Credit market heterogeneity, balance sheet (in)dependence, financial shocks

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Abstract

This paper presents a real business cycle model with financial frictions and two credit markets to investigate the qualitative and quantitative relevance of credit market heterogeneity. To address this line of inquiry we contrast the transmission of financial shocks in an economy where loans are the only form of credit to one in which both loans and bonds exist. We estimate the model using Bayesian methods over the sample period 1985Q1 – 2015Q1 for the U.S. economy. We find that credit market heterogeneity plays an important role in attenuating the impact of financial shocks by allowing borrowers to substitute away from the affected credit market. The shock attenuation property of credit market heterogeneity works through asset prices and substitution toward alternative credit types. Bank balance sheet linkages reduce the shock attenuation effect associated with heterogeneous credit markets. The origination of financial shocks can influence both the size and the persistence of their impact.

Keywords: Credit Market, Business Cycle, Financial Intermediation, Operational Diversification, Heterogeneity, DSGE

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1 Introduction

This paper presents a real business cycle model with financial frictions and two credit markets to investigate the qualitative and quantitative relevance of credit market heterogeneity. To address this line of inquiry we contrast the transmission of financial shocks in an economy where loans are the only form of credit to one in which both loans and bonds exist. We argue that the heterogeneous structure of credit markets can attenuate the impact of financial shocks. If credit markets behave differently to one another, increases in the supply of one form of credit could make up for reductions in the supply of another - a "spare tyre" as noted

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by Greenspan (1999). The existence of heterogeneous credit markets thus offers firms a means to substitute between different credit sources and, in doing so, reduces their exposure to credit market specific shocks. A similar narrative holds true for banks: operational diversification allows for the re-allocation of resources toward more profitable markets. In this way, losses to financial sector efficiency can be limited during times of distress.

The development of macroeconomic models with a role for credit has come a long way since Kiyotaki and Moore (1997), however these models still assume a single representative credit market[1]. As such, the literature is silent on the evolution of credit composition over the business cycle. Furthermore, the absence of credit market heterogeneity implies an incomplete understanding of the benefits associated with operational diversification in the financial sector. We aim to fill this gap in the literature by investigating how balance sheet linkages within the financial sector impacts on the stability benefits offered by operational diversification.

We introduce credit market heterogeneity based on an assumed risk difference between bonds and loans. This assumption is motivated with the theoretical literature on corporate debt structure, which views financial intermediaries (FIs hereafter) as a solution to problems of information asymmetry. In such a setting, the optimal choice of debt instrument is related to the riskiness of borrowers (Holmstrom and Tirole, 1997; Repullo and Suarez, 2000)[2]. It is then possible to achieve non-trivial heterogeneity between bond and loan markets by assuming the risk profile of these two markets differ. In the context of this analysis, we assume that loans are more risky than bonds. In addition, the role of FIs differs in each market. FIs' role in loan extension follows the traditional financial intermediation, whereas in the bond market FIs perform an additional role of underwriter.

Introducing credit heterogeneity by way of a risk-adjusted capital constraint provides a channel for FI balance sheets to influence the behaviour of the credit markets in our model. We introduce this heterogeneity in the credit market by assuming that FIs consist of a loan branch and a bond underwriting branch. Each branch is then subjected to a risk weighted capital requirement, which serves to drive a wedge between the returns of the FIs' assets. This channel is akin to the lending channel of monetary policy as described in Kishan and Opiela (2000). In line with credit market behaviour post-2008, the lending channel sees credit quantity changes as a result of supply-side factors as opposed to being driven by changes in demand (Adrian et al., 2012; Kaya and Wang, 2014). This characteristic differentiates our paper from that of De Fiore and Uhlig (2015), who incorporate credit heterogeneity into a costly state verification framework á la Townsend (1979). De Fiore and Uhlig (2015) do a good job at replicating the behaviour of aggregate credit data, however, their model is missing the important amplification effect of shocks since it is characterized by intra-period borrowing. As argued by Quadrini (2011), macroeconomic models characterized by intra-period borrowing are unable to contemporaneously capture the impact of expected future market conditions, resulting in a dampened response to shocks. Adrian et al. (2012) present a model of the financial sector with pro-cyclical leverage as well as the coexistence of bond and loan markets. Although providing a good

[1]See Gertler and Kiyotaki (2011), Quadrini (2011), Brunnermeier et al. (2012) and Bràzdik et al. (2012) for surveys of macroeconomic models characterized by financial intermediation.

[2]See also the models of Hoshi et al. (1993), Besanko and Kanatas (1993), Chemmanur and Fulghieri (1994), and Bolton and Freixas (2000) for examples where borrower types are revealed by their choice of debt instrument.

representation of FIs, the nature of the partial equilibrium framework of Adrian et al.'s (2012) model implies their analysis is silent on the broader macroeconomic implications of credit heterogeneity.

De Jonghe (2010) and Fomby et al. (2012) provide evidence which indicates that the stability benefits offered by revenue diversification could depend on balance sheet linkages between financial agents. If balance sheets are interdependent across the entire financial sector, negative shocks to one credit market spill-over to other credit markets, thus, limiting the shock attenuation property of credit market heterogeneity. When financial sector balance sheets are independent from one another, negative shocks in one credit market may not spill-over and, thus, shock attenuation can be facilitated via substitution between credit types. In our study, we provide a means to test this narrative with a framework that allows for both balance sheet dependence and independence.

The contribution of this paper is three-fold. First, to the best of our knowledge, this paper is the first attempt to introduce credit market heterogeneity into a Kiyotaki and Moore (1997) world. We build on the contribution of De Fiore and Uhlig (2015), providing a role for both FI capital and inter-period borrowing. These features incorporate insights offered by the existing literature on the importance of expected future market conditions and the financial sector's ability to fund credit expansions. Our new framework incorporates the notion that the operational role of FIs differs across credit markets. From this property stems the second contribution of this paper: providing a theoretical framework to study the effects of operational diversification within the banking sector. As opposed to De Fiore and Uhlig (2015) where FIs specialize in specific credit markets, our framework incorporates both specialization and diversification[3]. Finally, our study provides a framework in which the origination of financial shocks across agents can influence their impact on macroeconomic outcomes.

Our model performs reasonably well in terms of replicating the behaviour of US credit markets. Our results show that the impact of financial shocks in the presence of heterogeneous credit markets is attenuated as compared to a single credit market economy as found in Iacoviello (2015). This results from the ability of borrowers to substitute away from the shock affected credit market toward alternate sources of financing. Additionally, we find that inter-period borrowing amplifies the financial sector's resilience to financial shocks as compared to De Fiore and Uhlig (2015).

Financial sector resilience is partly as a result of the different operational roles required of FIs across the credit markets in our model. This characteristic affords revenue diversification in the financial sector, and in our model the effects thereof concur with existing evidence that links revenue diversification to financial stability (Elsas et al., 2010; Shim, 2013; De Jonghe et al., 2015; Köhler, 2015). In agreement with De Jonghe (2010) and Fomby et al. (2012), we find that the stability benefits of revenue diversification decrease when the balance sheets of financial agents are interdependent. This results from the shock spill-over that occurs under balance sheet interdependence.

Finally, we find that the origination of financial shocks can influence both the size and the persistence of their impact. Specifically, when savers are directly hit by financial shocks, the size of their impact on the real

[3] De Fiore and Uhlig (2015) allow for two types of FIs – commercial banks, offering loan finance, and capital mutual funds, offering bond financing. Our framework nests both the De Fiore and Uhlig (2015) setup as well as one where commercial banks can offer both loan and bond finance.

economy is limited since shocks on savers do not influence the functioning of the financial system. However, the impact of these shocks can be persistent through limiting savings behaviour. In comparison, shocks borne entirely by the financial sector are amplified as a result of their influence on the ability of the financial sector to efficiently intermediate fund flows between savers and borrowers. This is in line with Sandri and Valencia (2013), who find that when shocks are borne entirely by the financial sector, their impact on the real economy is more severe and prolonged.

The rest of the paper is structured as follows. Section 2 presents the empirical evidence on the behaviour of corporate finance and section 3 describes the model. In section 4 we describe extensions to the benchmark model. Section 5 discusses estimation of the model whilst section 6 investigates the qualitative and quantitative relevance of heterogeneous credit markets. Finally, section 7 concludes.

2 Empirical evidence on credit markets

In this section we motivate the need for credit market distinction by presenting empirical evidence on the heterogeneous behaviour of loan and bond markets[4]. Figure 1 plots the growth of real GDP and credit components on the balance sheets of non-financial corporations (NFCs) in the U.S. The figure shows loan growth to be much more pro-cyclical when compared to bonds. Bond growth seems either decoupled from aggregate activity or to exhibit mild counter-cyclical behaviour, which helped to mitigate the impact of the financial crisis by providing borrowers access to an alternative form of credit.

Figure 2 plots the nominal flows of credit to NFCs. The figure provides a different perspective on this shift in the prominence of bond and loan markets. It shows that although substitution from loans to bonds may have dampened the effect of the crisis, the shift was not pronounced enough to counteract the reduction in credit stemming from negative loan growth. By plotting the spreads of bond and loan interest rates to the federal funds rate, figure 3 shows the symmetrical behaviour of the two spreads despite the significant substitution from loans to bonds as shown in figure 2.[5]. It is, however, worth noting that there is a significant decline in the bond spread during the 2007-2008 crisis, prior joining the hiking of the loan spread. Taken together with the evidence shown in figure 2, this points toward supply-side factors initiating the substitution from loans to bonds. Reduced bank lending realized higher loan interest rates and the subsequent increase in demand for alternative sources of credit saw bond rates rise. Corroborating this perspective, Kaya and Wang (2014) find that FI balance sheet constraints and risk perceptions lead to increased bond issuance by firms.

This adjustment in firms' financing behaviour saw FIs shift away from loan syndication and toward the underwriting of securities (Kaya and Meyer, 2014). The underwriting role played by FIs thus aided in diversifying their revenue streams during a period of stress. In this way, the different structures of credit markets (and firms' ability to substitute between these markets) can aid in bolstering the resilience of the financial sector through the benefits offered by revenue diversification to financial stability (Elsas et al., 2010;

[4]To simplify the narrative, we refer to our second credit market as the "bond" market. In reality it represents the whole market for non-financial corporate debt securities, of which bonds are the largest component. Thus, we use the data of debt securities for bonds in the study. A description of all the data used is offered in section B in the appendix.

[5]See Appendix section B for details on series used in figure 3.

