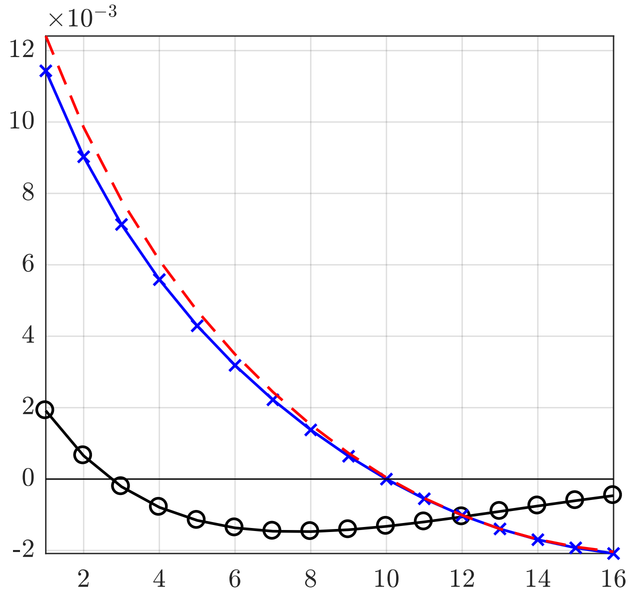


Notes: Impulse responses following an increase in bank deposits, that is, a positive shock to ϵ_t^m while the expected asset liquidation values (κ_t^e and κ_t^f) remain constant. The increase in deposits equals 3% of total domestic deposits M_t. Horizontal axis shows quarters. Vertical axis shows deviations from steady state. Mortgage loans as % of the aggregate bank balance sheet are calculated as: $\frac{B_t^f}{B_t^f+B_t^e+D_t}$. The mortgage-to-income ratio is calculated as: $\frac{B_t^f}{W_tL_t^i+r_t^kK_{t-1}}$.

factor. For banks the costs of funding decreases because the decline in the interest rate on deposits is larger than the increase in the required return on bank equity. As the weighted average costs of funding falls, banks increase their lending by lowering the lending rate on mortgages and corporate loans. When lending rates decline, impatient households prefer to increase their indebtedness and buy more houses and physical capital. Impatient households' demand for houses and physical capital given limited supply of both assets drives house prices and physical capital prices up.

The increase in mortgage lending is stronger than the increase in corporate lending. Figure 10 shows that the total amount of mortgage loans as percentage of the aggregate bank balance sheet increases. To understand this outcome, Figure 11 plots the expected return on physical capital $E_t\{r_{t+1}^k\}$, housing $E_t\{r_{t+1}^h\}$ and bank equity $E_t\{r_{t+1}^e\}$. As lending rates fall, housing demand by impatient households increases which drives up house prices. This same mechanism is at work for physical capital: the increase in demand for physical capital drives up the price of physical capital and thereby the expected return on physical capital. However, when patient households obtain funding to increase the production of physical capital, the return on physical capital falls. For housing demand, no offsetting supply effect is present. The house price increase relaxes the collateral

Figure 11: Expected return on physical capital, housing and bank equity following an increase in bank deposits



Notes: Impulse responses following an increase in bank deposits, that is, a positive shock to ϵ_t^m while the expected asset liquidation values (κ_t^e and κ_t^f) remain constant. The increase in deposits equals 3% of total domestic deposits M_t. Horizontal axis shows quarters. Vertical axis shows deviations from steady state. The expected return to physical capital $E_t\{r_{t+1}^k\}$ is represented by the circled (black) line, the expected return to housing $E_t\{r_{t+1}^h\}$ is represented by the barbed (blue) line and the expected return to bank equity $E_t\{r_{t+1}^e\}$ is given by the bar-striped (red) line.

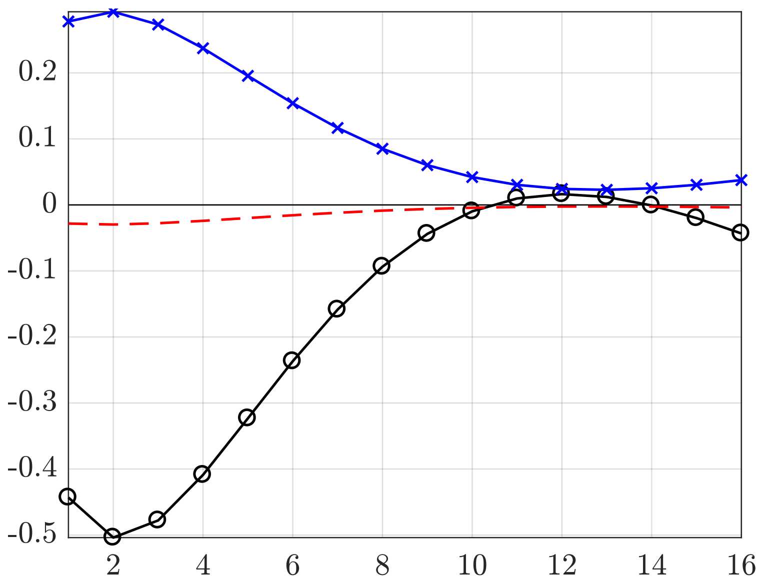
constraint for mortgage loans more than the collateral constraint for corporate loans. Consequently, the supply of mortgage loans can increase by more than the supply of corporate loans and bank investment is reallocated towards mortgages.

The aggregate housing stock is fixed, but from the perspective of the impatient household housing supply increases. This housing supply effect is, in the model, induced by patient households who sell part of their housing stock to impatient households. Patient households are willing to do so because the expected return on bank equity increases even more. These results imply that both a reduction in the supply elasticity of housing and a decrease in the share of households buying a house with their own wealth, increases house price fluctuations and therefore mortgage supply fluctuations.

4.2 Shadow bank growth

In this section we link the relative growth of mortgage loans to the growth rate of the shadow banking sector. In Section 4.1 the liquidation value was set equal to a constant. In the remainder of this paper, the liquidation value is endogenously determined by

Figure 12: Expected asset liquidation value following an inflow of deposits



Notes: Impulse responses following an increase in bank deposits, that is, a positive shock to ϵ_t^m. Horizontal axis quarters. Vertical axis shows deviations from steady state. The functional form for the asset liquidation value is: $\varphi^\iota\left(\frac{B_t^\iota}{B_t}, \frac{M_t^{sb}}{M_t}\right) \equiv \left(1 + \varphi_1^\iota \log\left\{\frac{B_t^\iota}{B_t^\iota + B_t^{\iota'}}\right\}\right)\left(-\log\left\{\frac{\varphi_2^\iota M_t^{sb}}{M_t}\right\}\right)$. The barbed (blue) line represents the expected liquidation value for mortgage loans (κ_t^f) without aggregate liquidity risk ($\varphi_1^f = 1$ and the second term in round brackets on the right hand side equals 1). The circled (black) lines represented the expected liquidation value for mortgage loans with high aggregate liquidity risk ($\varphi_1^f = 1$ and $\varphi_2^f = 6$). The bar-striped (red) line shows the expected liquidation value for corporate loans (κ_t^e) without aggregate liquidity risk ($\varphi_1^e = 1$ and the second term in round brackets on the right hand side equals 1).

