The influence of financial factors on credit spread variability in U.S. business cycles: the Great Moderation versus the Great Recession

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Abstract

In this paper, we use a New-Keynesian DSGE framework with a central role for financial intermediation to assess the influence of financial factors on credit spread variability in U.S. business cycles. Over the Great Moderation and Great Recession periods, we find a clear role for the influence of bank market power on both credit spread variability and the U.S. business cycle: in which both sticky rate adjustments and loan rate markups are important. To highlight any distinguishable features of the recent recession, we compare the 1990−91, 2001 and 2007−09 U.S. recessions and the sources of their credit spread variability. While the transmission mechanism of shocks in each U.S. business cycle has not changed significantly, we find evidence of a steady shift towards the influence of financial factors over credit spread variability, and a concurrent decline in the role of technology and monetary policy shocks. Particularly, relative to credit demand and bank funding, the role of financial intermediaries in credit supply has become the predominant force behind recent credit spread variability. Furthermore, in the recent U.S. business cycle, the influence of bank balance sheet adjustments have become an important factor in dislocating the interaction between short-term interest rates and real economic activity.

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1 Introduction

One notable recurring characteristic of financial stress in recessions is the phenomenon of large credit spread variability. Since the financial crisis reared its head in August 2007, systemic disruptions to financial intermediation has shown, once again, how large variations in credit spreads dislocate the interaction between short-term interest rates and real economic activity. Our study focuses on the financial factors that influence credit spread variability, and its impact on the U.S. business cycle over the Great Moderation and Great Recession periods.

For certain, disruptions to financial markets have been at the epicenter of the Great Recession of 2007−09 and, in no small part, played a role in the two preceding Great Moderation recessions of 1990−91 and 2001 (e.g., Bernanke and Lown, 1992; Brunnermeier, 2009; Gorton, 2009).[1] One comparative example being the savings and loan crisis prior to the 1990−91 recession, and the sub-prime mortgage crisis prior to the Great Recession of 2007−09. The sufficient condition for our study, however, is that all three recessions exhibited significant financial stress, and therefore widening credit spreads—prior to which credit spreads narrowed considerably. Our first objective, therefore, is to determine the extent to which financial intermediaries affect U.S. business cycle fluctuations through their influence on credit spreads. To do this, we establish the prevailing combination of demand- and supply-side financial factors that drive credit spread variability over the Great Moderation and Great Recession periods. Once we have established the credit spread transmission mechanism of financial intermediation, we investigate whether there is any contributing financial factor to credit spread variability in the recent 2007−09 recession that can be distinguished from the 1990−91 and 2001 recessions of the Great Moderation period. To understand the causes of recurring patterns in credit spread variability, and the consequences thereof for the real economy, we emphasize the central role of financial intermediation in driving recent business cycle fluctuations. What is important here is how financial intermediaries adjust interest rates in response to their own balance sheet adjustments and that of nonfinancial savers and borrowers. To which, independent of policy rate adjustments, alters the interaction between short-term interest rates and the real economy. We use a New-Keynesian dynamic stochastic general equilibrium (DSGE) framework to investigate the sources of credit spread variability, and subsequently establish the centrality of financial intermediation in propagating nominal and real shocks to the real economy.

Currently, the central influence of financial intermediation in the transmission mechanism of nominal and real shocks is yet to be fully incorporated within the New-Keynesian literature on financial factors in business cycles (e.g., Adrian and Shin, 2011, p.602). A volume of research on financial factors emphasizes both credit demand- and supply-side restrictions that exacerbate the business cycle. For example, creditworthiness and net worth constrain the borrowing ability of households and firms (Bernanke et al., 1999; Iacoviello, 2005), while bank capital requirements, interest rate stickiness and value-at-risk constraints impose frictions in financial intermediaries (Gerali et al., 2010; Adrian and Shin, 2011). Although demand-side factors are important for financial accelerator effects, the consensus one draws highlights the importance of financial intermediaries in propagating financial instability to real activity—through both the composition

[1] Based on S&P500 data, the recessions of 1990−91, 2001 and 2007−09 coincided, from peak to trough, with equity price collapses of 14.70%, 11.91% and 48.82%. The total equity price collapses were 14.7% (1990−91), 29.36% (2001) and 50.82% (2007-09). The data can be found at the Federal Reserve Bank of St. Louis's FRED database.

of balance sheet aggregates and the widening of credit spreads. Indeed, some key frameworks have been developed for thinking about how disruptions in financial intermediation transmit through the economy (e.g., Curdia and Woodford, 2010; Adrian and Shin, 2011; Gertler and Kiyotaki, 2011). Broadly speaking, these studies focus on how to curtail the effects of credit market frictions or bank balance sheet adjustments on real economic activity, through either conventional or unconventional monetary policies. On the one hand, Curdia and Woodford (2010) use a basic New-Keynesian model with credit frictions, and minimal financial intermediary structures, to investigate the interaction between credit spread variability and monetary policy. On the other hand, Adrian and Shin (2011); Gertler and Kiyotaki (2011) specify an active role for financial intermediation, where the primary goal is to centralize the role of financial intermediation in macroeconomic models to conform more closely to current institutional realities. And although their frameworks revolve around financial and nonfinancial borrowers who are exposed to some financial risk or friction, they have yet to be fully adapted to the New-Keynesian framework. While these studies do a great job of ascertaining causes and consequences of the recent U.S. credit cycle, there is limited research on applying these new macroeconomic frameworks on financial intermediation in U.S. business cycle analysis over the Great Moderation and Great Recession periods (Ireland, 2011, p.52). To be sure, it is clear that significant changes in the financial intermediary sector have occurred over the last three decades. On the other hand, to observe any commonalities (or clear dislocations) in the causes and consequences of the recurring phenomenon of credit spread variability, we investigate whether the *transmission mechanism* of shocks through financial intermediation has changed significantly, if at all, over the previous three U.S. business cycles. By answering this question we gain insight into the key financial factors that propagate and amplify financial stress to the real economy.