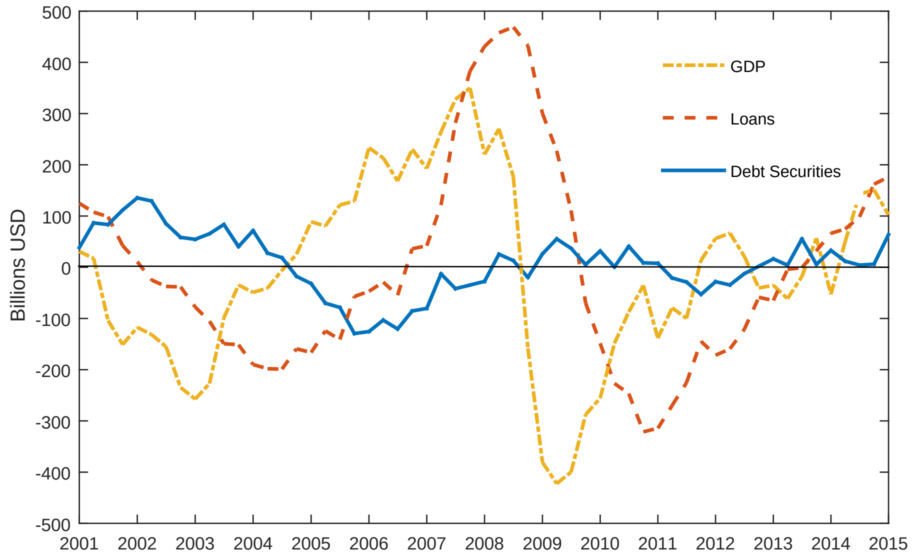

Figure 1: Non-financial corporate debt and real GDP in the U.S.

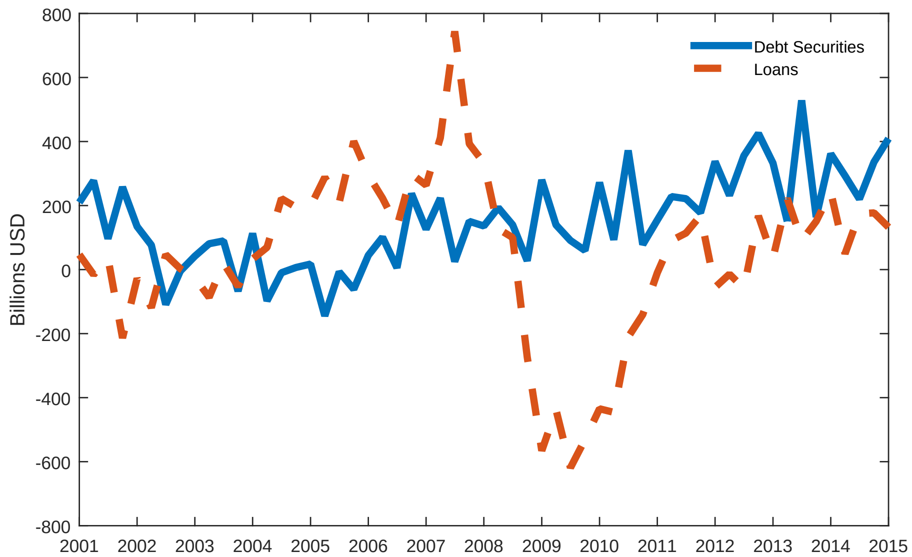

Figure 2: Credit flows for Non-financial corporations in the U.S.

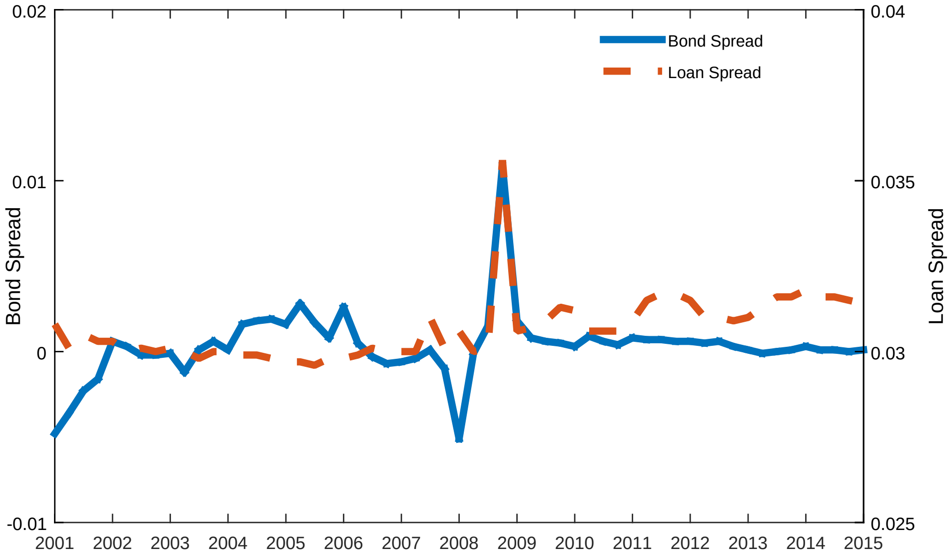

Figure 3: Bond spread vs. loan spread in the U.S.

Shim, 2013; De Jonghe et al., 2015; Köhler, 2015).

In summary, the aggregate credit data presented above reveals an increasing share for bonds in aggregate credit following the crisis whilst the share of loans declined. Empirical studies on this change in credit composition see it being initiated by developments within the financial sector, assigning a key role to FIs in changing the composition of aggregate debt. Several studies also find that this substitution between credit types can bolster financial stability, especially when the balance sheets of FIs are interdependent of one another. In the next section, we present a model that incorporates these insights into a general equilibrium framework where alternative sources of credit exist.

3 The model

The model is populated by infinitely lived households, entrepreneurs, and FIs. Households consume, accumulate real estate, and supply labour to entrepreneurs. Households are the savers in the model economy, providing funds in the form of one period deposits and bond purchases to FIs. Entrepreneurs produce output, consume, and incur one period debts (both loans and bonds) in order to finance their production. Entrepreneurs are the borrowers in this model economy. In each credit market their credit limit is determined by a collateral constraint as per Kiyotaki and Moore (1997). FIs consist of a loan branch and a bond underwriting branch, where each branch's supply of credit to entrepreneurs is subject to their balance sheet identity and a risk-weighted capital adequacy constraint.

Although households are the end holders of bonds, entrepreneurs have to interact with FIs in order to access this form of credit because they prefer to have their bond issues underwritten. The preference to underwriting arises because of information asymmetries that exist between entrepreneurs and households. Providing that entrepreneurs cannot gauge household demand, the supply of funds from bond issuances may be insufficient to meet their desire for credit. By underwriting their bond issuances, entrepreneurs can guarantee the amount of funds that they receive.

Non-trivial intermediation in bond and loan markets is achieved by subjecting FIs to utility costs for underwriting bonds and a branch-specific risk-weighted capital requirement constraint. Firstly, utility costs to underwriting arise because financial intermediaries do not wish to hold bonds on their balance sheet as this reflects a misjudgment on their behalf regarding household demand for bonds. Since FIs value their reputation as underwriters, such misjudgement infer utility costs which lead them to requiring a premium on underwritten bond issuances. Secondly, we augment the standard capital requirement constraint of each branch with asset risk weights in order to incorporate the assumed risk differential between bonds and loans. Specifically, bonds have a lower risk weight than loans and so, the risk premium on loans is higher than that on bonds such that a spread exists between loan and bond interest rates.

Our model with heterogenous credit markets contrasts to the transmission of financial shocks in the single credit market economy of Iacoviello (2015). In addition, our framework presents a means through which to gauge the benefits to operational diversification within the financial sector. Through adjustments to the capital adequacy constraints of FIs, we can allow for balance sheet linkages that bear real implications on financial sector resilience. Lastly, we introduce a new shock to bonds purchased by households. This shock is in fact akin to a shock to FIs' liabilities in our model and, hence, serves as a new financial shock. This new financial shock together with risk-weighted capital constraints allow us to study the transmission of credit market specific shocks on the real economy.

3.1 Households

The representative household maximizes its expected lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t \left\{ log(C_t^h) + jlog(H_t^h) + \tau log(1 - N_t) \right\}, \quad (1)$$

subject to the following budget constraint

$$C_t^h + D_t + B_t^h + q_t(H_t^h - H_{t-1}^h) = R_{t-1}^d D_{t-1} + R_t^h B_{t-1}^h + W_t N_t. \quad (2)$$

β_h gives the household discount factor. j and τ are coefficients. C_t and N_t represent household consumption and labor, respectively. D_t denotes bank deposits that earn a pre-determined gross return of R_t^d. B_t^h denotes household purchases of bonds. These purchases are intermediated by the FI and pay a gross return of R_t^h. q_t gives the price of real estate (H_t^h) in units of consumption and W_t is the wage rate paid to households.

As in Minetti and Peng (2013), we assume households are subject to a lending constraint such that their current period holdings of bonds cannot exceed a fraction ν_h of their net worth. Formally, this lending constraint is given by

$$B_t^h \leq \nu_h \left(R_t^h B_{t-1}^h + q_t H_{t-1}^h - \mathbb{E}_t \varepsilon_{t+1}^b \right). \tag{3}$$

Given our calibration, ν_h embeds the need for entrepreneurs to underwrite their bonds since it restricts household demand for bonds[6]. Practically, one can think of ν_h as the fraction of net worth that households are willing to devote to acquiring new risky assets.

We introduce a shock to bond holdings in the households' lending constraint, $\mathbb{E}_t \varepsilon_{t+1}^b$, capturing expected bond market losses that reduce households' wealth[7]. This shock, indeed, serves as a financial shock in the model, given that bonds held by households appear on the liability side of FIs' balance sheet. We assume that ε_t^b follows an AR(1) process:

$$\varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \iota_t^b. \tag{4}$$

In (4), $\iota_t^b \sim N(0, \sigma_b^2)$ is a white noise process with a normal distribution, zero mean, and variance of σ_b^2.

Optimal behaviour by households generates first-order conditions for deposits (5), real estate demand (6), bonds (7), and labour supply (8):

$$1 = m_t^h R_t^d, \tag{5}$$

$$q_t = \frac{j C_t^h}{H_t^h} + m_t^h q_{t+1} (1 + \nu_h \lambda_{t+1}^h), \tag{6}$$

$$1 + \lambda_t^h = m_t^h R_{t+1}^h (1 + \nu_h \lambda_{t+1}^h), \tag{7}$$

$$W_t = \frac{\tau C_t^h}{1 - N_t}, \tag{8}$$

where $m_t^h \equiv \frac{\beta_h C_t^h}{C_{t+1}^h}$ gives the household's stochastic discount factor, whilst $\Lambda_t^h \equiv \frac{\lambda_t^h}{C_t^h}$ gives the multiplier on constraint (3) normalized by the marginal utility of consumption. Equation 5 provides the behavioral rule for the benchmark interest rate in our economy. The asset pricing equation 6 equates the value of real estate to its direct utility benefits in units of consumption plus the discounted utility benefit it offers in the next period through its influence on household wealth. Equation 7 implies the period t utility cost of bond acquisition should equal to its discounted benefits in period $t+1$. Current period costs consist of reduced consumption as well as a tightening of the lending constraint. Next period benefits accrue from increased consumption offered by the interest income on bond holdings (R_{t+1}^h). Lastly, equation 8 gives the optimal wage rate.

[6]We calibrate ν_h so that households' demand for bonds is inadequate to meet the credit needs of entrepreneurs.

[7]In our model, households hold approximately 98% of all bonds in equilibrium. As a result, we assume that the entirety of the bond market losses are borne by households. The weighting of the size of the shock does not alter our results either qualitatively or quantitatively.