Equation (18). Accordingly, the relative growth of mortgage loans following the decrease in interest rates described in Figure 9 deepens the interbank market for mortgage loans. The expected liquidation value κ_t^f increases which improves the comparative advantage of shadow banks vis-à-vis regulated banks in supplying mortgage loans.

Positive feedback between the size of the shadow banking sector and the asset liquidation value, $\partial\kappa^f/\partial B^\iota > 0$, allows the shadow banking sector to grow. Specifically, more investment in mortgage loans by shadow banks increases the size of and thereby liquidity in the interbank market for mortgage loans. This increases the expected asset liquidation value and therefore the amount of uninsured deposits shadow banks can create by creating new loans. In equilibrium, this positive feedback between the size of the interbank market and the expected liquidation value internalizes the externality: $\partial\kappa^\iota/\partial B^\iota \to 0$.

The barbed line in Figure 12 shows that the market for mortgage loans becomes more liquid—the expected liquidation value for shadow bank assets increases—when banks receive an inflow of deposits. Even though shadow banks do not take the effect of their own behavior on the assets' liquidation value into account, liquidity in the market is improving. The comparative advantage of shadow banks with respect to supplying mortgages increases. The dotted line in Figure 12 shows how liquidity in the interbank market for corporate loans is decreasing, compared to the interbank market for mortgages, because the market for corporate loans is shrinking. Hence, an exogenous inflow of deposits in banks increases liquidity in the market for mortgage loans. This in turn fosters the comparative advantage of shadow banks over regulated banks.

4.3 Liquidity risk and the lender of last resort

In the model, liquidity risk in the banking sector depends on the size of the shadow banking sector. When a pessimistic signal occurs, two things can happen. First, if the shadow banking sector is relatively small compared to the regulated banking sector, $\left(M_t^{sb}/M_t \approx 0\right)$, the interbank market continues to function efficiently as only a small share of the banking sector sells assets. In this case the regulated banking sector buys—or lends the funding shortfall to—the shadow banking sector. Regulated bank deposits increase and aggregate liquidity is unaffected because households do not increase their holdings of cash: $M_t^{cb} = 0$ and $\Delta M_t^{rb} = \Delta M_t^{sb}$.

Second, if the shadow banking sector is relatively large $\left(M_t^{sb}/M_t \approx 1\right)$, a large share of the interbank market starts to sell assets. Without sufficient activity in the interbank market regulated banks cannot diversify their assets and/or insure idiosyncratic liquidity risks. It becomes increasingly difficult for regulated banks to guarantee the safety and liquidity of their deposits. Regulated bank deposits might therefore be converted into cash: $M_t^{cb} > 0$ and $\Delta M_t^{sb} > \Delta M_t^{rb}$. In this case, aggregate liquidity decreases and regulated banks need additional funding from the central bank.

Regulated banks can borrow from the central bank or reduce their lending to the central bank to compensate for the decrease in depository funding. When households increase their holdings of cash, the liability side of the central bank balance sheet increases, see Equation (26). The central bank balance sheet implies that either central bank deposits R_t should decrease or bank borrowing from the central bank B_t^{cb} should increase. However, for regulated banks to have a level of central bank deposits $R_t > 0$, they must have borrowed from the central bank in the first place $B_t^{cb} = R_t$. In this case, $\Delta M_t^{cb} = -\Delta R_t$. In steady state banks do not borrow from the central bank to hold (costly) central bank deposits in excess of any requirement. Therefore R_t cannot decrease to compensate for the deposit outflow. Alternatively, borrowing from the central bank must increase $\Delta B_t^{cb} = \Delta M_t^{cb}$. In other words, by providing cash to households via the banking sector, the central bank must also provide liquidity insurance to banks.

In practice, the central bank lends to regulated banks if they have adequate collateral.

There is no need to internalize the increase in liquidity risk if the market expects that the central bank will always lend to the regulated banking sector because they have sufficient adequate collateral. The central bank is the lender of last resort and can provide regulated banks additional funding equal to: $\Delta B_t^{cb} = \Delta M_t^{sb} - \Delta M_t^{rb}$. Buying shadow bank assets poses no threat to the regulated banks' future funding position, if they can always borrow from the central bank. Regulated bank deposits remain safe and liquid and depositors are unlikely to convert their regulated bank deposits into cash. Hence, the risk associated with the creation of uninsured shadow bank deposits, $\partial\kappa_t^{\iota}/\partial M_t^{s}$, depends on whether the central bank is likely to lend to regulated banks.

A growing shadow banking sector increases the regulated banks' reliance on liquidity support by the central bank. Yet, regulated banks do not pay a fee for this liquidity insurance. Although it becomes more likely that the central bank must provide liquidity support when the shadow banking sector grows, the costs of liquidity support by the central bank are unaffected. In contrast, borrowing from the central bank is even likely to become less expensive if the central bank is expected to lower the policy rate in response to a financial crisis. Also, as has been the case during the global financial crisis, the central bank might accept a broader set of assets as collateral when all banks have a funding shortness. Consequently, shadow banks create too many uninsured deposits compared to the social optimum, i.e., they expose the banking system to excessive liquidity risk, because liquidity insurance by the central bank is not priced.