To give credence to our key points made, and before we can introduce the framework for the credit spread transmission mechanism of financial intermediation (in Section 2), we relate our discussion thus far to the effectiveness of conventional monetary policy in U.S recessions. (see also, Woodford, 2010, p. 36)

Firstly, the influence of monetary policy over short-term interest rates in financial intermediation is crucial to understanding the credit spread transmission mechanism; and the effectiveness of monetary policy is revealed through its influence over important financial market prices, such as long-term nonfinancial loan rates and the equity market (Adrian and Shin, 2011, p. 604). However, as mentioned, the Great Recession and the two preceding Great Moderation recessions exhibited significant financial stress in both equity and credit markets. We therefore observe that the degree of credit spread variability in recessions is at odds with a predictable influence of monetary policy over financial intermediation, and hence, investment decisions, consumption demand and production activities. In fact, the recent crisis gives a clear example of how uncertainty in financial intermediation dislocates the equilibrium interplay between the policy rate and aggregate demand: from mid-2007 to the end of 2008 credit spreads in nonfinancial markets increased sharply to which, counterintuitive to the perceived expansionary policy stance during this period, widening spreads indicated tighter financial conditions.[2] How do we explain the dislocation of the conventional transmission mechanism? On the one hand, conventional monetary policy facilitates expanding bank balance sheets (or

[2]For certain, the level of the policy rate, by itself, is not an adequate indication of the stance of monetary policy, but the consensus at the time was that the Fed's policy was expansionary.

recapitalization) by sharply lowering the policy rate (as in 1991, 2001, and 2008) and reducing financial market volatility through liquidity injections.[3] Whereby, the increase supply of money and lower costs to bank funding should stimulate aggregate spending and credit growth. On the other hand, financial intermediaries have more influence over nonfinancial market credit spreads, and larger credit spreads are conducive to expanding balance sheets (Adrian and Shin, 2011). For example, a negative shock to interbank funding will cause credit spreads to widen, attenuating the pass-through of downward policy rate adjustments and exacerbating underlying weaknesses in financial markets through bearish equity markets and poor credit supply—ultimately propagating the shock to the real economy. Conversely, rapidly expanding interbank funding leading up to the August 2007 crisis, occurred contemporaneously with historically *narrow* interbank spreads and steady *upward* policy rate adjustments (see also, Woodford, 2010, p. 25 and 37).[4]

Secondly, the deep 2007−09 recession and sluggish growth since suggests that ignoring the causes and consequences of persistently wide credit spreads has prolonged repercussions for real economic activity.[5] By forcing down the policy rate in 2008 the monetary authorities enabled banks to strengthen their balance sheets through sharp increases in profitability (see also, Gertler and Kiyotaki, 2011, p. 605). Banks were also recapitalized by monetary authority funds at little or no cost. Indeed, interest on reserves held at Federal Reserve Banks implies that the policy of the Fed was to strictly enable recapitalization of financial intermediaries to stabilize financial markets during the crisis (e.g. Keister and McAndrews, 2009). Although a necessary condition, financial stability is not sufficient for alleviating weak aggregate demand and production: even if potential systemic insolvency of banks is relieved, the poor economic outlook in the wider economy will still mean that credit spreads on household and firm loans incorporate high risk premiums as banks shore up capital buffers against further potential negative shocks to their balance sheets Gilchrist and Zakrajek (see also, 2012, p.1718). It is therefore clear that under stressed financial market conditions credit spread variability has significant consequences for the effectiveness of monetary policy and the efficient allocation of resources.

The contribution of our paper is twofold. Firstly, it synthesizes recent milestones in the New-Keynesian DSGE literature on financial intermediation (for example, Curdia and Woodford, 2009; Gerali et al., 2010) and the fundamental factors of the Great Recession in the U.S. (for example, Ireland, 2011). That said, we present a centralized framework for financial intermediaries' interest rate setting behavior in the transmission of nominal, real and financial shocks through credit spread variability. Secondly, based on this transmission mechanism, we can use the established relationship between credit spread variability and financial stress to compare the U.S. recession periods in the Great Moderation to the recent Great Recession. Therefore, we provide insights on the financial factors behind credit spread variability and whether their behavior has fundamentally changed over the Great Moderation and Great Recession periods. The main findings of our paper show a clear role for the influence of bank market power on both credit spread variability and the U.S.