In the model we assume bonds are less liquid than deposits. Households require that the return on holdings of bonds be a premium on that offered for deposits held at the bank. Combining equations 5 and 7 gives this premium as

$$R^h_{t+1} - R^d_t = \frac{1+\lambda^h_t}{m^h_t(1+\nu_h\lambda^h_{t+1})} - \frac{1}{m^h_t}. \tag{9}$$

In steady state a positive spread between R^h and R^d exists so long as $\lambda^h > 0$ and $0 < \nu_h < 1$. We can show that λ^h will be greater than zero when[8]

$$j < \frac{(1-\beta_h)qH^h}{C^h}. \tag{10}$$

3.2 Entrepreneurs

Entrepreneurs maximize their lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t_e \left\{ log(C^e_t) \right\}, \tag{11}$$

subject to the following budget constraint:

$$C^e_t + q_t(H^e_t - H^e_{t-1}) + R^b_{t-1}B_{t-1} + R^l_t L_{t-1} + W_t N_t = Y_t + B_t + L_t. \tag{12}$$

β_e is the entrepreneurial discount factor and C^e_t gives entrepreneurial consumption. H^e_t gives the real estate holdings of entrepreneurs. B_t gives the size of bond borrowing on which a pre-determined gross interest of R^b_{t-1} is paid in period t. L_t and R^l_t denote loans and the gross return to loans, respectively.

The borrowing constraints for entrepreneurs are as follows:

$$B_t \leq \frac{\omega\nu_e q_{t+1}H^b_t}{R^b_t}, \tag{13}$$

$$L_t \leq \frac{(1-\omega)\nu_e q_{t+1}H^e_t}{R^l_{t+1}}. \tag{14}$$

where ω governs the share of collateral devoted to the bond market, whereas ν_e can be interpreted as the loan-to-value ratio of entrepreneurs.

Entrepreneurs' production technology follows a Cobb-Douglas function form with input shares of α for real estate and $(1-\alpha)$ for labour. Formally,

[8] To derive this result we take the steady state of equation 6, and require that $\lambda^h > 0$.

$$Y_t = \left(H^e_{t-1}\right)^{\alpha} \left(N^e_t\right)^{1-\alpha}. \tag{15}$$

As was done for households, let $\Lambda^i_t \equiv \frac{\lambda^i_t}{C^e_t}$ for $i = b, l$ give the multipliers on the borrowing constraints (13) and (14). Furthermore, denoting $m^e_t \equiv \frac{\beta_e C^e_t}{C^e_{t+1}}$ as entrepreneurs' stochastic discount factor, the optimal conditions for real estate, bonds, loans, and labour are as follows:

$$q_t = \nu_e \left[\frac{\omega\lambda^b_t}{R^b_t} + \frac{(1-\omega)\lambda^l_t}{R^l_{t+1}}\right]\mathbb{E}_t q_{t+1} + m^e_t \mathbb{E}_t \left(\alpha\frac{Y_{t+1}}{H^e_t} + q_{t+1}\right), \tag{16}$$

$$1 - \lambda^b_t = m^e_t R^b_t, \tag{17}$$

$$1 - \lambda^l_t = m^e_t R^l_{t+1}, \tag{18}$$

$$W_t = \frac{(1-\alpha)Y_t}{N_t}. \tag{19}$$

Equation 16 shows that the cost to an additional unit of real estate in units of consumption is equal to the benefit arising from a relaxtion of the borrowing constraint plus the benefits that result from its influence on entrepreneurial wealth as well as its use in production. Equations 17 and 18 are the asset pricing equations for bonds and loans, respectively. Equation 19 gives the optimal wage rate.

Since borrowers take interest rates on loans and bonds as given, we can take the steady state of equations 17 and 18 to derive the equilibrium condition for the coexistence of two debt instruments on entrepreneurs' balance sheets:

$$\lambda^b = \lambda^l + \beta_e(R^l - R^b). \tag{20}$$

Given that $R^l > R^b$, equation 20 states that for entrepreneurs to be indifferent between bonds and loans as sources of credit, the shadow value of their bond borrowing constraint needs to be larger than that on loans. This equilibrium condition implies that entrepreneurs are more constrained in accessing credit in the form of bonds than loans. It is intuitive to require a differential in the tightness of the two borrowing constraints such that both credit types exist in equilibrium. Since entrepreneurs can tap credit from the bond market at a cheaper rate than that charged on loans, they would make use of bond finance only if given the choice. However, by ensuring that $\lambda^b > \lambda^l$, we limit their ability to do so.

In order to ensure entrepreneurs are credit constrained in equilibrium, we need to place restrictions on the feasible values for their discount factor β_e. Entrepreneurs will be borrowing constrained in both bond and loan markets so long as condition (21) holds, given $\beta_e R^l < 1$, $\beta_e R^b < 1$, and $R^l > R^b$.[9] Thus, provided that the steady state interest rate on loans is higher than that on bonds, entrepreneurs will be credit constrained in equilibrium so long as the inverse of the discount rate is larger than a weighted average of household and

[9]We make use of the steady state of equations 5 and 36 in deriving this condition.

FI discount rates.

$$\frac{1}{\beta_e} > \frac{\vartheta\varphi_l}{\beta_f} + \frac{1-\vartheta\varphi_l}{\beta_h} \tag{21}$$

3.3 Financial intermediaries

FIs maximize their utility from consumption (C_t^f). Here we introduce a utility cost ($\nu_f B_t^f$) due to the risks inherent in underwriting. Underwriting risk is captured by insufficient household demand for bonds, requiring FIs to hold the remainder of it on their own balance sheet. Given that their holdings of bonds is defined as per equation 24, the FI's objective function is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_f^t \left\{ log(C_t^f) - \nu_f B_t^f \right\}. \tag{22}$$

In equation 22, β_f gives the FI's discount factor, whilst ν_f parametrizes the utility cost from underwriting risk.

We assume that credit extension occurs via two separate branches within the FI, namely the loan branch and the bond underwriting branch. Each branch intermediates the flows associated with a specific credit type. This setup produces a budget constraint for the loan branch that is standard in the literature:

$$C_{l,t}^f + L_t + R_{t-1}^d D_{t-1} = D_t + R_t^l L_{t-1}. \tag{23}$$

$C_{l,t}^f$ refers to the consumption of the loan branch, which is equivalent to the profit made from the intermediation of loans between households and entrepreneurs.

In the case of the bond underwriting branch, bond credit is extended using funds received from household bond purchases. We assume that households' demand for bonds is inadequate to meet the bond-financing needs of entrepreneurs. In equilibrium FIs are prepared to hold the remaining underwritten bonds (B_t^f) on the asset side of their balance sheets. Equation 24 gives the aggregation of household (B_t^h) and bank holdings (B_t^f) of entrepreneurial bonds:

$$B_t = B_t^h + B_t^f. \tag{24}$$

The budget constraint for the bond underwriting branch is given by:

$$C_{b,t}^f + B_t + R_t^h B_{t-1}^h = B_t^h + R_{t-1}^b B_{t-1}. \tag{25}$$

Here, $C^f_{b,t}$ refers to the underwriting branch's consumption. Using the definition for aggregate bonds (24), we can substitute out for B_t, in which case equation 25 becomes:

$$C^f_{b,t} + B^f_t = R^b_{t-1}B^f_{t-1} + (R^b_{t-1} - R^h_t)B^h_{t-1}. \tag{26}$$

Equation 26 shows that the underwriting branch derives an income from performing its role as underwriter in intermediating the purchase of entrepreneurial bonds by households ($(R^b_{t-1} - R^h_t)B^h_{t-1}$) and own bond holdings ($R^b_{t-1}B^f_{t-1}$). Combining equations 23 and 26, the aggregate FI budget constraint becomes:

$$C^f_t + B^f_t + L_t + R^d_{t-1}D_{t-1} = D_t + R^b_{t-1}B^f_{t-1} + (R^b_{t-1} - R^h_t)B^h_{t-1} + R^l_t L_{t-1}. \tag{27}$$

We assume that each branch of the FI needs to finance a portion of their assets with branch capital. Letting E^i_t for $i = l, b$ denote FI branch i's capital, this condition is formally stated as follows:[10]

$$E^l_t \geq \vartheta[\varphi_l(L_t - \mathbb{E}_t\varepsilon^l_{t+1})], \tag{28}$$

$$E^b_t \geq \vartheta[\varphi_b(B_t)]. \tag{29}$$

Having a separate capital constraint for each FI branch is akin to assuming balance sheet independence between the two branches.[11] This assumption is likened to operational diversification in the financial sector. Under balance sheet independence gains or losses made by one branch do not materially affect those of the other. This implies that operational diversification helps to stabilize the financial sector when a credit market specific shock hits the sector. We relax this assumption in section 4.1.

Conditions (28) and (29) state that in each period FI branch capital must be greater than a fraction ϑ of its assets, taking into account expected losses. To generate a wedge between the cost of external finance for loans as compared to bonds, we assume that the imposed risk coefficient on loans (φ_l) is greater than that of on bonds (φ_b). This captures that, ceteris paribus, FIs need to hold more capital for loan extension than holding underwriting bonds according to the capital regulatory authority.

As per Iacoviello (2015), we define FI loan branch capital at the beginning of the period (before credit market shocks have been realized) as $E^l_t = L_t - D_t - \mathbb{E}_t\varepsilon^l_{t+1}$. Analogously, bond underwriting branch capital is given by $E^b_t = B_t - B^h_t$. Given the FI's small share in total bond holdings, we assume bond market losses originate on the household balance sheet.[12] Letting $\kappa_i = 1 - \vartheta\varphi_i$ for $i = b, l$, we can rewrite (28) and (29) as

[10] Here E^b_t refers to the bond underwriting branch's capital whilst E^l_t refers to the loan branch's capital.

[11] The balance sheet (27) can be viewed as the aggregated balance sheet of the two branches.

[12] See equation 3.

$$D_t \leq \kappa_l (L_t - \mathbb{E}_t \varepsilon^l_{t+1}), \tag{30}$$

$$B^h_t \leq \kappa_b B_t. \tag{31}$$

ε^l_{t+1} gives losses arising from a shock to loan markets. The representation of this shocks sees the losses originated on the balance sheet of the FI loan branch. We assume that ε^l_t follows an AR(1) process:

$$\varepsilon^l_t = \rho_l \varepsilon^l_{t-1} + \iota^l_t. \tag{32}$$

In (32), $\iota^l_t \sim N(0, \sigma^2_l)$ is a white noise process with a normal distribution with zero mean and variance of σ^2_l.

The FI takes R^d_t and R^h_t as given and chooses D_t, B^h_t, B^f_t, and L_t to maximize (22) subject to (27), (30), and (31). Let $\Lambda^f_{i,t} \equiv \frac{\lambda^f_{i,t}}{C^f_t}$ for $i = l, b$ be the multipliers on constraints (30) and (31), whilst $m^f_t \equiv \frac{\beta_f C^f_t}{C^f_{t+1}}$ gives the FI's stochastic discount factor. The first order conditions for D_t, B^h_t, B^f_t, and L_t are given by

$$m^f_t R^d_t = 1 - \lambda^f_{l,t}, \tag{33}$$

$$m^f_t R^h_{t+1} = 1 + \nu_f C^f_t - \lambda^f_{b,t}, \tag{34}$$

$$m^f_t R^b_t = 1 + \nu_f C^f_t - \kappa_b \lambda^f_{b,t}, \tag{35}$$

$$m^f_t R^l_{t+1} = 1 - \kappa_l \lambda^f_{l,t}. \tag{36}$$

Equation 33 equates the utility benefit of lending from households in the current period to the discounted utility cost it generates in the next period. The next period utility cost is given by the interest rate on deposits multiplied by the stochastic discount factor. $1 - \lambda^f_{l,t}$ gives the utility gain offered by new deposits less the utility cost from a tightening of the capital constraint.