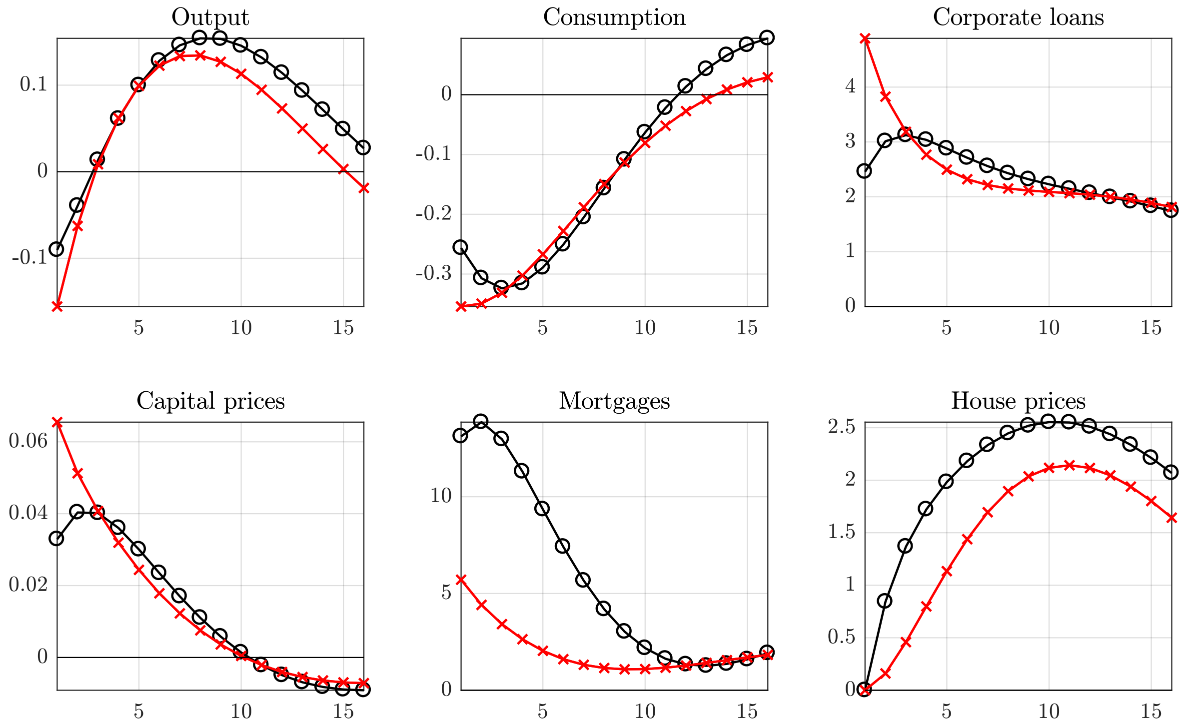
In this case, the increase in market liquidity as a consequence of a deeper interbank market outweighs the increase in funding liquidity risk as the latter effect is not fully priced. The barbed line in Figure 12 shows that the expected asset liquidation value increases and the shadow bank equity constraint (17) is relaxed when shadow bank lending increases because the actual increase in liquidity risk is not internalized. The circled line in Figure 12 shows how liquidity in the market for mortgages actually decreases when the increase in liquidity risk is internalized. The difference between the barbed and the circled line represents the value of the liquidity insurance provided by the central bank.

5 Policy options

5.1 Loan-to-value constraints

A reallocation of bank investment towards mortgage loans can adversely impact economic growth and financial stability. Such a reallocation does not depend on the financial structure of the banking sector and is not associated with an externality. In fact, the reallocation is determined by limited housing supply and the collateral constraints for

Figure 13: An increase in bank deposits and restrictions on admissible loan-to-value ratios



Notes: Impulse responses following an increase in bank deposits, that is, a positive shock to ϵ_t^m. Restrictions on admissible loan-to-value ratios, circled (black) line LTV is 100% ($\zeta^f = 1$) and barbed (red) line LTV is 80% ($\zeta^f = 0.8$). Horizontal axis quarters. Vertical axis shows deviations from steady state.

both mortgage loans and corporate loans work, if anything, in the opposite direction limiting credit supply. However, an increase in household debt relative to income makes it harder to repay the debt. Indeed, Figure 10 shows that the loan is financed to a larger extent by an increase in collateral value and not by an increase in household income. Although the model excludes actual Ponzi schemes by construction, in practice it might be harder to distinguish an increase in mortgage debt supported by fundamentals from an increase in household debt supported by Ponzi finance (Minsky, 1986).

Prudential authorities in some countries have recently responded to the increase in household debt relative to household income and/or house value by introducing restrictions on admissible loan-to-value (LTV) and loan-to-income ratios. These restrictions should create a precautionary buffer against house price fluctuations. From Equations (10) and (11) and the analysis in Appendix B, we conclude that the steady-state loan-to-value-ratio falls when these constraints tighten. A lower LTV ratio provides a buffer against future house price fluctuations.

Figure 13 reveals two additional benefits of restrictions on admissible LTV ratios.

First, stricter constraints on admissible LTV ratios limit house price and thereby mortgage supply fluctuations when shocks hit the economy. Although the restrictions by themselves are not sufficient to prevent the reallocation of investment and thereby shadow banking growth, they do attenuate bank investment in mortgage loans and thereby shadow banking growth. Hence, restrictions on admissible LTV ratios provide a larger buffer against house price fluctuations, and simultaneously attenuate fluctuations in house prices and mortgage loans. Second, restrictions on admissible LTV ratios reallocate bank investment from mortgage loans to corporate loans. This effect is not only present in the steady state but also when credit supply expands. As less lending are re-allocated towards houses, the fall in interest rates following the inflow of deposits has a stronger positive effect on investment. Hence, restrictions on admissible LTV ratios can reallocate investment to physical capital while it limits household mortgage debt and house price growth.

5.2 Interest on cash

The increase in liquidity risk due to the creation of uninsured shadow bank deposits is, if not internalized by the banks, a pecuniary externality and socially excessive. Pecuniary externalities violate the first welfare theorem when the liquidation value affects not only the bank's budget constraint, but also its collateral constraint. As the liquidation price is present in the bank equity constraint, the first welfare theorem is violated. The growth of mortgage debt increases regulatory arbitrage, but the banking sector does not price the increase in liquidity risk associated with more uninsured shadow bank deposits. The shadow banking sector creates too many uninsured deposits compared to the social optimum which leaves the financial system excessively vulnerable to a liquidity crisis.

The key externality driving a wedge between private and social optimal values is the negligence of an increase in liquidity risk when shadow banks create uninsured deposits. As the creation of insured deposits creates liquidity risk, the central bank provides liquidity insurance. However, since liquidity insurance is not priced, banks issue too many deposits rather than equity leaving the financial sector vulnerable to liquidity crises. A deposit insurance scheme reallocates the risk of creating uninsured deposits outside the regulated banking sector towards the shadow banking sector. However, as argued above, it does not solve the financial systems' reliance on liquidity insurance provided by the central bank.

Central banks can realign private and social interests by regulating the total amount of (uninsured) bank deposits. One possibility is a Pigouvian tax as suggested by Stein (2012). In his proposal the central bank regulates the total amount of private uninsured deposit creation by introducing a flexible cap-and-trade system in which banks are granted tradable permits to create uninsured deposits. The price of these permits reveals information about the banking sectors' investment opportunities. The regulator can adjust the amount of permits in the system in accordance with its objectives when prices change.

Although the cap-and-trade system proposed by Stein (2012) is an effective instrument to regulate the creation of uninsured deposits by regulated banks, it has adverse consequences on shadow banks and the real economy. For one thing, the system does not allow the regulator to observe the optimal level of permits. When the price of permits increases, the banking sector might have better investment opportunities, but it does not signal how much investment is optimal. Moreover, restricting the creation of uninsured deposits increases regulatory arbitrage as deposits become more scarce. Accordingly, shadow banks, who are not regulated, have a larger incentive to create uninsured deposits while any liquidity risk remains insured by the central bank. The cap-and-trade system therefore does not eliminate the key externality, but relocates risks outside the regulated banking sector.

Here, we suggest a more direct approach: the central bank pays interest on cash. Thereby the central bank eliminates the incentive for both regulated banks and shadow banks to create uninsured deposits. The basic idea is that paying interest on cash raises the opportunity costs for households to deposit their savings in regulated and shadow banks. If the interest rate on cash is set higher than the interest rate on bank deposits, banks must raise the deposit rate to attract depository funding thereby reducing the incentive to finance themselves with deposits rather than equity.