[3]The policy rate was cut by 292 basis points in 1991, 434 basis points in 2001 and 399 basis points in 2008.

[4]Asset-backed securities issuers, money market mutual funds and other market-based financial institutions contributed excessively more to U.S. total net lending in the period, namely: commercial paper, fed funds, repos and money market mutual fund shares. Data can be found at the Federal Reserve Bank of St. Louis' FRED database. See Bech et al. (2011) for a empirical analysis on the dislocation of the repo and fed funds markets over the financial crisis period.

[5]The observed widening of spreads comes from commonly used interest rate data, for example: the 10 year−3 month Treasury spread, the Baa−Fed funds spread and the Mortgage−Fed funds spread. See Woodford (2010) and Gertler and Kiyotaki (2011, p.576) for similar examples.

business cycle. While the transmission mechanism of shocks in each of the three previous U.S. recessions has not changed significantly, we find evidence of a steady shift towards the influence of financial factors over credit spread variability. Firstly, the role of technology and monetary policy shocks has declined steadily since the mid−1980's. Secondly, relative to credit demand and bank funding, the role of financial intermediaries in credit supply has become the predominant force behind recent credit spread variability. Furthermore, in the recent U.S. business cycle, the influence of bank balance sheet adjustments have become an important factor in dislocating the interaction between short-term interest rates and real economic activity.

The rest of the paper is organized as follows. Section 2 introduces the credit spread transmission mechanism of financial intermediation. Section 3 develops the New-Keynesian DSGE model with financial market interactions, and Section 4 presents the Bayesian estimation results. Sections 5 discusses the causes and consequences of credit spread variability and its impact on the U.S. business cycle. Section 6 compares the influences of financial factors on credit spread variability over the Great Moderation and Great Recession periods. Section 7 concludes.

2 The credit spread transmission mechanism of financial intermediation

The purpose of this section is to define the credit spread transmission mechanism of financial intermediation in a way that can be readily incorporated into a DSGE model with credit and banking. More importantly, however, we provide a coherent framework that is consistent with the observed realities discussed and the literature theory of financial intermediation Woodford (see, for example, 2010).

To begin with, we distinguish interest rate spreads into term spread and credit spread portions. On the one hand, we simply assume that the term spread is determined by the expected future path of the target short-term policy rate. On the other hand, the credit spread includes the *whole* portion of variability over-and-above the direct influence of short-term policy rate changes. Specifically, financial intermediaries primarily exert market power over their net interest margins between their assets and liabilities, to the extent that they impute a measure of risk or desired profitability on interest rates charged (see also, Adrian and Shin, 2011).[6] By borrowing on short-term rates and lending on long-term rates banks carry balance sheet risk, but also large profit-making margins. We interpret balance sheet adjustments as the primary source of credit spread variability in the interbank market, and market power as the mechanism by which long-term nonfinancial loan rates adjust disjointedly to short-term interest rates (see also, Gerali et al., 2010).

We define two types of banking operations by their target credit market participants. Investment banks operate in the interbank market by lending short-term interbank loans to commercial banks.[7] Commercial

[6]Indeed, our definition of the credit spread is analogous to the definition of the term spread as discussed in Adrian and Shin (2011, p.602). In our model setup, the term premium becomes implicit in the markup on nonfinancial loan rate setting. As the term spread is, in reality, market determined, this assumption does not infringe or overestimate the market power of banks over interest rate setting, but rather acts as an implicit lower bound. Which, to a large extent, is accounted for by the common trend between short- and long-term rates, including their respective means over the sample period. Gilchrist and Zakrajek (2012) also find that it is the *pricing* of default risk that has the most predictive power of their credit spread over the period 1985−2010 (i.e. supply-side factors of financial intermediation determine credit spread variability and not the risk of default on the demand-side).

[7]For example, excess reserves at Federal Reserve Banks and financial commercial paper.

banks supply long-term loans to finance household consumption and firm production activities. Investment banks finance their interbank lending through household liquidity supply and bank capital accumulation. Bank capital is comprised of equity capital and retained earnings. We introduce a bank capital-asset requirement and value-at-risk constraint in the interbank market which, in response to the policy rate, affects the adjustment of the average interbank rate. Leverage, therefore, occurs on the balance sheets of banks which directly affects credit supply conditions for households and firms (nonfinancial borrowers). Frictions also arise through the monopolistically competitive power of commercial banks. As in Gerali et al. (2010), interest-rate stickiness and stochastic markups capture the profit maximizing behavior of banks in loan rate setting. Commercial banks therefore endogenize bank capital-asset adjustments, and the value-at-risk constraint imposes a measure of risk on the implicit credit spread between the asset holdings of each type of bank. Comparable to the theoretical setup in Woodford (2010), the quantity of interbank funds equates with the available credit supply to households and firms. To close the market equilibrium conditions, the demand side of credit is bound by household creditworthiness and firm net worth (Iacoviello, 2005). Our focus here will be to investigate how these features impact the variability of credit spreads in both the interbank market and usual credit market.