The first order condition for B^h_t shows that in order to intermediate the purchase of bonds by households, FIs require that the net benefit obtained from bond market intermediation equates to the discounted interest rate on bonds demanded by households. Benefits from intermediation in the bond market consist of an additional consumption that bankers can enjoy as a result of the funds received from households plus the utility gain (in consumption units) from lower underwriting risk. At the same time, household purchases of bonds infer a cost to bankers via a tightening of their capital constraint (31).

Equation 35 states that in underwriting bonds, FIs set the interest rate payable by bond issuers such that it equates to the utility cost of underwriting less the utility gained by the increase in bank capital necessitated by an extension of credit. In the case of loans, equation 36 equates the net cost of loan issuance today to the discounted benefits that accrue to the FIs in the next period. Period t utility costs consist of a one unit reduction in FI consumption less the utility value of higher capital as required by the capital requirement constraint (30). The benefits arising from loan extension equate to the interest rate on loans multiplied by the FI's stochastic discount factor.

Using equations 33 to 36, we can derive the spreads between the different interest rates in our model economy from the FI's perspective:

$$R^l_{t+1} - R^d_t = \frac{\lambda^f_{l,t}}{m^f_t}(1 - \kappa_l), \tag{37}$$

$$R^b_t - R^h_{t+1} = \frac{\lambda^f_{b,t}}{m^f_t}(1 - \kappa_b). \tag{38}$$

Equation 37 shows that the FI loan branch requires a premium over the deposit rate on their holdings of entrepreneurial loans whilst equation 38 governs the underwriting premium required by the FI bond underwriting branch. One can see that the loan-deposit spread and the underwriting premium are increasing in the multipliers on each FI branch's capital constraint. This results from the liquidity differential that capital constraints generate between the asset and liability sides of each branch's balance sheets.

The spreads between the interest rates on deposits and household bonds as well as that between the interest rates on entrepreneurial bonds and loans are given by:

$$R^h_{t+1} - R^d_t = \frac{1}{m^f_t}(\nu_f C^f_t + \lambda^f_{l,t} - \lambda^f_{b,t}), \tag{39}$$

$$R^l_{t+1} - R^b_t = \frac{1}{m^f_t}(\kappa_b \lambda^f_{b,t} - \kappa_l \lambda^f_{l,t} - \nu_f C^f_t). \tag{40}$$

From equation 39 one can see that a positive spread between R^h and R^d as required by households requires $\nu_f C^f_t + \lambda^f_{l,t} - \lambda^f_{b,t} > 0$. Using steady state conditions of equations 33 and 34, this will be the case so long as $\frac{1}{\beta_h} < R^h$. Looking at equation 40, one can see that the spread between entrepreneurial loan and bond rates is declining in FIs' disutility to underwriting and increasing in the tautness of each branch's capital constraint. As a result, an assumption regarding the magnitude of ν_f is necessary in order to preserve a positive spread between R^l_t and R^b_t in equilibrium, that is, $\nu_f < \kappa_b \Lambda^f_b - \kappa_l \Lambda^f_l$.

To ensure non-trivial financial intermediation, we require FIs to be credit constrained in equilibrium. Given that $\beta_f < \beta_h$, i.e., FIs are more impatient than households, the steady state of equation 33 shows that FIs will be credit constrained in equilibrium as long as the following condition holds:[13]

$$\lambda^f = 1 - \beta_f R^d = 1 - \frac{\beta_f}{\beta_h} > 0. \tag{41}$$

3.4 Market Clearing

Market clearing requires the bond aggregation condition (24) as well as the following to hold:

[13]We make use of the steady state of equation 5 in deriving this result.

$$H_t^h + H_t^e = 1, \tag{42}$$

$$Y_t = C_t^h + C_t^e + C_t^f. \tag{43}$$

We normalize the quantity of real estate (42) in the economy whilst equation 43 gives the aggregate resource constrain in our model economy.

4 Model extensions

Here, we discuss two extensions to the baseline model described in section 3. In the first extension, we impose balance sheet dependence between the loan and bond underwriting branches by subjecting FIs to an aggregate capital constraint. This extension serves to investigate how balance sheet linkages influence benefits to operational diversification within the financial sector. In the second extension we restrict our baseline model to be characterized by a single credit market as in Iacoviello (2015). We make use of this extension to gauge the importance of credit market heterogeneity to the transmission of financial shocks.

We refer to our baseline model as model 1, the extension to balance sheet dependence as model 2, and the single credit market economy as model 3. For brevity, we do not discuss the frameworks of these extensions in depth. In the case of model 2, we illustrate how balance sheet dependence is introduced and how it affects FIs' optimal behaviour. For model 3, we highlight the equations that are surplus to requirements for a single credit market economy and provide the complete set of equations in section A.2 of the appendix.

4.1 A heterogeneous credit market economy with balance sheet dependence

In the baseline model (model 1) we assume that the balance sheets of the FI loan and bond underwriting branches are independent of one another. As a result, bond and loan credit extension are not subject to the same financial constraints. In model 2, we reverse this assumption and introduce balance sheet dependence between branches by subjecting them to a common capital adequacy constraint. To be explicit, bar this change, the remainder of the model 2 setup is identical to that of model 1.

Defining aggregate FI capital as $E_t^f = E_t^l + E_t^b$, we impose balance sheet dependence by merging the individual capital constraints (28) and (29):

$$E_t^f \geq \vartheta \left[\varphi_l (L_t - \mathbb{E}_t \varepsilon_{t+1}^l) + \varphi_b B_t \right]. \tag{44}$$

The balance sheet independence of model 1 can be likened to operational diversification in the financial sector, whereas balance sheet dependence (44) is akin to operational diversification within a financial sector agent. Thus, model 2 embodies a financial sector where agents are allowed to participate in multiple credit markets, whereas in model 1 financial sector agents are restricted to a specific credit market.

The FOCs for D_t, B_t^h, B_t^f, and L_t are as follows:

$$m_t^f R_t^d = 1 - \lambda_t^f, \tag{45}$$

$$m_t^f R_{t+1}^h = 1 + \nu_f C_t^f - \lambda_t^f, \tag{46}$$

$$m_t^f R_t^b = 1 + \nu_f C_t^f - \kappa_b \lambda_t^f, \tag{47}$$

$$m_t^f R_{t+1}^l = 1 - \kappa_l \lambda_t^f. \tag{48}$$

$\Lambda_t^f \equiv \frac{\lambda_t^f}{C_t^f}$ gives the multiplier on constraint (44). Compared to the FI problem of model 1, the single capital constraint of model 2 produces a similar narrative for interest rate movements; however, the common multiplier (λ_t^f) that results from balance sheet dependence implies that interest rates will mimic each other much more closely in model 2 than in model 1. To ensure non-trivial financial intermediation in model 2, it requires $\beta_f < \beta_h$ as this sees $\lambda^f > 0$. Similarly, a positive spread between R^l and R^b is ensured so long as $\nu_f < (\kappa_b - \kappa_l)\Lambda^f$.[14]

4.2 A single credit market economy

We reduce model 1 to an economy in which loans are the only form of credit by removing the underwriting role for FIs and assuming households no longer invest in bonds market. Model 3's setup is thus a carbon copy of model 1's, except that it has no role for equations (3), (13), and (24). The complete set of equations for model 3 can be found in section A.2 of the appendix.

5 Estimation

We estimate the model using Bayesian methods over the sample period 1985Q1 – 2015Q1 for the U.S. economy. We augment the baseline model to include six shocks in total. Firstly, we introduce a preference shock (ε_t^h) to household consumption in equation A.1. The second shock is a housing price shock (ε_t^q) common to both households and entrepreneurs in equations A.2 and A.9. The third one is a technology shock as given by ε_t^a in equation A.10. The fourth one is a shock to entrepreneurs' loan to value ratio (ε_t^e) in the collateral constraints of (A.11) and (A.12). The fifth one is a financial shock to bond markets (ε_{t+1}^b) in equation A.3. Lastly, we introduce a financial shock in loan markets (ε_{t+1}^l) in equation A.19.[15]

Following usual practice, we match the number of shocks to the number of observed variables and select the observed variables that have a direct link to the shocks described above. For the shock to household preferences, we make use of household consumption data. Similarly, we make use of real estate price and entrepreneur real estate wealth data to identify the real estate price and loan to value ratio shocks. We use real GDP to identify the technology shock. The financial shocks in loan and bond markets are identified with non-financial corporate bond and loan data.

[14]Note that a positive spread between R^h and R^d is already ensured from the household's side so long as $j < \frac{(1-\beta_h)qH^h}{C^h}$.
[15]See appendix A.1 for the complete set of equations for the baseline model with shocks.

We take the log first difference of each variable, subtracting their respective means thereafter. Figure 4 provides a plot of the transformed data.[16]

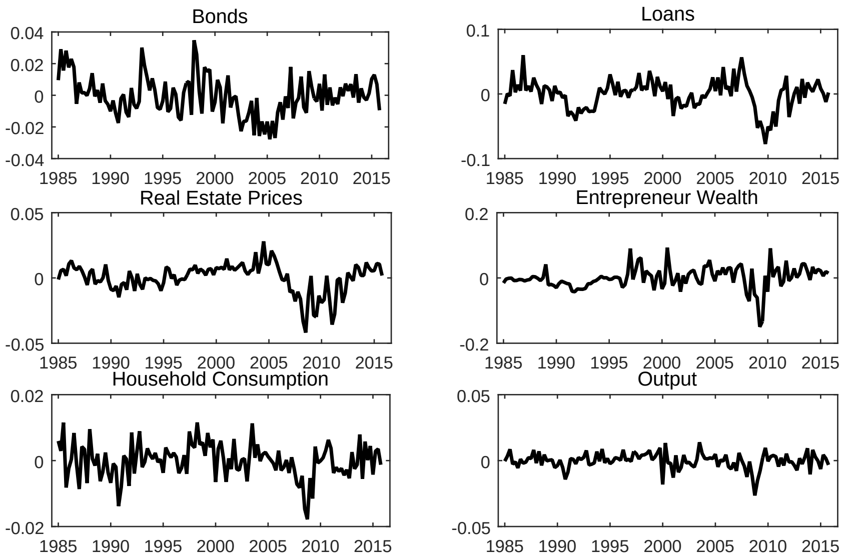

Figure 4: Data used in estimation. See section B for data sources.

5.1 Calibration

Table 1 lists the parameters that are calibrated prior to estimation. We set the discount rates for households, entrepreneurs, and FIs as $\beta_h = 0.9925$, $\beta_e = 0.94$, and $\beta_f = 0.945$, respectively. The calibrated discount rates are coherent with binding constraints of (10), (21), and (41) in equilibrium. We set the weight on leisure in households' utility function as $\tau = 2$. This sees households devote roughly a third of their available time to labour. Setting the household real estate preference as $j = 0.075$ and the share of real estate in production as $\alpha = 0.05$ implies an annualized ratio of real estate wealth to output of 3.67.