Deposits can be used for consumption while equity cannot. From the patient households' FOC with respect to deposits and after substituting the FOC with respect to bank equity, we can induce that households are willing to pay a premium for deposits relative to equity:

$$(M_t^j)^{\sigma^m} = \frac{\gamma^m}{\lambda_t^p}\left(\frac{1+i_t^q}{i_t^q - i_t^m}\right). \tag{27}$$

From (27) we find that if deposit demand is positive, the rate on deposits is lower than the required return on equity: $i_t^q > i_t^m$. Consequently, banks have an incentive to finance themselves with deposits rather than equity.

Cash can also be used for consumption, but households limit their holdings of it because cash does not pay interest. We therefore propose that the central bank pays interest on cash to compete with the banking sector in the creation of liquid, safe claims. In the initial case where the central bank pays no interest $i_t^{m,cb} = 0$, households will only hold cash for consumption purposes when no alternative is available. If the central bank pays interest on cash which is higher than the interest rate on bank deposits $i_t^{m,cb} > i_t^{m,s}$, depositors would like to hold only cash and no bank deposits. In this case, both types of banks must raise the deposit rate to retain their deposits, finance themselves fully with equity or borrow from the central bank for the same rate: $i_t^{m,cb}$. Consequently, when $i_t^{m,cb} = i_t^q$ banks become indifferent between debt and equity finance as both have exactly the same costs. That is, the Modigliani and Miller (1958) irrelevance proposition is no longer violated.

In practice the central bank can set the interest rate on central bank deposits equal to the interest rate banks receive on their deposits at the central bank. At this interest rate the externality associated with the creation of uninsured deposits is eliminated. In the model presented in this paper, the (risk-free) required return on bank equity is equal to the interest rate banks receive on their deposits at the central bank. The deposit rate trades at a discount of this rate as consumers are willing to accept a lower interest rate for liquid and safe deposits (the literature refers to this difference as the money premium). The difference between the policy rate and the deposit rate stimulates banks to finance themselves with deposits rather than equity. Hence, if the central bank offer households a savings account that pays an interest rate equal to the interest rate banks receive on their deposits at the central bank, this difference disappears. Depositors become indifferent between central bank deposits and bank deposits while banks become indifferent between deposit and equity finance.

6 Conclusion

In this paper we showed how an exogenous decline in real interest rates caused by an inflow of deposits could explain both the reallocation of bank investment from corporate loans to mortgages and the growth of the shadow banking sector relative to the regulated banking sector. Specifically, inelastic housing supply relative to the supply of physical capital causes house prices to rise which relaxes the collateral constraint for mortgage debt and induces the reallocation, in relative terms, towards mortgage loans. Positive feedback between the depth of the interbank market for mortgage loans and the liquidation value of shadow bank assets increases shadow banks' comparative advantage over regulated banks in supplying mortgages.

In the model we showed that the growing shadow banking sector leaves the banking sector excessively vulnerable to financial crises. When shadow banks grow and they finance their loans with uninsured deposits, liquidity risk increases. The shadow banking sector relies indirectly on liquidity insurance provided by the central bank. As shadow banks create more uninsured deposits, the banking system's reliance on liquidity support by the central bank increases. However, liquidity insurance is not priced in the market.

The increase in liquidity risk is therefore not fully incorporated in the expected liquidation price of shadow bank assets. Consequently, shadow banks issue too many uninsured deposits relative to the social optimum.

Macroprudential regulation—such as restrictions on admissible loan-to-value ratios—can offer a first line of defense to preserve financial stability because these constraints re-allocate bank investment back towards corporate loans. In addition, central banks can remove the incentive for banks to finance themselves with deposits rather than equity by paying interest on cash. Thereby the central bank raises the households' opportunity costs of holding bank deposits. Banks must increase the deposit rate which reduces the incentive for banks to finance themselves with deposits rather than bank equity. This eliminates a key externality and leaves the economy less vulnerable to liquidity risk.

References

Adrian, T. and Ashcraft, A. B. (2012). Shadow banking regulation. *Annual Review of Financial Economics*, 4(1):99–140.

Benigno, G. and Fornaro, L. (2014). The financial resource curse. *Scandinavian Journal of Economics*, 116(1):58–86.

Bernanke, B. (2005). The global saving glut and the U.S. current account deficit. Sandridge Lecture, Virginia Association of Economics, Richmond, Virginia, March 10.

Borio, C., Kharroubi, E., Upper, C., and Zampolli, F. (2016). Labour reallocation and productivity dynamics: Financial causes, real consequences. Bank for International Settlements Working Paper 534.

Brunnermeier, M. K. (2009). Deciphering the liquidity and credit crunch 2007–2008. *Journal of Economic Perspectives*, 23(1):77–100.

Brunnermeier, M. K. and Pedersen, L. H. (2009). Market liquidity and funding liquidity. *Review of Financial Studies*, 22(6):2201–2238.

Brunnermeier, M. K. and Sannikov, Y. (2014). A macroeconomic model with a financial sector. *American Economic Review*, 104(2):379–421.

Caballero, R. J., Farhi, E., and Gourinchas, P.-O. (2008). An equilibrium model of global imbalances and low interest rates. *American Economic Review*, 98(1):358–393.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.

DeAngelo, H. and Stulz, R. M. (2015). Liquid-claim production, risk management, and bank capital structure: Why high leverage is optimal for banks. *Journal of Financial Economics*, 116(2):219–236.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy*, 91(3):401–419.

Gennaioli, N., Shleifer, A., and Vishny, R. W. (2013). A model of shadow banking. *Journal of Finance*, 68(4):1331–1363.

Gertler, M., Kiyotaki, N., and Prestipino, A. (2016). Wholesale banking and bank runs in macroeconomic modeling of financial crises. In John B. Taylor, H. U., editor, *Handbook of Macroeconomics*, volume 2, pages 1345–1425. Elsevier, Amsterdam.

Glaeser, E. L., Gyourko, J., and Saiz, A. (2008). Housing supply and housing bubbles. *Journal of urban Economics*, 64(2):198–217.

Goodhart, C. (1988). *The evolution of central banks*, volume 1. MIT press, Cambridge, MA.

Gorton, G. and Pennacchi, G. (1990). Financial intermediaries and liquidity creation. *Journal of Finance*, 45(1):49–71.

Green, R. K., Malpezzi, S., and Mayo, S. K. (2005). Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources. *American Economic Review*, 95(2):334–339.

Greenwood, R., Hanson, S. G., and Stein, J. C. (2015). A comparative-advantage approach to government debt maturity. *Journal of Finance*, 70(4):1683–1722.

Greenwood, R., Hanson, S. G., and Stein, J. C. (2016). The Federal Reserve's balance sheet as a financial-stability tool. In *Designing Resilient Monetary Policy Frameworks for the Future*. Jackson Hole Symposium: Federal Reserve Bank of Kansas City.

Hanson, S. G., Shleifer, A., Stein, J. C., and Vishny, R. W. (2015). Banks as patient fixed-income investors. *Journal of Financial Economics*, 117(3):449–469.