There are two counteracting forces to take note of in banking operations. Firstly, for bank balance sheets, a widening credit spread raises the profitability of each additional loan. It is therefore the instrument by which capital-asset ratios are strengthened if there is a negative shock to bank capital. Similarly, when improved creditworthiness (or net worth) increases the feasible loan amount for nonfinancial borrowers, banks can stabilize their capital-asset ratios by raising loan rates relative to the policy rate, to increase bank capital through retained earnings. This simultaneously raises the cost of loan financing, which attenuates the amount of loans borrowers receive and therefore raises the capital-asset ratio. At the same time, however, a wider credit spread increases the profitability of raising the pool of interbank funds (see also, Adrian and Shin, 2011, p.602). Banks expand their balance sheets and therefore the supply of credit to households and firms increases, which leads to real growth. In this light, the boom phase of a credit cycle is dominated by the incentive to expand bank balance sheets, while the bust phase would be dominated by larger capital-asset ratios and tightening credit markets stemming from widening credit spreads.

Indeed, total bank assets and bank capital-asset ratios are the key balance sheet variables for macroeconomic analysis in modern financial markets and the real economy (Adrian and Shin, 2011). And although the dynamics of these variables form an intricate part of our model, it is credit spread variability that we observe as being the key arbiter in modern financial markets and the real economy (see also, Curdia and Woodford, 2010; Woodford, 2010).

3 Model Economy

Heterogeneity in the nonfinancial sector implies an intricate role for financial intermediation in the efficient allocation of resources. Households supply liquidity (bank funding) through short-term safe assets and portfolio (bank and entrepreneur) equity investment. Households and entrepreneurs also represent ultimate borrowers.[8] Entrepreneurs manage firm production activities, demand homogenous labor to produce wholesale goods and finance physical capital with investment. Investment in physical capital is constrained by the flow of bank loans and revenues. Monopolistically competitive branders in the retail goods sector introduce Calvo-type sticky prices, whereas unions aggregate labor supply and introduce the Calvo-type sticky wages in the model.

The banking sector developed in Gerali et al. (2010) provides the core framework for credit supply frictions in financial intermediation: a monopolistically competitive banking sector with sticky retail loan rate adjustments and quadratic capital-asset adjustment costs for the interbank rate. We stylize this core framework to suit our credit spread transmission mechanism for the U.S. economy. In addition, based on the common occurrence of equity price collapses in U.S. recessions, we incorporate a role for the equity market in bank capital accumulation; and as mentioned, we introduce a value-at-risk (VaR) constraint on interbank loans which constrains bank market power in loan rate setting. Variability in credit spreads will therefore dislocate the predictable influence of the conventional Taylor-type monetary policy rule, and potentially cause an inefficient allocation of resources between consumption and production activities.[9]

Central to our paper, is the distinction between endogenous and exogenous sources of credit spread variability. The endogenous sources of credit spread variability (quadratic adjustment costs to loan rate setting and capital-asset ratios) function as credit supply frictions, and therefore encapsulates the credit spread transmission mechanism by which exogenous shocks are propagated. On the other hand, ten exogenous shocks act as initial sources of credit spread variability: eight of which are financial shocks to credit (supply and demand) factors, bank funding, the equity market, and the policy rate. The remaining two shocks are the nominal (price) and real (technology) shocks to domestic goods.

3.1 Financial intermediation

There is a continuum of bank units, where each bank unit $j \in [0,1]$ consists of a perfectly competitive investment bank and a monopolistically competitive commercial bank. Commercial banks supply loans to nonfinancial (ultimate) borrowers in the retail market, and receive funding from investment banks in the interbank market. Investment banks finance their lending activities with household assets and bank capital, which constrains the supply of interbank funds. Given that the bank balance sheet identity is always binding, aggregate investment bank assets always equates with the aggregate supply of bank funding to commercial banks.[10] Therefore, because investment bank assets are subject to bank capital-asset requirements, for a given quantity of bank capital, the supply schedule for interbank funds will be upward sloping (see also, Woodford, 2010, p.31-32). Whereas, the downward sloping demand schedule for interbank funding depends

[8] Aggregating saver and borrower households does not detract from the equilibrium dynamics of a similar alternative model specified with a two-type representative household setup.

[9] That is to say, we are under the assumption that the monetary policy rule is the optimal path for short-term interest rates. Curdia and Woodford (2010) find it reasonably effective for monetary policy to react to credit spreads, however, the degree of adjustment is heavily dependent on the source of endogenous influences over credit spread variability. Also, a number of complexities arise when attempting to translate their stylized model into more complex (or differentiated) endogenous sources. Therefore, our assumption is reasonable in the context of our study.