Table 1: Calibrated parameters.

Parameter	Symbol	Value
Household discount factor	β_h	0.9925
Entrepreneur discount factor	β_e	0.94
Financial Intermediary discount factor	β_f	0.945
Financial intermediary disutility to underwriting	ν_f	0.1
Real estate share in production	α	0.05
Household real estate preference	j	0.075
Household labour supply parameter	τ	2
Capital to assets ratio	ϑ	0.1
Risk weight on loans	φ_l	1
Risk weight on bonds	φ_b	0.2

We calibrate $\vartheta = 0.1$ implying that each FI branch is required to hold at least 10% of the value of their

[16] Appendix B contains the source of the observed variable for estimation.

assets in capital. A key novelty of our model lies in the individual risk weighted capital constraint applied to each FI branch. We made use of the corporate risk weights provided in Basel 2 (Basel Comittee on Banking Supervision, 2006) to calibrate the risk weighted parameters for bonds and loans. Specifically, we make use of the AAA-rated corporate bond weight for $\varphi_b = 0.2$, and the unrated corporate debt weight for $\varphi_l = 1$.

5.2 Prior distributions and posterior estimates

Table 2 reports the prior distributions and posterior estimates of the parameters. The prior distributions of the estimated parameters are reported in columns 3-5. We assume that all parameters are independent a priori and allow for their prior domains to cover a wide range of values. We follow Iacoviello (2015), in being conservative with regards to the importance of shocks. Specifically, we assume that each shock accounts for 0.3 percent of the total variance in output.

The last three columns of table 2 contains the posterior means and the 10% and 90% critical values for the estimated parameters. As evidenced by the difference between the prior and posterior distributions, the data appears to be informative with regards to both the structural parameters and the stochastic processes of the shocks. The estimated posterior mean for ν_h implies that households devote approximately 24% of their wealth to purchases of entrepreneurial bonds. The estimated ν_e gives a LTV ratio of 45% for entrepreneurs, whilst a posterior mean of 0.35 for ω sees their financing mix tilted in favour of loans. The estimated autocorrelation parameters on the shock processes indicate a high degree of persistence in all shocks.

Table 2: Parameter estimates (model 1).

Parameter		Prior distribution			Posterior distribution		
		Mean	Denisty	Std. Dev.	10%	Mean	90%
Households new bonds in total portfolio	ν_h	0.06	gamma	0.05	0.1805	0.2345	0.2923
Loan-to-value ratio for entrepreneurs	ν_e	0.7	beta	0.05	0.3535	0.4507	0.5416
Collateral share between bonds and loans	ω	0.5	beta	0.05	0.3028	0.3459	0.3871
Autocorr. tech shock	ρ_a	0.5	beta	0.1	0.9195	0.9415	0.9613
Autocorr. bond shock	ρ_b	0.5	beta	0.1	0.9428	0.9580	0.972
Autocorr. loan shock	ρ_l	0.5	beta	0.1	0.9943	0.9960	0.9977
Autocorr. HH pref shock	ρ_h	0.5	beta	0.1	0.9224	0.9435	0.9624
Autocorr. LTV shock	ρ_e	0.5	beta	0.1	0.9097	0.9292	0.949
Autocorr. house price shock	ρ_q	0.5	beta	0.1	0.8446	0.8717	0.8993
Std. dev. tech shock	ι^a	0.003	invg	1	0.0137	0.0155	0.0172
Std. dev. bond shock	ι^b	0.003	invg	1	0.0478	0.0610	0.0744
Std. dev. loan shock	ι^l	0.003	invg	1	0.1311	0.1472	0.1632
Std. dev. HH pref shock	ι^h	0.003	invg	1	0.1222	0.1674	0.2193
Std. dev. LTV shock	ι^e	0.003	invg	1	0.0605	0.0895	0.1214
Std. dev. house price shock	ι^q	0.003	invg	1	0.0814	0.0969	0.1114

The posterior density is constructed by simulation using the Random-Walk Metropolis algorithm (two chains with 30,000 draws each) as described in An and Schorfheide (2007).

6 Credit market heterogeneity and financial shocks

In this section we study the qualitative and quantitative relevance of credit market heterogeneity by contrasting the transmission of financial shocks across models 1, 2, and 3. Firstly, we contrast the transmission mechanism of loan shocks in models 1 and 3 to illustrate the attenuation benefits that arise when heterogeneous credit markets exist. Next, we investigate how balance sheet linkages influence this attenuation property by contrasting the transmission of loan shocks in models 1 and 2. Lastly, we compare the transmission mechanisms of both loan and bond shocks in model 1 to illustrate the importance of an efficiently functioning financial sector to economic outcomes.

In our model the transmission mechanisms through which financial shocks affect the real economy are as follows. A lower level of credit reduces entrepreneurial demand for real estate, imparting a negative influence on real estate prices. This, in turn, limits entrepreneurs' credit access through their collateral constraints. This results in a downward spiral in real estate prices and credit quantities, which see financial shocks produce a persistent negative effect on asset prices and credit extension and, hence, output.

The introduction of a secondary credit market as per model 1 provides an alternative to the downward spiral in real estate prices and credit quantities as described above. Since entrepreneurs are able to access both bond and loan credit markets in model 1, reductions in the supply of one credit type as a result of a credit market specific shock can be attenuated by increases in the supply of credit from the unaffected market.

In model 2, loan and bond markets are linked via a common capital constraint given by equation (44). As a result, loan shocks can spill over into the bond market limiting the attenuation impact as compared to model 1. In model 3 entrepreneurs are unable to substitute between credit types and, as a result, the impact of a financial shock can have a much more detrimental and persistent impact on aggregate output as compared to both models 1 and 2.

6.1 Financial shock in loan markets

To illustrate the shock attenuation property of credit market heterogeneity, we contrast the transmission of an innovation in $\iota_t^l \sim N(0, \sigma_l)$ in model 1 to that in model 3. Figures 5 to 6 below plot the impulse response functions (IRFs hereafter) of the main variables to a negative loan shock.

Comparing the response of the variables that are common across both models, figure 5 clearly indicates that the presence of an additional credit market attenuates the impact of a negative loan market shock. Not only is the impact of the loan shock smaller in model 1 than in model 3, but the variables of model 1 return to equilibrium at a quicker rate than those of model 3. A similar narrative applies to the other variables in figure 5 in that they take much longer to return to equilibrium in the single credit market economy of model 3 than in its multiple credit markets counterpart.

The shock attenuation property of credit market heterogeneity works through asset prices and substitution toward alternative credit types. First, in model 1 real estate prices recover much quicker compared to their sustained negative response in model 3. Second, as shown in figure 5, although loans decline in both models following the shock, bonds increase marginally in model 1. Thus, the inclusion of an additional credit market has improved the resilience of our model's financial sector as evidenced by the quicker recovery of credit (loan) extension after the shock in model 1. Both, in turn, help output to recover quicker in our model with heterogeneous credit markets (model 1).

The results show that model 1 is able to replicate the shift toward bond finance witnessed in the data. From figure 6, we can see that the increase in bonds following the loan shock results mostly from an increase

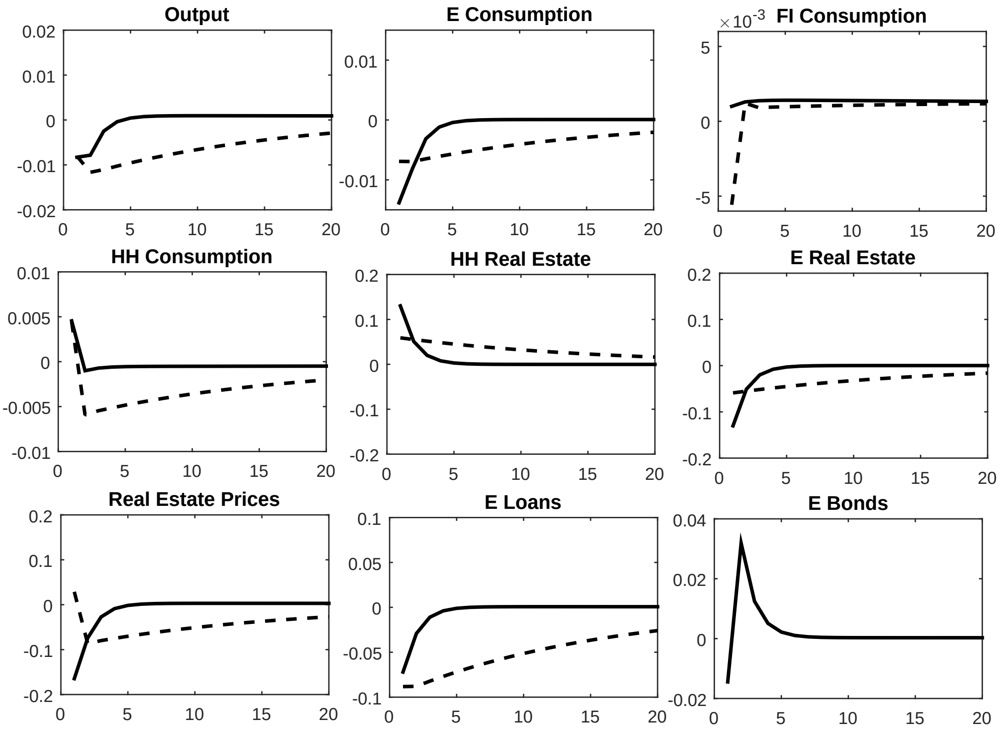

Figure 5: Impulse response functions for a shock to ι_l (solid line: model 1; dash line: model 3).

in household bond holdings, but also from marginal increase in FI bond holdings. This shift toward bond finance is facilitated by a reduction in bond interest rates, whilst the marginal increase in FI consumption (as per figure 5) is aided by a rise in the underwriting premium and the loan-deposit spread.

This reveals how operational diversification bolsters the financial sector's resilience by offering alternate revenue streams. The rise in the underwriting premium in combination with increased household bond holdings provide profits to the financial sector that help to attenuate the impact of loan losses[17]. Here, it is prudent to highlight that the balance sheet independence between the two FI branches of model 1 implies that the insights offered by our model on operational diversification in the financial sector.

It is worth noting that the magnitude of our responses are smaller than those of De Fiore and Uhlig (2015). Although this could partly be due to differences in shock size and origination[18], the attenuation of financial shocks under credit market heterogeneity could become amplified in our model vis-á-vis De Fiore and Uhlig (2015) via the contemporaneous impact of expected future market conditions. With heterogeneous credit markets, the impact of shocks on both current and future market conditions is attenuated, reducing negative contemporaneous feedback from expected future market conditions. In this way, inter-period borrowing can introduce a virtuous feedback loop in a multiple credit market economy leading to amplified shock attenuation effects. In contrast, an intra-period framework would provide no such virtuous feedback link, explaining the disparity in magnitudes between the results presented here and those of De Fiore and Uhlig

[17] Although the loan-deposit spread also increases as a result of the shock, lower loan holdings erode financial sector profits gained through this channel.