Jordà, Ò., Schularick, M., and Taylor, A. M. (2015). Betting the house. *Journal of International Economics*, 96(Supplement 1):S2–S18.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2015). The impact of Treasury supply on financial sector lending and stability. *Journal of Financial Economics*, 118(3):571–600.

Mian, A. and Sufi, A. (2014). *House of debt: How they (and you) caused the Great Recession, and how we can prevent it from happening again.* University of Chicago Press, Chicago.

Mian, A. R., Sufi, A., and Verner, E. (2016). Household debt and business cycles worldwide. National Bureau of Economic Research Working Paper 21581.

Mink, M. (2016). Aggregate liquidity and banking sector fragility. De Nederlandsche Bank Working Paper 534.

Minsky, H. P. (1986). *Stabilizing an unstable economy.* Yale University Press, New Haven.

Modigliani, F. and Miller, M. H. (1958). The cost of capital, corporation finance and the theory of investment. *American Economic Review*, 48(3):261–297.

Moreira, A. and Savov, A. (2014). The macroeconomics of shadow banking. National Bureau of Economic Research Working Paper 20335.

Pozsar, Z., Adrian, T., Ashcraft, A. B., and Boesky, H. (2010). Shadow banking. Federal Reserve Bank of New York Staff Reports 458.

Saiz, A. (2010). The geographic determinants of housing supply. *Quarterly Journal of Economics*, 125(3):1253–1296.

Stein, J. C. (2012). Monetary policy as financial-stability regulation. *Quarterly Journal of Economics*, 127(1):57–95.

Wong, T., Fong, T., Li, K.-f., and Choi, H. (2011). Loan-to-value ratio as a macroprudential tool-Hong Kong's experience and cross-country evidence. Monetary Authority Working Paper 01/2011.

A Variable names and definitions

Table 3: Variable names and definitions

	Notation	Source	Definition
Shadow bank growth	$\Delta \ln Y_t^{sb}$	Flow of funds accounts FRB US	Δ log of other financial intermediaries except insurance companies and pension funds; total financial assets
Regulated bank growth	$\Delta \ln Y_t^{rb}$	Flow of funds accounts FRB US	Δ log of domestic financial sectors; total financial assets
Growth of mortgage loans	$\Delta \ln M_t^{total}$	Flow of funds accounts FRB US	Δ log all sectors; total mortgages; asset
Growth of mortgage loans (only depository institutions)	$\Delta \ln M_t^{pdi}$	Flow of funds accounts FRB US	Δ log private depository institutions; total mortgages; asset
Growth of corporate loans	$\Delta \ln C_t^{total}$	Flow of funds accounts FRB US	Δ log nonfinancial corporate business; loans; liability
MBS and ABS markets growth	$\Delta \ln Z_t^{total}$	Flow of funds accounts FRB US	Δ log of total GSE ABS and private MBS markets
Inflation (CPI)	-	Federal Reserve Bank of St. Louis	Consumer Price Index for All Urban Consumers: All Items, Percent Change from Year Ago, Quarterly, Seasonally Adj.
Federal Funds Rate	-	Federal Reserve Bank of St. Louis	Effective Federal Funds Rate, Percent, Quarterly, Not Seasonally Adj.
GDP growth	-	Federal Reserve Bank of St. Louis	Real Gross Domestic Product, Percent Change from Preceding Period, Quarterly, Seasonally Adjusted Annual Rate

Table 4: Descriptive statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Jarque-Bera	Obs.
Shadow bank growth	10.699	11.655	29.978	-9.868	6.688	16.839	248
Regulated bank growth	6.978	7.231	14.416	-6.480	3.484	19.192	248
Growth of mortgage loans	7.784	8.760	14.423	-4.142	4.337	30.938	248
Growth of mortgage loans (private depository institutions)	7.148	7.844	16.808	-6.703	5.328	16.124	248
Growth of corporate loans	6.716	8.408	21.250	-22.023	7.316	129.442	248
MBS and ABS markets growth	12.594	12.735	39.739	-17.791	9.561	1.072	248
Inflation (CPI)	3.656	3.032	14.426	-1.607	2.817	179.824	248
Federal Funds Rate	4.949	4.750	17.780	0.070	3.593	47.745	248
GDP growth	3.059	3.050	16.500	-10.000	3.550	27.011	248

Figure 14: VAR estimation results of Equation (2) for shadow banks different ordering

Notes: Ordering and ordering: $X_t = [M_t^{total}, C_t^{total}, Y_t^b, B_t^{real}, Z_t^{total}]$. Estimation period 1955$Q$3–2017$Q$2, time (quarters) horizontal axis, percentage point deviation on the vertical axis. The titles explain the response of one of the variables included to a shock of any of the variables included. Dotted red lines denote confidence intervals at 95% significance level.

B Household and firm problem

Patient household problem

Patient household utility function:

$$U_t^j = E_t \sum_{t=0}^{\infty} (\beta^j)^t \varepsilon_t^j \left(\frac{((C_t^j)^\eta (H_t^j)^{1-\eta})^{1-\sigma^c}}{1-\sigma^c} + \gamma^m \frac{(M_t^j)^{1-\sigma^m}}{1-\sigma^m} - \gamma^l \frac{(L_t^j)^{1+\sigma^l}}{1+\sigma^l} \right). \tag{28}$$

Patient household budget constraint:

$$\begin{aligned} M_t^p + Q_t + q_t^h (H_t^p - H_{t-1}^p) =& (1+i_{t-1}^m) M_{t-1}^p + (1+i_{t-1}^q) Q_{t-1} + r_t^h H_{t-1}^p \\ & - C_t^p + L_t w_t + \theta(\Pi_t^{rb} + \Pi_t^p). \end{aligned} \tag{29}$$

Patient household Lagrangian:

$$\begin{aligned} \mathcal{L}^p =& E_0 \sum_{t=0}^{\infty} (\beta^p)^t \, \varepsilon_t^p \left(\frac{((C_t^p)^\eta (H_t^p)^{1-\eta})^{1-\sigma^c}}{1-\sigma^c} + \gamma^m \frac{(M_t^p)^{1-\sigma^m}}{1-\sigma^m} - \gamma^l \frac{(L_t^p)^{1+\sigma^l}}{1+\sigma^l} \right) \\ & + \lambda_t^p \Big[(1+i_{t-1}^m) M_{t-1}^p + (1+i_{t-1}^q) Q_{t-1} + r_t^h H_{t-1}^p + L_t w_t \\ & + \theta(\Pi_t^{rb} + \Pi_t^p) - C_t^p - I_t - M_t^p - Q_t - q_t^h (H_t^p - H_{t-1}^p) \Big], \end{aligned} \tag{30}$$

where λ_t^p is the Lagrangian multiplier associated with the patient household budget constraint. The FOCs conditions w.r.t. $C_t^p, L_t^p, H_t^p, M_t^p, Q_t$ are given by:

$$\eta C_t^{p(\eta-1)} H_t^{p(1-\eta)} (C_t^{p\eta} H_t^{p(1-\eta)})^{-\sigma^c} = \lambda_t^p \tag{31}$$

$$\varepsilon_t^p \gamma^l (L_t^p)^{\sigma^l} = \lambda_t^p w_t \tag{32}$$

$$\varepsilon_t^p (1-\eta) H_t^{p(-\eta)} C_t^{p\eta} (C_t^{p\eta} H_t^{p(1-\eta)})^{-\sigma^c} - \lambda_t^p q_t^h + \lambda_{t+1}^p \beta^p (q_{t+1}^h + r_{t+1}^h) = 0 \tag{33}$$

$$\varepsilon_t^p \gamma^m (M_t^{j,\iota})^{-\sigma^m} + \lambda_{t+1}^p \beta^p (1+i_t^m) = \lambda_t^p \tag{34}$$

$$\lambda_{t+1}^p \beta^p (1+i_t^q) = \lambda_t^p. \tag{35}$$

Rewriting the FOCs, substituting out the Lagrangian multipliers λ_t^p and setting $\sigma^c = 1$ gives the patient household Euler Equation:

$$C_t^p = E_t \left\{ \left(\frac{C_{t+1}^p}{\beta^p (1+i_t^q)} \right) \left(\frac{H_{t+1}^p}{H_t^p} \right)^{(1-\eta)} \right\}, \tag{36}$$

and patient household housing demand:

$$\frac{1}{H_t^p C_t^{j\eta}} = \left(\frac{\eta}{1-\eta}\right)\left(\frac{P_t^h}{C_t^p H_t^{p(1-\eta)}} - \frac{\beta^p(P_{t+1}^h + r_{t+1}^h)}{C_{t+1}^p H_{t+1}^{p(1-\eta)}}\right), \tag{37}$$

and patient household deposit demand:

$$\frac{C_t^p H_t^{p(1-\eta)}}{(M_t^j)^{\sigma^m}} = \frac{\eta}{\gamma^m}\left(1 - \frac{1+i_t^m}{1+i_t^q}\right). \tag{38}$$

Impatient household Problem

Impatient household Lagrangian:

$$\begin{aligned}
\mathcal{L}^i =& E_0 \sum_{t=0}^{\infty} \left(\beta^i\right)^t \Bigg\{ \left(\frac{((C_t^i)^\eta (H_t^i)^{1-\eta})^{1-\sigma^c}}{1-\sigma^c} + \gamma^m \frac{(M_t^i)^{1-\sigma^m}}{1-\sigma^m} - \gamma^l \frac{(L_t^i)^{1+\sigma^l}}{1+\sigma^l} \right) + \\
& \lambda_t^i \Big[(1+i_{t-1}^f) B_{t-1}^f + (1+i_{t-1}^e) B_{t-1}^e - (1+i_{t-1}^m) M_{t-1}^i - r_t^h H_{t-1}^i - w_t L_t^i - \\
& r_t^k K_t - (1-\theta)(\Pi_t^{rb} + \Pi_t^p) + C_t^i + I_t - B_t^f - B_t^e + M_t^i + q_t^h (H_t^i - H_{t-1}^i) \Big] - \\
& \lambda_t^i q_t^k \left[K_t(1-\delta) + I_t \left(1 - \frac{\phi}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) - K_{t+1} \right] + \\
& \mu_t^e \left(B_t^e - q_t^k K_t \right) + \\
& \mu_t^f \left(B_t^f - q_t^h H_t \right) \Bigg\}.
\end{aligned} \tag{39}$$

where λ_t^i is the Lagrangian multiplier associated with the impatient household budget constraint, q_t^k is the shadow value of physical capital associated with the physical capital accumulation identity and μ_t^e and μ_t^f denote the shadow value of the loan-to-value constraints. The FOCs w.r.t. $K_t, I_t, B_t^f, B_t^e, C_t^i, H_t^i, M_t^p, L_t^p$:

$$\lambda_t^i q_t^k = \lambda_{t+1}^i r_{t+1}^k + \lambda_{t+1}^i q_{t+1}^k (1-\delta) + q_{t+1}^k \mu_{t+1}^e \tag{40}$$

$$\begin{aligned}\lambda_t^i =& \lambda_t^i q_t^k \left(1 - \frac{\phi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \phi\left(\frac{I_t}{I_{t-1}} - 1\right)\left(\frac{I_t}{I_{t-1}}\right)\right) + \\ & \lambda_{t+1}^i q_{t+1}^k \beta^j \left(\phi\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right)\end{aligned} \tag{41}$$

$$\lambda_t^i = \lambda_{t+1}^i \beta^i (1 + i_t^f) + \mu_t^f \tag{42}$$

$$\lambda_t^i = \lambda_{t+1}^i \beta^i (1 + i_t^e) + \mu_t^e \tag{43}$$

$$\lambda_t^i = \eta C_t^{i(\eta-1)} (C_t^{i\eta} H_t^{i(1-\eta)})^{-\sigma^c} \tag{44}$$

$$\lambda_t^i q_t^h = (1-\eta) H_t^{i(-\eta)} (C_t^{i\eta} H_t^{i(1-\eta)})^{-\sigma^c} + \lambda_{t+1}^i \beta^i (q_{t+1}^h + r_{t+1}^h) + \mu_t^f q_t^h \tag{45}$$

$$\frac{\gamma^m}{(M_t^i)^{\sigma^m}} = \lambda_t^i \left(1 - \frac{1 + i_t^m}{1 + i_t^e}\right) + \mu_t^e \left(\frac{1 + i_t^m}{1 + i_t^e}\right), \tag{46}$$

$$\gamma^l (L_t^i)^{\sigma^l} = \lambda_{t+1}^i W_t^i. \tag{47}$$

Rewriting the FOCs, substituting out the Lagrangian multiplier λ_t^i and μ_t^f and setting $\sigma^c = 1$ gives the patient household Euler Equation:

$$\begin{aligned}\frac{1}{C_t^{i\eta} H_t^i} = \left(\frac{\eta}{1-\eta}\right) \Bigg[& \frac{q_t^h}{C_t^i H_t^{i(1-\eta)}} - \frac{\beta^i (q_{t+1}^h + r_{t+1}^h)}{C_{t+1}^i H_{t+1}^{i(1-\eta)}} + \\ & q_t^h \left(\frac{\beta^i (1 + i_t^f)}{C_{t+1}^i H_{t+1}^{i(1-\eta)}} - \frac{1}{C_t^i H_t^{i(1-\eta)}}\right)\Bigg]\end{aligned} \tag{48}$$

and deposit demand:

$$\frac{C_t^i H_t^{i(1-\eta)}}{(M_t^i)^{\sigma^m}} = \frac{\eta}{\gamma^m} \left(1 - \frac{1 + i_t^m}{1 + i_t^f}\right) + \mu_t^f \left(\frac{1 + i_t^m}{1 + i_t^f}\right). \tag{49}$$

Firm Problem

Firm Lagrangian:

$$\mathcal{L}^f = r_t^k K_{t-1} + w_t L_t - \lambda_t^f \left(E_t(\pi_s) A_t (K_{t-1})^{1-\alpha} (L_t)^\alpha - Y_t\right), \tag{50}$$

where λ_t^f denotes firms' marginal costs which are in a competitive environment equal to the price level. We obtain the following FOCs w.r.t. K_{t-1} and L_t:

$$r_t^k = \frac{(1-\alpha)Y_t}{K_{t-1}} \tag{51}$$

$$w_t = \frac{\alpha Y_t}{L_t} \tag{52}$$

Assuming free-entry and exit, firms will enter until expected economic profits are zero. Accordingly, firm profits:

$$\Pi_t = E_t(\pi_s)(Y_t - W_t(L_t^p - L_t^i) - r_t^k K_t), \tag{53}$$

will be equal to zero.