[10] We therefore assume that the commercial bank is a wholly-owned subsidiary of the investment bank, and the consolidated profits are used as retained earnings at the end of each period (see also, Gerali et al., 2010). To be sure, no distinction between banks is required in principal. Yet, analogous to differentiating household types, differentiating banks into commercial and investment units makes analysis conceptually easier for the model economy.

on the quantity of available interbank funds at any given credit spread between savers and ultimate borrowers. The intersection of these supply and demand schedules determines the equilibrium quantity of interbank funds and the prevailing credit spread. Therefore, shocks to investment bank funding directly affects the capacity of the financial sector to supply liquidity to nonfinancial borrowers. Financial intermediation in both the interbank and retail bank markets, therefore, have direct consequences for the efficient allocation of resources in real economic activity. (see Woodford, 2010, p.29-35)

3.1.1 Investment Bank

The investment bank chooses household safe-assets (B_t) and the amount of commercial bank liabilities (L_t^c) to issue to maximize periodic discounted cash-flows:

$$\max E_0 \sum_{t=0}^{\infty} \beta_B^t \left[i_t^c L_t^c - i_t B_t - \frac{\kappa_k}{2} \left(\frac{K_t^B}{L_t^c} - \tau_t \right)^2 K_t^B \right] \tag{1}$$

subject to the binding balance sheet identity

$$L_t^c = K_t^B + B_t, \tag{2}$$

where (K_t^B) is the total bank capital. The coefficient κ_k captures the quadratic adjustment cost of the deviation of the current capital-assets ratio (K_t^B/L_t^c) from a target minimum capital requirement ratio (τ_t), according to the Basel regulations. This banking sector setup allows for interbank spread variability emanating from capital-asset ratio adjustments.

The bank capital accumulation equation is as follows:

$$K_t^B = (1 - \delta_B) K_{t-1}^B + \Delta Q_t^{\psi} \Psi^B + \omega_{B,t-1}, \tag{3}$$

where, analogous to entrepreneurs, the initial stock of bank equity (Ψ^B) remains unchanged. What matters here is the market capitalization of bank equity ($Q_t^{\psi} \Psi^B$). As the market value of bank equity increases, bank capital accumulates and, in turn, the feasible supply of credit increases (i.e. a rightward shift of the credit supply schedule). δ_B is the bank capital depreciation rate, capturing management costs for banks. Retained earnings ($\omega_{B,t-1}$) are bank profits net of dividend payments.[11]

We assume no frictions between short-term safe-asset classes, and that investment banks have access to unlimited funds from the central bank at the policy rate i_t. Therefore, arbitrage implies that investment banks remunerate household safe-assets at i_t. Conversely, for the supply of interbank funds, the commercial bank remunerates investment bank assets at i_t^c. Combining the first order conditions for (B_t) and (L_t^c) gives the interbank spread between the interbank loan rate and the policy rate,

$$i_t^c = i_t - \kappa_k \left(\frac{K_t^B}{L_t} - \tau_t \right) \left(\frac{K_t^B}{L_t} \right)^2. \tag{4}$$

[11] $\omega_{B,t} = \Pi_{B,t} - \zeta_{\psi} Q_t^{\psi} \Psi^B$. The consolidated profits ($\Pi_{B,t}$) are used as retained earnings at the end of each period, and ζ_{ψ} represents the exogenous dividend policy.

3.1.2 Commercial Bank

Intermediate funds ($L^c_{j,t}$) collected by the commercial bank j are differentiated at zero cost and resold to households and entrepreneurs at their individual markups. Quadratic adjustment costs on household (h) and entrepreneur (e) loans, parameterized by κ_h and κ_e, capture the pass-through effect of interest rates on bank profits. All commercial banks $j \in [0,1]$ apply a symmetrical objective function for all loan types indexed $z = e, h$, described as the following:

$$\max_{\{i^z_{j,t}\}} E_0 \sum_{t=0}^{\infty} \beta^t_B \left[i^z_{j,t} L^z_{j,t} - i^c_t L^c_{j,t} - \frac{\kappa_z}{2} \left(\frac{i^z_{j,t}}{i^z_{j,t-1}} - 1 \right)^2 i^z_t L^z_t \right]$$

subject to loan demand schedules (indexed $z = e, h$) from households and entrepreneurs

$$L^z_{j,t} = \left(\frac{i^z_{j,t}}{i^z_t} \right)^{-\varepsilon^z_t} L^z_t. \tag{5}$$

We assume that the interbank market determines the feasible quantity of loans in the retail sector, therefore, $L^c_{j,t} = L_{j,t} = L^h_{j,t} + L^e_{j,t}$ (see also, Gerali et al., 2010; Woodford, 2010). Risk on the quality of commercial bank assets enters through a value-at-risk constraint: $(1 + i^c_t)L^c_{j,t} \leq \nu_B(1 + i^z_{j,t})L^z_{j,t}$. Where ν_B is the interbank loan-to-value ratio.[12]

In the symmetric equilibrium the first order conditions give the rates charged to households and entrepreneurs. Under flexible interest rates and no value-at-risk constraint, rates on loans are a markup over marginal cost:

$$i^z_t = \frac{\varepsilon^z_t}{\varepsilon^z_t - 1} i^c_t. \tag{6}$$

Following the rationale of Gerali et al. (2010), the log-linearized equation for loan rate setting charged to entrepreneurs and households (indexed by $z = e, h$) is,

$$\begin{aligned} \hat{i}^z_t = & \frac{\kappa_z}{(1-\nu_B)(\varepsilon^z - 1) + (1+\beta_B)\kappa_z} \hat{i}^z_{t-1} + \frac{\beta_B \kappa_z}{(1-\nu_B)(\varepsilon^z - 1) + (1+\beta_B)\kappa_z} E_t \hat{i}^z_{t+1} \\ & + \frac{2(\varepsilon^z - 1)}{(1-\nu_B)(\varepsilon^z - 1) + (1+\beta_B)\kappa_z} \hat{i}^c_t + \frac{(1-\nu_B)(\varepsilon^z - 1)}{(1-\nu_B)(\varepsilon^z - 1) + (1+\beta_B)\kappa_z} \mu_{z,t}, \end{aligned} \tag{7}$$