[18] Whereas we estimate the size of our shock on US data, De Fiore and Uhlig (2015) calibrate their shock so that its response is in line with the EU data. Furthermore, whereas our shock originates on FI balance sheets and is isolated to the loan market only, theirs is modelled as a shock to the productivity of entrepreneurs' collateral in loan markets that affects both bond and loan markets.

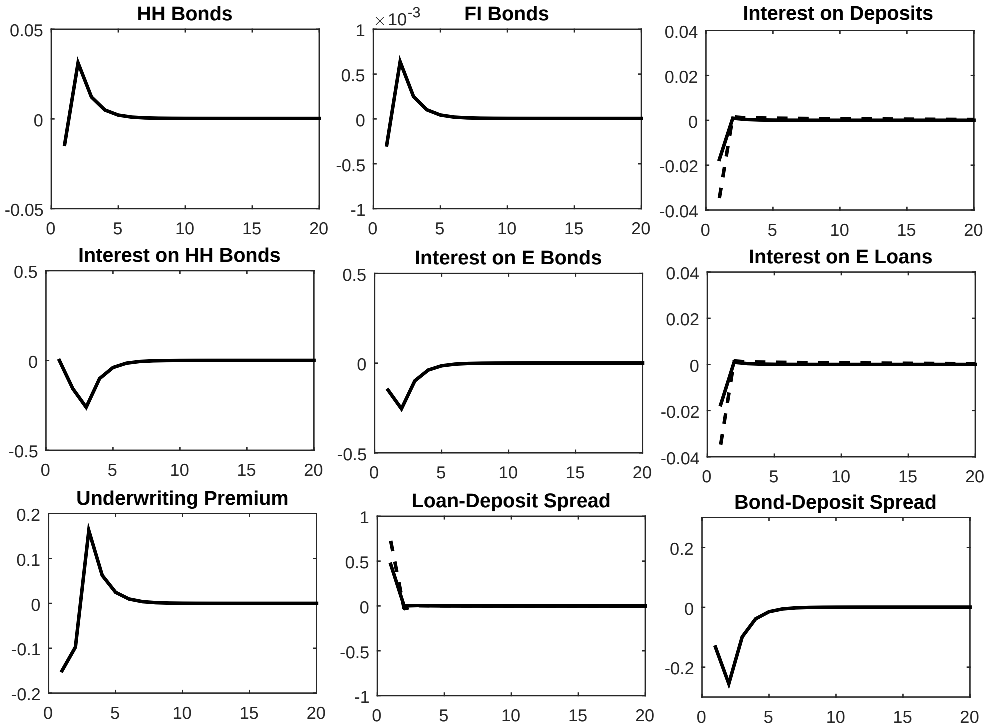

Figure 6: Impulse response functions for a shock to ι_l. (solid line: model 1; dash line: model 3).

(2015).

Regardless of magnitude effects, model 1 successfully replicates the empirical evidence of bond and loan spreads during the 2007-2008 financial crisis; however, compared to figure 3, figure 6 shows that we are unable to replicate the rise in the bond-deposit spread post-2008. That being said, the relatively muted positive response of bonds to the loan shock matches the evidence contained in figures 1 and 2 where bonds depict a-cyclical behaviour.

6.2 Balance sheet dependence and shock attenuation

In this section we investigate how balance sheet dependence influences the shock attenuation properties of model 1 as described in section 6.1. To do so, we contrast the transmission of an innovation in $\iota_t^l \sim N(0, \sigma_l)$ in model 1 to that in model 2.

Figures 7 and 8 show that balance sheet linkages between FI branches imparts a non-negligible influence on the shock attenuation properties offered by heterogeneous credit markets. The response of model 2's variables are both larger and more persistent than those of model 1. Balance sheet dependence between FI branches also produces a further disparity between the models: in model 2 entrepreneurs are unable to shift toward bond finance in response to the loan market shock. Thus, balance sheet dependence allows for the loan market shock to spill over into bond markets, as illustrated by the decline in entrepreneurial bonds in figure 7.

Figure 8 reveals the causal chain behind the disparity in bond market dynamics between models 1 and 2. Although household bonds (B_t^h) increase by more in model 2 than in model 1, the common balance sheet of model 2 requires a much larger reduction in FI holdings of entrepreneurial bonds (B_t^f) which serves to dominate the rise in B_t^h. In comparison, balance sheet independence in model 1 allows both B_t^h and B_t^f to increase (see figure 6 for a clear illustration). Additionally, figure 8 shows that although deposit and loan interest rates behave similarly across models 1 and 2, the response of household and entrepreneurial bond rates are much more muted in model 1. As a result, the contemporaneous rise in the underwriting premium is larger in model 1 than that in model 2. Thus, benefits to revenue diversification are greater in the financial sector of model 1 than that of model 2.

Comparing figures 5 and 7 reveals a very similar response between models 2 and 3 to the financial shock for all common variables bar FI consumption and entrepreneurial loans. The positive response of FI consumption in model 2 is indicative of a more resilient financial sector as compared to model 3. Further evidence in favour of model 2's financial sector resilience vis-á-vis model 3 can be found by comparing the impact of the financial shock on entrepreneurial loans. Compared to model 3, the impact of the loan shock is both shorter and less severe in model 2.

Although the shock attenuation properties of model 2 are smaller than model 1, a comparison of models 2 and 3 shows that shock spill-over as a result of balance sheet linkages within the financial sector do not erase all of the benefits offered by credit market heterogeneity. These results are thus coherent with the literature which finds that operational diversification within a financial agent promotes financial stability and balance sheet linkages limit the degree to which revenue diversification can attenuate the impact of shocks (De Jonghe, 2010; Elsas et al., 2010; Fomby et al., 2012; Köhler, 2015). Specifically, we find that shock attenuation is more pronounced when the balance sheets of financial sector agents are independent as this removes a channel through which financial shocks can spill-over to unaffected markets.

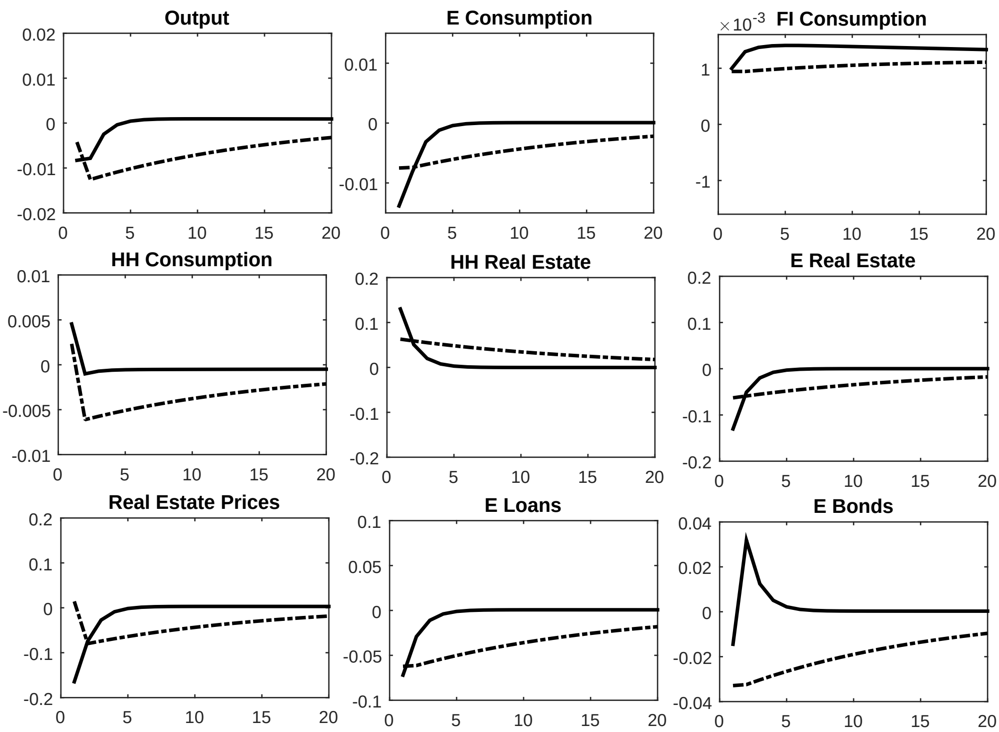

Figure 7: Impulse response functions for a shock to ι_l (solid line: model 1; dash-dot line: model 2).

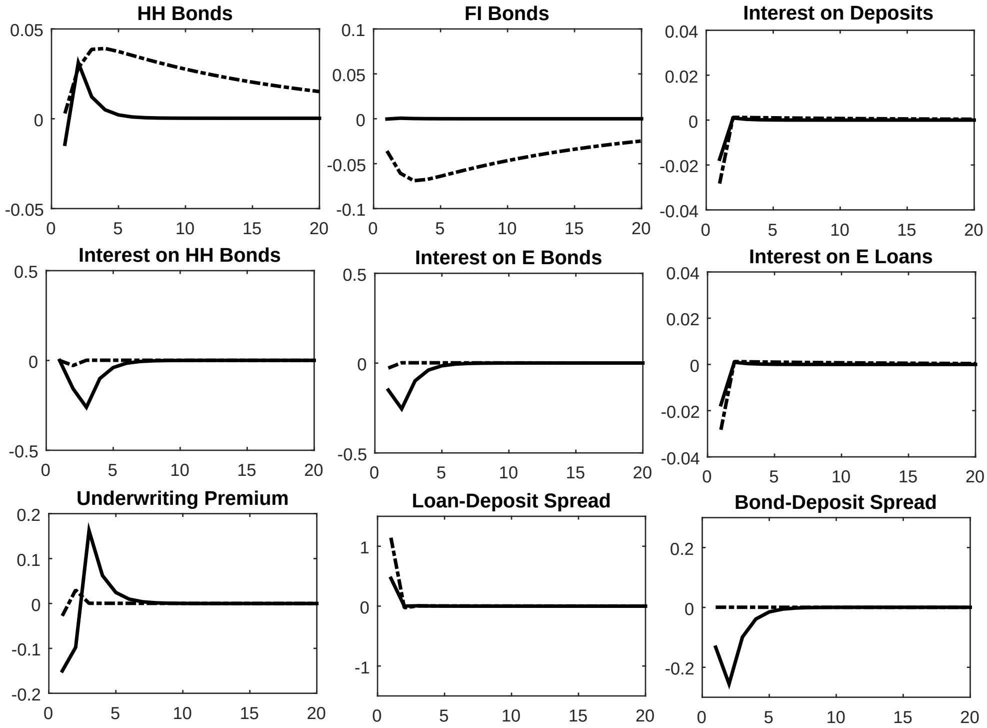

Figure 8: Impulse response functions for a shock to ι_l (solid line: model 1; dash-dot line: model 2).

6.3 Financial shocks in bond and loan markets

In our final exercise, we contrast the transmission of an innovation in $\iota_t^l \sim N(0, \sigma_l)$ to that of an innovation in $\iota_t^b \sim N(0, \sigma_b)$ in model 1. Figures 9 and 10 plot the IRFs of the main variables in response to a negative loan shock and bond shock in model 1.