C Bank optimization problem

The bank maximizes its profits subject to its budget constraint and equity buffer constraint:

$$\begin{aligned}
\max \Big\{ & (E_t\{\pi_s\}[(1+i_t^f)B_t^{f,rb} + (1+i_t^e)B_t^{e,rb}] - i_t^{m,rb}M_t^{rb} - i_t^{q,rb}Q_t^{rb} - B_t^{f,rb} - \\
& B_t^{e,rb} - \chi((1+i_t^f)B_t^f + (1+i_t^e)B_t^e)\Big\} - \\
& \lambda_t^{rb}(B_t^{e,rb} + B_t^{f,rb} + \chi((1+i_t^f)B_t^f + (1+i_t^e)B_t^e) - Q_t^{rb} - M_t^{rb}) \\
& \mu_t^{rb}((1+i_t^{m,rb})M_t^{rb} - \pi_b[(1+i_t^f)B_t^f + (1+i_t^e)B_t^e]),
\end{aligned} \tag{54}$$

where λ_t^{rb} and μ_t^{rb} are the Lagrangian multipliers associated with the budget constraint and equity buffer constraint respectively. The FOCs w.r.t. $B_t^{f,rb}$, $B_t^{e,rb}$, M_t^{rb}, Q_t^{rb} are denoted by:

$$i_t^f = \chi(1+i_t^f) + \lambda_t^{rb}(1+\chi(1+i_t^f)) + \mu_t^{rb}\pi_b(1+i_t^f), \tag{55}$$

$$i_t^e = \chi(1+i_t^f) + \lambda_t^{rb}(1+\chi(1+i_t^e)) + \mu_t^{rb}\pi_b(1+i_t^e), \tag{56}$$

$$i_t^{m,sb} = \lambda_t^{rb} + \mu_t^{rb}(1+i_t^{m,rb}), \tag{57}$$

$$i_t^{q,sb} = \lambda_t^{rb}. \tag{58}$$

From the FOCs we get that the shadow value with respect to the budget constraint $\lambda_t^{rb} = i_t^{q,sb} > 0$. Consequently, we know that the budget constraint holds with equality. Next we can combine the FOCs w.r.t. M_t^{rb} and Q_t^{rb} to obtain: $\mu_t^{rb} = \left(\frac{i_t^{m,sb} - i_t^{q,sb}}{1+i_t^{m,rb}}\right)$. From the household problem we know that $i_t^{m,sb} < i_t^{q,sb}$ if $\gamma^m > 0$, i.e., when households value deposits, the bank equity buffer constraints holds with equality. Combining the FOCs we obtain:

$$i_t^f - \chi(1 + i_t^f) = \lambda_t^{rb}(1 + \chi(1 + i_t^f)) + \mu_t^{rb}\pi_b(1 + i_t^f), \tag{59}$$

$$i_t^e - \chi(1 + i_t^f) = \lambda_t^{rb}(1 + \chi(1 + i_t^e)) + \mu_t^{rb}\pi_b(1 + i_t^e). \tag{60}$$

We can interpret these results as follows. Regulated banks will increase investment in either asset as long as the budget constraints and the equity buffer constraints do not bind. It is possible to substitute the budget and equity buffer constraints in the maximization problem to obtain:

$$\max\Big\{E_t\{\pi_s\}[(1 + i_t^f)B_t^{f,rb} + (1 + i_t^e)B_t^{e,rb}] - \tag{61}$$
$$\pi_b[(1 + i_t^f)B_t^f + (1 + i_t^e)B_t^e] - (1 + i_t^{q,rb})Q_t^{rb}\Big\}.$$

From this we know that as long as the return on a particular asset is larger than the costs of deposit insurance and equity, regulated banks increase investment. Hence, the equity buffer constraint determines the amount of deposits, the credit supply curve is flat for lending rates larger than the costs of deposit insurance and equity, and bank equity is determined as the residual from the balance sheet identity.

For shadow banks the problem is similar:

$$\max\Big\{(E_t\{\pi_s\}[(1 + i_t^f)B_t^{f,sb} + (1 + i_t^e)B_t^{e,sb}] - i_t^{m,sb}M_t^{sb} - i_t^{q,sb}Q_t^{sb} - B_t^{f,sb} -$$
$$B_t^{e,sb}\Big\} - \lambda_t^{sb}(B_t^{e,sb} + B_t^{f,sb} - Q_t^{sb} - M_t^{sb})$$
$$\mu_t^{sb}((1 + i_t^{m,s})M_t^s - \nu[k_t^f(1 + i_t^f)B_t^f + k_t^e(1 + i_t^e)B_t^e]) \tag{62}$$

where $\nu \equiv [P(d|H)\pi_g + (1 - P(d|H) - P(d|L))\pi_b + P(d|L)\pi_d]$. The FOCs w.r.t. $B_t^{f,sb}$, $B_t^{e,sb}$, M_t^{sb}, Q_t^{sb} are denoted by:

$$E_t\{\pi_s\}(1 + i_t^f) - 1 = \lambda_t^{sb} + \mu_t^{sb}\nu k_t^f(1 + i_t^f) \tag{63}$$

$$E_t\{\pi_s\}(1 + i_t^e) - 1 = \lambda_t^{sb} + \mu_t^{sb}\nu k_t^e(1 + i_t^e) \tag{64}$$

$$i_t^{m,sb} = \lambda_t^{sb} + \mu_t^{sb}(1 + i_t^{m,sb}) \tag{65}$$

$$i_t^{q,sb} = \lambda_t^{sb}. \tag{66}$$

From the FOCs wrt M_t^{rb} and Q_t^{rb} we obtain again $\lambda_t^{sb} > 0$ and $\mu_t^{sb} > 0$ and so both constraints hold with equality. Substituting out the multipliers gives:

$$E_t\{\pi_s\}(1+i_t^f)-1=i_t^{q,sb}+\left(\frac{1+i_t^f}{1+i_t^{m,sb}}\right)\nu k_t^f(i_t^{m,sb}-i_t^{q,sb}) \tag{67}$$

$$E_t\{\pi_s\}(1+i_t^e)-1=i_t^{q,sb}+\left(\frac{1+i_t^e}{1+i_t^{m,sb}}\right)\nu k_t^e(i_t^{m,sb}-i_t^{q,sb}) \tag{68}$$

and similar to the regulated banking problem we can substitute the constraints in the profit function to obtain:

$$\max\Big\{(E_t\{\pi_s\}[(1+i_t^f)B_t^{f,sb}+(1+i_t^e)B_t^{e,sb}]-\nu[k_t^f(1+i_t^f)B_t^f+ \\ k_t^e(1+i_t^e)B_t^e]-(1+i_t^{q,sb})Q_t^{sb}\Big\} \tag{69}$$

From this we know that as long as the return on a particular asset is larger than the expected liquidation costs and equity, regulated banks increase investment. Hence, similar to regulated banks the equity buffer constraint determines the amount of deposits, the credit supply curve is flat for lending rates larger than the costs liquidation insurance and equity, and bank equity is determined as the residual from the balance sheet identity.