where $\mu_{z,t} = \varepsilon^z_t / (\varepsilon^z_{t-1})$ is the stochastic markup. Eq. 7 shows that entrepreneur and household loan rate setting depends on: the stochastic markup, past and expected future loan rates, and the marginal cost of the loan branch ($\hat{i}^c_t$) which depends on the policy rate and the balance sheet position of the bank. As ν_B tends to one, stochastic markup volatility has a smaller influence over retail loan rate setting. Here, we define the retail credit spreads on households and entrepreneurs as the retail rate i^z_t markup over i^c_t. Therefore, for each loan type z, the sum of the interbank spread and retail credit spread gives the net credit spread between i^z_t and i_t (equivalently, the profitability of the marginal loan z for financial intermediation).

[12] See Woodford (2010, p.32) and Adrian and Shin (2011, p.608-9). Our technical appendix discusses the setup in more detail.

3.2 Households

We adopt the conventional consumption-based asset pricing framework for equity. The demand driven equity price is market determined by contemporaneous wealth effects on households' intertemporal consumption choices, capital gains (or losses) and dividend returns. Moreover, equity is redeemable as collateral for bank loans; but a constant aggregate stock of equity shares in the economy prevents households from accumulating equity shares to leverage.

The representative household derives utility from consumption and leisure choices, and liquid financial wealth services in the form of safe assets (see also, Iacoviello, 2005; Christiano et al., 2010). The household maximizes their expected lifetime utility function given by

$$E_0 \sum_{t=0}^{\infty} \beta_h^t \left[\frac{(\tilde{C}_t)^{1-\gamma}}{1-\gamma} - \frac{(H_t)^{1+\eta}}{1+\eta} + \xi_{b,t} ln \frac{B_t}{P_t} \right] \tag{8}$$

where β_h^t is the discount factor. Consumption ($\tilde{C}_t = C_t - \phi C_{t-1}$) includes habit formation parameterized by ϕ. Household preferences are subject to a demand shock ($\xi_{b,t}$) on real safe-asset balances (B_t/P_t). The disutility of labor is given by H_t and η measures the Frisch elasticity of labor supply. γ is the the coefficient of relative risk aversion.

Each household's choices satisfy the following budget constraint

$$C_t + \frac{B_t}{P_t} + \xi_{\psi,t} \frac{Q_t^{\psi}}{P_t} \Psi_t + \frac{I_{t-1}^h L_{t-1}^h}{P_t} = \frac{W_t}{P_t} H_t + \frac{I_{t-1} B_{t-1}}{P_t} + \frac{L_t^h}{P_t} + \frac{Q_t^{\psi}}{P_t} \Psi_{t-1} + \Pi_{\psi,t}. \tag{9}$$

The household allocates periodic income from aggregate union-set wages (W_t), gross return on assets ($I_{t-1}B_{t-1}$), capital gains/losses ($Q_t^{\psi}\Psi_{t-1}$), real dividends ($\Pi_{\psi,t}$) and new loans (L_t^h) to current consumption, new financial wealth holdings and the repayment of previous loans ($I_{t-1}^h L_{t-1}^h$). $\xi_{\psi,t}$ is an exogenous shock to the current market value of equity holdings. The dividend policy is exogenously determined, and defined as proportional to each household's equity holdings $\zeta_{\psi} Q_t^{\psi} \Psi_{t-1}$. In addition to the budget constraint, households also face a borrowing constraint

$$I_t^h L_t^h \leq \nu_{h,t} \left[\phi_w W_t H_t + (1-\phi_w) Q_t^{\psi} \Psi_t \right]. \tag{10}$$

The household's wage income together with her investment in the equity market serve as collateral, where $0 \leq \phi_w \leq 1$ is the weight on wage income. $\nu_{h,t}$ is the loan-to-value ratio and, correspondingly, $1 - \nu_{h,t}$ can be interpreted as the proportional transaction cost for banks of repossessing collateral assets in cases of defaults. Following the literature (eg. Iacoviello, 2005), we assume the size of shocks is small enough so that the borrowing constraint is always binding.