The more muted response of variables to the bond shock as compared to the loan shock shows that it is important to account for the existence of credit market heterogeneity – shocks to different credit markets can realize asymmetrical macroeconomic responses. Loan shocks are borne entirely by the financial sector. When the loan shock hits, the FI loan branch has to reduce the size of its balance sheet in order to meet capital requirements. This prohibits the flow of funds from savers to borrowers, resulting in a large decline in aggregate economic activity. On the other hand, bond shocks have no such direct impact on the ability of the financial sector to intermediate fund flows from savers to borrowers. Bond shocks affect household wealth, acting as an indirect shock to the FI's liabilities and as a result has a much more muted impact on the economy as compared to a loan shock.

The disparity between the impact of a bond shock and a loan shock can be explained with reference to the household lending constraint (equation 3) and the FI's branch-specific capital constraints (equations 30 and 31). Loan shocks are manifested on the balance sheet of the FI loan branch only, whereas bond shocks are manifested on the households' lending constraint. As a result, households are able to offer additional credit via their demand for entrepreneurial bonds following a loan shock. When bond shocks hit, household wealth decreases and, since households represent the savers in our economy, a shock to their wealth reduces their demand for both deposits and bonds. This prevents substitution between credit types as was seen in

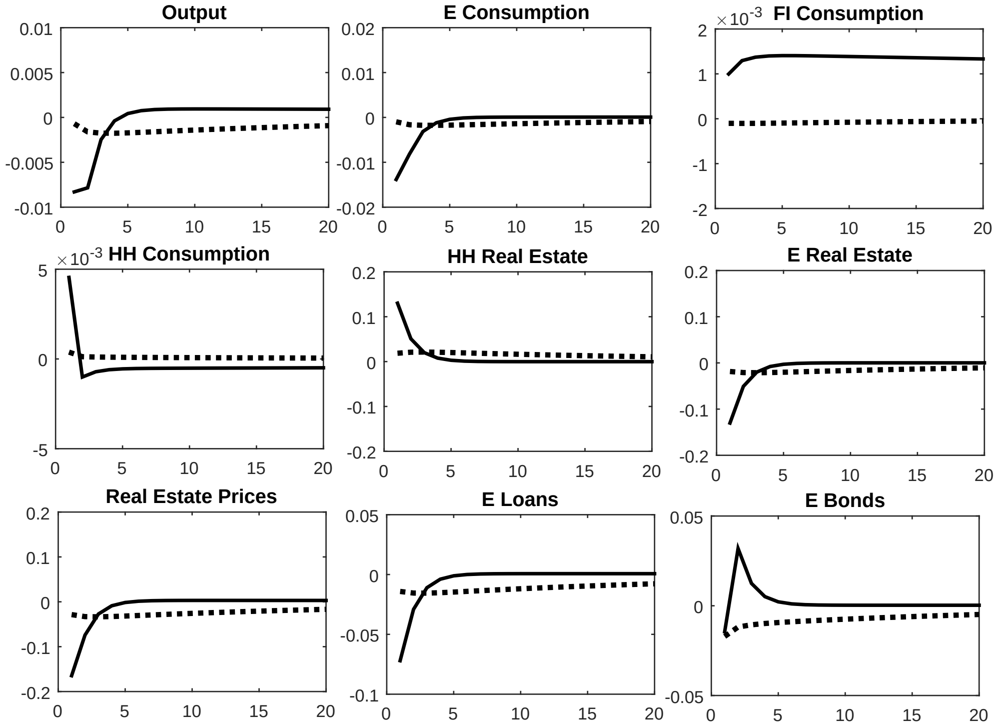

Figure 9: Impulse response functions for a shock to ι_l (solid line) and ι_b (dotted line).

the case of loan shocks (see figure 5).

In summary, the analysis in section 6.1 reveals that credit market heterogeneity plays an important role in attenuating the impact of financial shocks by allowing borrowers to substitute away from affected credit markets. Section 6.1 also illustrates how operational diversification within the financial sector can contribute to its resilience in response to market specific shocks by affording access to revenue streams from unaffected markets. Building on this result, section 6.2 shows that balance sheet linkages between financial agents play an important role in determining the degree to which operational diversification can attenuate the impact of financial shocks. When the balance sheets of financial agents are interdependent, benefits to operational diversification are limited as a result of shock spill-over. Finally, section 6.3 shows that the origination of financial shocks can influence both the size and persistence of their impact. Specifically, when shocks are borne by savers as opposed to FIs, the size of their impact on the real economy is limited since it does not reduce the efficient functioning of the financial system. At the same time, when savers are directly hit by financial shocks, the impact thereof can be very persistent by way of limiting the aggregate amount of savings in the economy. In comparison, shocks that are borne by FIs have a more severe, but less persistent impact on the real economy. The severity of the impact results from reduced financial sector efficiency in intermediating fund flows from savers to borrowers, whilst reduced shock persistence stems from the limited impact that FI borne shocks.

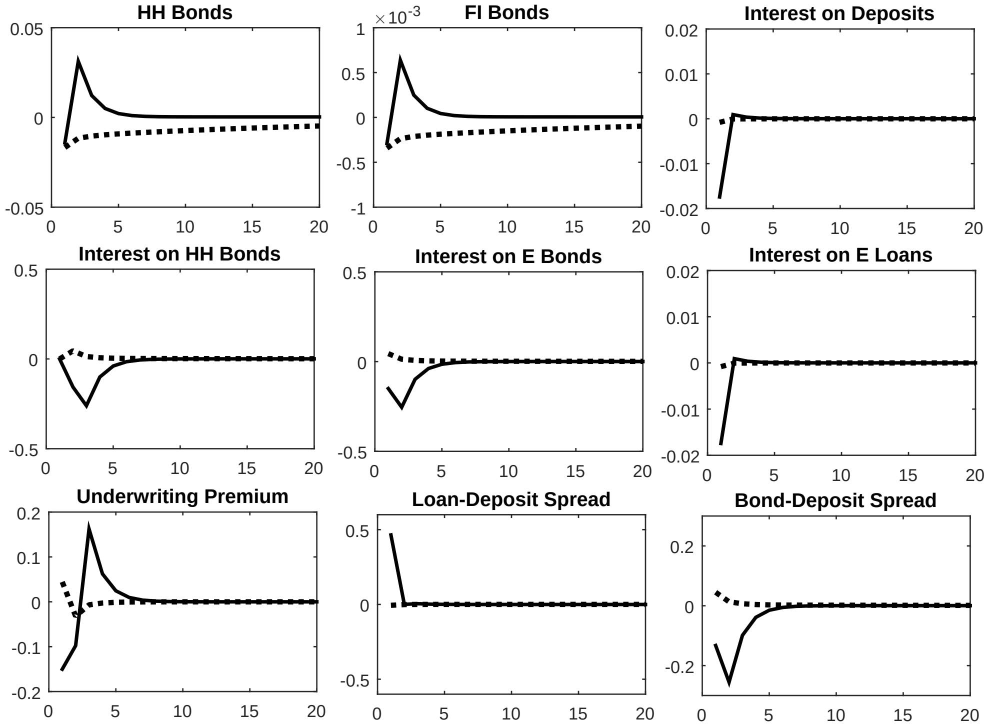

Figure 10: Impulse response functions for a shock to ι_l (solid line) and ι_b (dotted line).

7 Conclusion

We present a model where two credit markets exist and study the qualitative and quantitative relevance of credit market heterogeneity in a general equilibrium setting. In our model, we allow the financial sector to perform both loan extension and bond underwriting activities which affords a comparison between the transmission of financial shocks where a single representative credit market is assumed to a scenario where multiple credit markets exist. Furthermore, the introduction of an additional credit market allows us to contrast the impact of credit market specific shocks. We estimate the model using US data and show that credit market heterogeneity can help mitigate the impact of financial shocks. Additionally, we find that the financial sector is more robust to balance sheet shocks in a framework that incorporates credit market heterogeneity as evidenced by a quicker recovery in credit extension. We also find that financial sector resilience to financial shocks is decreasing in the degree of balance sheet dependence between financial agents.

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A Complete set of equations

A.1 Model 1: heterogeneous credit markets (bonds and loans)

Households:

The representative household maximizes its expected lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t \left\{ log(\varepsilon_t^h C_t^h) + jlog(H_t^h) + \tau log(1 - N_t) \right\}. \tag{A.1}$$

Subject to the budget constraint (A.2) and lending constraint (A.3):

$$C_t^h + D_t + B_t^h + \varepsilon_t^q q_t (H_t^h - H_{t-1}^h) = R_{t-1}^d D_{t-1} + R_t^h B_{t-1}^h + W_t N_t, \tag{A.2}$$

$$B_t^h = \nu_h \left(R_t^h B_{t-1}^h + q_t H_{t-1}^h - \mathbb{E}_t \varepsilon_{t+1}^b \right). \tag{A.3}$$

Letting $m_t^h = \frac{\varepsilon_{t+1}^h \beta_h C_t^h}{\varepsilon_t^h C_{t+1}^h}$, optimal behaviour by the household generates the following first order conditions:

$$1 = m_t^h R_t^d, \tag{A.4}$$

$$\varepsilon_t^q q_t = \frac{j}{H_t^h} \frac{1}{u_{ch,t}} + m_t^h \varepsilon_{t+1}^q q_{t+1} (1 + \nu_h \lambda_{t+1}^h), \tag{A.5}$$

$$1 + \lambda_t^h = m_t^h R_{t+1}^h (1 + \nu_h \lambda_{t+1}^h), \tag{A.6}$$

$$W_t = \frac{\tau}{1 - N_t} \frac{1}{u_{ch,t}}. \tag{A.7}$$

Entrepreneurs:

Entrepreneurs allocate their available resources between real estate, bonds, loans, and labour in order to maximize their lifetime utility function given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t \left\{ log(C_t^e) \right\}. \tag{A.8}$$

Subject to their budget constraint (A.9), production function (A.10), and borrowing constraints (A.11 and A.12):

$$C_t^e + \varepsilon_t^q q_t (H_t^e - H_{t-1}^e) + R_{t-1}^b B_{t-1} + R_t^l L_{t-1} + W_t N_t = Y_t + B_t + L_t, \tag{A.9}$$

$$Y_t = \varepsilon_t^a \left(H_{t-1}^e\right)^\alpha \left(N_t^e\right)^{1-\alpha}, \tag{A.10}$$

$$B_t \leq \frac{\omega \varepsilon_t^e \nu_e q_{t+1} H_t^b}{R_t^b}, \tag{A.11}$$

$$L_t \leq \frac{(1-\omega)\varepsilon_t^e \nu_e q_{t+1} H_t^e}{R_{t+1}^l}. \tag{A.12}$$

Optimal behaviour by entrepreneurs generates the following first order conditions:

$$\varepsilon_t^q q_t = \varepsilon_t^e \nu_e \left[\frac{\omega \lambda_t^b}{R_t^b} + \frac{(1-\omega)\lambda_t^l}{R_{t+1}^l}\right] \mathbb{E}_t \varepsilon_{t+1}^q q_{t+1} + m_t^e \mathbb{E}_t \left(\alpha \frac{Y_{t+1}}{H_t^e} + q_{t+1}\right), \tag{A.13}$$

$$1 - \lambda_t^b = m_t^e R_t^b, \tag{A.14}$$

$$1 - \lambda_t^l = m_t^e R_{t+1}^l, \tag{A.15}$$

$$\frac{(1-\alpha)Y_t}{N_t} = W_t. \tag{A.16}$$

Financial Intermediaries:

The FI's objective function is given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_f^t \left\{ log(C_t^f) - \nu_f B_t^f \right\}. \tag{A.17}$$

FI's maximize (A.17) subject to their budget constraint (A.18), and branch specific capital constraints as per (A.19) and (A.20):

$$C_t^f + B_t + L_t + R_{t-1}^d D_{t-1} + R_t^h B_{t-1}^h + = D_t + B_t^h + R_t^l L_{t-1} + R_{t-1}^b B_{t-1}, \tag{A.18}$$

$$D_t \leq \kappa_l (L_t - \mathbb{E}_t \varepsilon_{t+1}^l), \tag{A.19}$$

$$B_t^h \leq \kappa_b B_t. \tag{A.20}$$

This produces first order conditions as follows:

$$m_t^f R_t^d = 1 - \lambda_t^{f,l}, \tag{A.21}$$

$$m_t^f R_{t+1}^h = 1 + \nu_f C_t^f - \lambda_t^{f,b}, \tag{A.22}$$

$$m_t^f R_t^b = 1 + \nu_f C_t^f - \kappa_b \lambda_t^{f,b}, \tag{A.23}$$

$$m_t^f R_{t+1}^l = 1 - \kappa_l \lambda_t^{f,l}. \tag{A.24}$$

Market Clearing:

$$H_t^h + H_t^e = 1 \tag{A.25}$$

$$Y_t = C_t^h + C_t^e + C_t^f \tag{A.26}$$

$$B_t = B_t^h + B_t^f \tag{A.27}$$

Shocks:

The model allows for six shocks. First, there is a preference shock to household consumption as given by ε_t^h in equation A.1. Second, is a housing price shock that is common to both households and entrepreneurs as per ε_t^q in equations (A.2) and (A.9). Third, is a technology shock as given by ε_t^a in equation (A.10). Fourth is a shock to entrepreneurs' loan to value ratio as given by ε_t^e in equations (A.11) and (A.12). Fifth is the financial shock to bond markets as per ε_{t+1}^b in equation (A.3). Lastly, the sixth shock relates to a financial shock in loan markets as given by ε_{t+1}^l in equation (A.19).

These shocks all follow AR(1) processes with the following specifications:

$$log(\varepsilon_t^h) = \rho_h log(\varepsilon_{t-1}^h) + \iota_t^h, \tag{A.28}$$

$$log(\varepsilon_t^q) = \rho_q log(\varepsilon_{t-1}^q) + \iota_t^q, \tag{A.29}$$

$$log(\varepsilon_t^e) = \rho_e log(\varepsilon_{t-1}^e) + \iota_t^e, \tag{A.30}$$

$$log(\varepsilon_t^a) = \rho_a log(\varepsilon_{t-1}^a) + \iota_t^a, \tag{A.31}$$

$$\varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \iota_t^b, \tag{A.32}$$

$$\varepsilon_t^l = \rho_l \varepsilon_{t-1}^l + \iota_t^l. \tag{A.33}$$

In equations (A.28) to (A.33) above, $\iota_t^i \sim N(0, \sigma_i^2)$ is a white noise process with a normal distribution with zero mean and variance of σ_i^2 for $i = a, b, e, h, l, q$.

A.2 Model 3: Single credit market (loans only)

Households:

The representative household maximizes its expected lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t \left\{ log(\varepsilon_t^h C_t^h) + j log(H_t^h) + \tau log(1 - N_t) \right\}. \tag{A.34}$$

Subject to the budget constraint (A.35):

$$C_t^h + D_t + \varepsilon_t^q q_t (H_t^h - H_{t-1}^h) = R_{t-1}^d D_{t-1} + W_t N_t, \tag{A.35}$$

$$\tag{A.36}$$

Letting $m_t^h = \frac{\varepsilon_{t+1}^h \beta_h C_t^h}{\varepsilon_t^h C_{t+1}^h}$, optimal behaviour by the household generates the following first order conditions:

$$1 = m_t^h R_t^d, \tag{A.37}$$

$$\varepsilon_t^q q_t = \frac{j}{H_t^h} \frac{1}{u_{ch,t}} + m_t^h \varepsilon_{t+1}^q q_{t+1}, \tag{A.38}$$

$$W_t = \frac{\tau}{1 - N_t} \frac{1}{u_{ch,t}}. \tag{A.39}$$

Entrepreneurs:

Entrepreneurs allocate their available resources between real estate, bonds, loans, and labour in order to maximize their lifetime utility function given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t \left\{ log(C_t^e) \right\}. \tag{A.40}$$

Subject to their budget constraint (A.41), production function (A.42), and borrowing constraint (A.43):

$$C_t^e + \varepsilon_t^q q_t (H_t^e - H_{t-1}^e) + R_t^l L_{t-1} + W_t N_t = Y_t + L_t, \tag{A.41}$$

$$Y_t = \varepsilon_t^a \left(H_{t-1}^e \right)^{\alpha} \left(N_t^e \right)^{1-\alpha}, \tag{A.42}$$

$$L_t \leq \frac{\varepsilon_t^e \nu_e q_{t+1} H_t^e}{R_{t+1}^l}. \tag{A.43}$$

Optimal behaviour by entrepreneurs generates the following first order conditions:

$$\varepsilon_t^q q_t = \varepsilon_t^e \nu_e \left[\frac{\lambda_t^l}{R_{t+1}^l} \right] \mathbb{E}_t \varepsilon_{t+1}^q q_{t+1} + m_t^e \mathbb{E}_t \left(\alpha \frac{Y_{t+1}}{H_t^e} + q_{t+1} \right), \tag{A.44}$$

$$1 - \lambda_t^l = m_t^e R_{t+1}^l, \tag{A.45}$$

$$\frac{(1-\alpha) Y_t}{N_t} = W_t. \tag{A.46}$$

Financial Intermediaries:

The FI's objective function is given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_f^t \left\{ log(C_t^f) \right\}. \tag{A.47}$$

FI's maximize (A.47) subject to their budget constraint (A.48), and capital constraint (A.49):

$$C_t^f + L_t + R_{t-1}^d D_{t-1} = D_t + R_t^l L_{t-1}, \tag{A.48}$$

$$D_t \leq \kappa_l (L_t - \mathbb{E}_t \varepsilon_{t+1}^l), \tag{A.49}$$

$$\tag{A.50}$$

This produces first order conditions as follows:

$$m_t^f R_t^d = 1 - \lambda_t^{f,l}, \tag{A.51}$$

$$m_t^f R_{t+1}^l = 1 - \kappa_l \lambda_t^f. \tag{A.52}$$

Market Clearing:

$$H_t^h + H_t^e = 1 \tag{A.53}$$

$$Y_t = C_t^h + C_t^e + C_t^f \tag{A.54}$$

$$B_t = B_t^h + B_t^f \tag{A.55}$$

Shocks:

Model 3 allows for five shocks. First, there is a preference shock to household consumption as given by ε_t^h in equation (A.34. Second, is a housing price shock that is common to both households and entrepreneurs as per ε_t^q in equations (A.2) and (A.9). Third, is a technology shock as given by ε_t^a in equation (A.42). Fourth is a shock to entrepreneurs' loan to value ratio as given by ε_t^e in equations(A.43). Lastly, the fifth shock relates to a financial shock in loan markets as given by ε_{t+1}^l in equation (A.49).

These shocks all follow AR(1) processes with the following specifications:

$$log(\varepsilon_t^h) = \rho_h log(\varepsilon_{t-1}^h) + \iota_t^h, \tag{A.56}$$

$$log(\varepsilon_t^q) = \rho_q log(\varepsilon_{t-1}^q) + \iota_t^q, \tag{A.57}$$

$$log(\varepsilon_t^e) = \rho_e log(\varepsilon_{t-1}^e) + \iota_t^e, \tag{A.58}$$

$$log(\varepsilon_t^a) = \rho_a log(\varepsilon_{t-1}^a) + \iota_t^a, \tag{A.59}$$

$$\varepsilon_t^l = \rho_l \varepsilon_{t-1}^l + \iota_t^l. \tag{A.60}$$

In equations (A.56) to (A.60) above, $\iota_t^i \sim N(0, \sigma_i^2)$ is a white noise process with a normal distribution with zero mean and variance of σ_i^2 for $i = a, e, h, l, q$.

B Data list

The U.S. data is downloaded from the Federal Reserve Bank of St. Louis FRED database. Our sample runs from 1985Q1 to 2015Q1. All figures are in real terms and where necessary, are deflated using the implicit GDP deflator. To produce figure 1 presented in section 2, we apply an HP-filter with $\lambda = 1600$ to each of the series to produce the cyclical variation plotted in the figure. For figure 3, we use the 3-month AA rated commercial paper rate as the interest rate for bonds whereas the bank prime lending rate is used for loans.

- Output (Y_t):
  - U.S. Real Gross Domestic Product. Source: US. Bureau of Economic Analysis.
- Household consumption (C_t^h):
  - Real Personal Consumption Expenditures. Source: US. Bureau of Economic Analysis.
- Entrepreneur consumption (C_t^e):
  - Nonfinancial Corporate Business: Profits Before Tax (excluding IVA and CC Adj.). Source: US. Bureau of Economic Analysis.
- Financial intermediary consumption (C_t^f):
  - Financial business; Corporate Profits Before Tax (excluding IVA and CC Adj.). Source: Financial Accounts of the US. Table Z.1.
- Real Estate prices (q_t):
  - All-Transactions House Price Index for the United States, Index 2009=100. Source: US. Federal Housing Finance Agency.
- Household real estate wealth ($q_t H_t^h$):
  - Households and Nonprofit Organizations; Real Estate at Market Value. Source: Board of Governors of the Federal Reserve System (US).
- Entrepreneur real estate wealth ($q_t H_t^e$):
  - Nonfinancial Corporate Business; Real Estate at Market Value. Source: Board of Governors of the Federal Reserve System (US).
- Hours worked (N_t):
  - Average Weekly Hours of Production and Non-supervisory Employees: Manufacturing. Source: US. Bureau of Labor Statistics.
- Entrepreneurial loans (L_t):

  - Nonfinancial Corporate Business; Total Loans; Liability. Source: Board of Governors of the Federal Reserve System (US).

- Entrepreneurial bonds (B_t):
  - Nonfinancial Corporate Business; Debt Securities; Liability. Source: Board of Governors of the Federal Reserve System (US).

- Interest rate on deposits (R_t^d):
  - Effective Federal Funds Rate. Source: Board of Governors of the Federal Reserve System (US).

- Interest rate on household bonds (R_t^h):
  - 3-Month AA Nonfinancial Commercial Paper Rate. Source: Board of Governors of the Federal Reserve System (US).

- Interest rate on loans (R_t^l):
  - Bank Prime Loan Rate. Source: Board of Governors of the Federal Reserve System (US).

- GDP deflator:
  - Gross Domestic Product: Implicit Price Deflator. Source: US. Bureau of Economic Analysis.