D Proof Proposition 3.1

For shadow banks the weighted average costs of funding is denoted by:

$$i_t^{sb}=\frac{q_t^{sb}}{q_t^{sb}+m_t^{sb}}i_t^q+\frac{m_t^{sb}}{q_t^{sb}+m_t^{sb}}i_t^m. \tag{70}$$

Using the shadow bank balance sheet constraint (15) and the shadow bank equity buffer constraint for asset ι (17):

$$i_t^{sb}=i_t^q+\frac{\pi_b[\kappa_t^\iota(1+i_t^\iota)b_t^\iota]}{b_t^\iota(1+i_t^m)}\left(i_t^m-i_t^q\right). \tag{71}$$

For regulated banks the weighted average costs of funding are:

$$i_t^{rb}=\frac{q_t^{rb}}{q_t^{rb}+m_t^{sb}}i_t^q+\frac{m_t^{rb}}{q_t+m_t^{rb}}i_t^m. \tag{72}$$

Using the regulated bank balance sheet constraint (15) and the regulated bank equity buffer constraint (16) :

$$i_t^{rb} = i_t^q + \frac{\pi_b[(1+i_t^\iota)b_t^\iota]}{(1+i_t^m)(1+\chi)\, b_t^\iota}\,(i_t^m - i_t^q)\,. \tag{73}$$

Equating the marginal costs of shadow banks (71) with the marginal costs of regulated banks (73) to determine which banking sector has higher marginal costs we obtain that both banking sectors have the same marginal costs if:

$$\frac{1}{1+\chi} = \kappa_t^\iota. \tag{74}$$

From this we can conclude that both banks invest in both assets if:

$$\frac{1}{1+\chi} = \kappa_t^e = \kappa_t^f. \tag{75}$$

Regulated banks invest only in corporate loans assets and shadow banks invest only in mortgage loans if:

$$\frac{1}{1+\chi} > \kappa_t^e \quad \text{and} \quad \frac{1}{1+\chi} < \kappa_t^f \tag{76}$$

Regulated banks invest only in mortgage loans and shadow banks invest only in corporate loans if:

$$\frac{1}{1+\chi} < \kappa_t^e \quad \text{and} \quad \frac{1}{1+\chi} > \kappa_t^f. \tag{77}$$

E Including idiosyncratic credit risk

In the main text we argued that both regulated and shadow banks always completely diversify their portfolios if they have the opportunity to do so. To diversify all idiosyncratic risk the bank must trade with other intermediaries as they are not able to completely diversify idiosyncratic risk by themselves because it is, for example, costly (see Hanson et al. (2015)). To diversify the risk of these projects, both types of banks trade in the interbank market. Specifically, they sell $S_t^{\iota,i}$ units of risky projects and they buy $B_t^{\iota,i}$ units of risky projects financed by other banks. Consequently, the actuarially fair priced deposit guarantee system is expressed as:

$$
\begin{aligned}
D_t = \Big[& P(d)P(d|L)(1-\pi_d) + (P(d)(1-P(d|L)-P(u|L))+ \\
& P(u)P(u|H))(1-\pi_b) + (P(u)P(u|H) + P(d)P(u|L)(1-\pi_g)]\pi_b + \\
& P(d)P(d|L)\pi_d(\pi_b - \pi_d)\Big] \pi_b[(1+i_t^\iota)(I_t^\iota - S_t^\iota))] + \\
& P(d)P(d|L)[(1+i_t^\iota)B_t^\iota](\pi_b - \pi_d),
\end{aligned} \tag{78}
$$

which states that the deposit insurance premium consists of two parts. The first part calculates the probability of failure for the bank's own investment projects which are subject to both idiosyncratic and aggregate risk ($I_t^\iota - S_t^\iota$), see Figure 8 for the probabilities of these projects defaulting. Second, the bank also owns (potentially) diversified securities B_t^ι. These securities are not subject to idiosyncratic risk, but only to aggregate risk. The deposit insurance in this case only needs to cover the difference between the bad and disaster state. Diversification lowers the premium paid for deposit insurance and therefore allows regulated banks to invest more in the risky asset. So, diversification allows banks to attract more deposits for a given amount of equity. Therefore regulated banks will always completely diversify their portfolio if diversification costs are sufficiently low.

Shadow banks do not gain directly from diversification. The shadow bank equity buffer constraint is specified by:

$$
\begin{aligned}
& [P(u|L)\pi_g + (1-P(u|L)-P(d|L))\pi_b + \\
P(d|L)\pi_d][k_t^\iota(1+i_t^\iota)(I_t^\iota + B_t^\iota - S_t^\iota)] &\geq (1+i_t^{m,s})M_t^s,
\end{aligned} \tag{79}
$$

from which we learn that shadow banks do not gain directly from diversification as it does not impact the fundamental value of the asset. It is best to read the participation constraint as a "worst case scenario outcome" which is the occurrence of a pessimistic signal. Diversification does not matter as it does not allow shadow banks to create additional risk-free debt claims. However, shadow banks liquidate all their assets in case a signal about the future state of the world is pessimistic. Regulated banks buy these assets, but only if the price of the securities is fair:

$$
\kappa_t^\iota = (1-\chi)\left(E_{t|S'=L}(\pi_s)\right)\varphi_1^\iota\left(\frac{B_t^\iota}{B_t}\right)\varphi_2^\iota\left(\frac{M_t^{sb}}{M_t}\right), \tag{80}
$$

where χ is the DGS premium described by (79). It is evident from (79) and (80) that χ is larger if the shadow banks sell non-diversified assets. Consequently, the liquidation value is in expectation lower when shadow banks have a non-diversified portfolio. For this reason, shadow banks also diversify their portfolio completely when diversification costs are sufficiently low.

If we assume a symmetric equilibrium (all banks are alike), $S_t^{f,i} = B_t^{f,i}$ and $S_t^{e,i} = B_t^{e,i}$ so we can conclude that $I_t^{f,i} = S_t^{f,i} = B_t^{f,i}$ and $I_t^{e,i} = S_t^{e,i} = B_t^{e,i}$ and we obtain the diversified optimization problem stated in the main text.

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