The household first order conditions for labor, household loans, assets, and equity are the following:

$$\frac{W_t}{P_t} = \frac{(\tilde{C}_t)^{\gamma} (H_t)^{\eta}}{1 + \lambda_t (\tilde{C}_t)^{\gamma} \nu_{h,t} \phi_w} \tag{11}$$

$$(\tilde{C}_t)^{-\gamma} = \beta_h E_t \left[(\tilde{C}_{t+1})^{-\gamma} \frac{I_t^h}{\Pi_{t+1}} \right] + \lambda_t I_t^h \tag{12}$$

$$a\xi_{b,t} \left(\frac{B_t}{P_t} \right)^{-1} = (\tilde{C}_t)^{-\gamma} - \beta_h E_t \left[(\tilde{C}_{t+1})^{-\gamma} R_t \right] \tag{13}$$

$$1 = \beta_h E_t \left[\left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t} \right)^{-\gamma} \frac{Q_{t+1}^{\psi}(1+\zeta_\psi)}{\xi_{\psi,t} Q_t^{\psi} \Pi_{t+1}} \right] - \lambda_t \tilde{C}_t^{\gamma} \nu_{h,t}(1-\phi_w) \tag{14}$$

where the Lagrangian multiplier (λ_t) is the marginal utility of an additional unit of loans. Eq. 11 is the households' labor supply schedule, and Eq. 12 is the consumption Euler equation. Eq. 13 indicates that the demand for assets depends on households' consumption and the real return on safe-assets (R_t), where $R_t < R_t^h \ \forall \ t$. Eq. 14 gives the consumption-based asset pricing equation for equity investment. Specifically, the resulting equilibrium market price for equity incorporates demand-side wealth effects on consumption. Given the assumption of a constant total stock of equity shares in the whole economy, the aggregate demand for equity shares across a continuum of households implies that $\Psi_t \equiv \Psi$.

3.3 Retailers

The retail sector is characterized by monopolistically competitive branders and introduces Calvo-type sticky prices into the model (Bernanke et al., 1999; Iacoviello, 2005). Retailers purchase intermediate goods $Y_{j,t}$ from entrepreneurs at the wholesale price $P_{j,t}^W$ in a competitive market, and differentiate them at no cost into $Y_{k,t}$. Each retailer sells with a mark-up over $P_{j,t}^W$ at price $P_{k,t}$, taking into account their individual demand curves from consumers. Following Calvo (1983), we assume that the retailer can only adjust the retail price with probability $(1-\theta_R)$ in each period. Therefore, the decision problem for the retailer is

$$\max_{\{P_{k,t}^*\}} E_t \sum_{z=0}^{\infty} \theta_R^z \Lambda_{t,z} \left[P_{k,t}^* Y_{k,t+z} - P_{j,t+z}^W X Y_{k,t+z} \right] \tag{15}$$

subject to the consumer demand schedule for goods,

$$Y_{k,t+z} = (\frac{P_{k,t}^*}{P_{t+z}})^{-\varepsilon_t^p} Y_{t+z} \tag{16}$$

where $\Lambda_{t,z}$ is the consumption-based relevant discount factor, and $P_{k,t}^*$ denotes the optimal sales price set by the retailers, who are able to adjust the price in period t. $X_t \equiv P_t / P_t^W$ is the aggregate markup of the retail price over the wholesale price. In steady state, $X = \varepsilon^p/(\varepsilon^p - 1)$, where ε^p is the steady state price-elasticity of demand for intermediate good $Y_{j,t}$.

The aggregate price level is determined by

$$(P_t)^{1-\varepsilon_t^p} = \theta_R (\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} P_{t-1})^{1-\varepsilon_t^p} + (1-\theta_R)(P_t^*)^{1-\varepsilon_t^p} \tag{17}$$

where γ_p determines the degree of price indexation for non-optimizing retailers. Solving and linearizing the optimization problem and combining it with Eq. 17 gives the forward-looking Phillips curve, where current inflation is positively related to expected inflation and negatively related to the mark-up.

3.4 Entrepreneurs

Our representative entrepreneur manages firm production to produce the intermediate good Y_t using a standard Cobb-Douglas production function

$$Y_t = \xi_{z,t} K_{t-1}^{\alpha} H_t^{1-\alpha} \tag{18}$$

where $0 < \alpha < 1$. K_{t-1} is physical capital, H_t is the labor supply, and $\xi_{z,t}$ is an exogenous technology shock for total factor productivity. In addition, the representative entrepreneur also faces the following borrowing constraint

$$I_t^e L_t^e \leq \nu_{e,t}[\phi_k Q_t^k K_{t-1} + (1-\phi_k) Q_t^{\psi} \Psi^e] \tag{19}$$

where $\phi_k \in (0,1)$ is the weight on physical capital stock. Q_t^k is the nominal price of physical capital, $\nu_{e,t}$ is the exogenous stochastic loan-to-value ratio, and I_t^e is the gross nominal interest rate on entrepreneur bank loans (L_t^e). The value of physical capital ($Q_t^k K_{t-1}$) serves as collateral, while the market value of the initial stock of entrepreneur equity ($Q_t^{\psi} \Psi^e$) serves as a market-based signal for net worth. The equity market is introduced into the production sector in such a way that it has an impact on the entrepreneur's creditworthiness and, in turn, affects the productivity of the economy.[13]

Following Iacoviello (2005), we assume that in each period the representative entrepreneur chooses the desired amount of physical capital, labor and bank loans to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_e^t \left[\frac{(\tilde{C}_t^e)^{1-\gamma^e}}{1-\gamma^e} \right] \tag{20}$$

subject to the production technology (Eq. 18), borrowing constraint (Eq. 19) and the following flow of funds constraint

$$\frac{Y_t}{X_t} + \frac{L_t^e}{P_t} = C_t^e + \frac{I_{t-1}^e L_{t-1}^e}{P_t} + \frac{W_t}{P_t} H_t + V_t + Adj_t^e + \Pi_{\psi,t}^e. \tag{21}$$

Adj_t^e captures capital adjustment costs:

$$Adj_t^e = \kappa_v \left(\frac{V_t}{K_{t-1}} - \delta_e\right)^2 \frac{K_{t-1}}{(2\delta_e)} \tag{22}$$

where V_t is the investment used to accumulate capital, $K_t = (1-\delta_e)K_{t-1} + V_t$, and κ_v is the variable capital adjustment cost parameter. $\Pi_{\psi,t}^e = (\zeta_{\psi} Q_t^{\psi} \Psi^e)/P_t$ is the real dividend paid out. We assume entrepreneurs are more impatient than households ($\beta_e^t < \beta_h^t$) and have a greater preference for immediate gains, therefore, γ^e should be less than γ.[14]

[13]This is a "short-cut" to modeling supply-side credit market restrictions transmitted through bullish equity markets (i.e. lower bank funding) contemporaneously with shocks to demand-side net worth, which entrepreneurs will always fully accept.

[14]Log utility implies that Entrepreneurs are not risk neutral, but rather lie between the two extremes of risk averse and risk neutral. We add the risk aversion coefficient to estimate the degree of impatience, while the usual binding constraint conditions must hold ($1/I^e - \beta_e) > 0$).(see Iacoviello, 2005, p. 743, fn. 7)

The first order conditions for labor, bank loans, and physical capital are the following:

$$\frac{W_t}{P_t} = \frac{(1-\alpha)Y_t}{H_t X_t} \tag{23}$$

$$(\tilde{C}_t^e)^{-\gamma^e} = \beta_e E_t\left[(\tilde{C}_{t+1}^e)^{-\gamma}\frac{I_t^e}{\Pi_{t+1}}\right] + \lambda_t I_t^e \tag{24}$$

$$Q_t^k = \beta_e E_t\left[\frac{1}{(\tilde{C}_{t+1}^e)^{\gamma^e}}\left(\frac{\kappa_v}{\delta_e}\left(\frac{V_{t+1}}{K_t} - \delta_e\right)\frac{V_{t+1}}{K_t} - \frac{\kappa_v}{2\delta_e}\left(\frac{V_{t+1}}{K_t} - \delta_e\right)^2\right)\right.$$
$$\left. + Q_{t+1}^k(1-\delta_e) + \frac{\alpha Y_{t+1}}{(\tilde{C}_t^e)^{\gamma^e} X_{t+1} K_t}\right] + \lambda_t \nu_{e,t}\phi_k Q_t^k \tag{25}$$

where λ_t^e is the Lagrangian multiplier of the borrowing constraint. Eq. 25 is the investment schedule, where the shadow price of physical capital is defined as $Q_t^k = (\tilde{C}_t^e)^{-\gamma^e}(1 + \kappa_v/\delta_e(V_t/K_{t-1} - \delta_e))$. The investment schedule states that the shadow price of capital must equal the expected marginal product of capital plus the discounted expected shadow price and capital adjustment costs. Eq. 23 is the standard labor demand schedule. Eq. 24 gives the entrepreneur consumption Euler equation.

3.5 Labor supply decisions and the Wage-setting equation

The wage-setting equilibrium stems from the work of Gali et al. (2007). Monopolistically competitive unions set the optimal wage at the prevailing labor demand equilibrium. There is a continuum of unions, and each union represents workers of a certain type τ, which is uniformly distributed across all households.

The unions' problem is to choose $\{W_t^\tau\}_{t=0}^{\infty}$ to maximize the consumption-weighted wage income of their workers. However, following Calvo (1983), in each time period only a random fraction $1-\theta_w$ of unions have the opportunity to reset the optimal wage (W_t^*) for its workers, whereas those unions that cannot reset wages simply index to the lagged wage rate, as in Christiano et al. (2005) and Smets and Wouters (2007). Therefore, the wage index is given by

$$(W_t)^{1-\varepsilon^w} = \theta_w\left(\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_w} W_{t-1}\right)^{1-\varepsilon^w} + (1-\theta_w)(W_t^*)^{1-\varepsilon^w} \tag{26}$$

where γ_w is the degree of wage indexation, and the objective function for the optimal wage is the following:

$$\max_{\{W_t^*\}} E_t \sum_{i=0}^{\infty}(\theta_w\beta)^i\left[\left(\frac{W_t^* H_{t+i}^\tau}{P_{t+i}\tilde{C}_{t+i}} - \frac{(H_{t+i}^\tau)^{1+\eta}}{1+\eta}\right)\right]$$

subject to the the labor demand schedule

$$H_{t+i}^\tau = \left(\frac{W_t^*}{W_{t+i}}\right)^{-\varepsilon_t^w} H_{t+i}.$$

Assuming a constant wage elasticity of substitution ($\varepsilon_{t=0}^w$), the the first order condition for W_t^* is:

$$E_t \sum_{i=0}^{\infty}(\theta_w\beta)^i\left[\frac{W_t^*}{P_{t+i}}\left(\frac{1}{MRS_{t+i}}\right)\right] = E_t \sum_{i=0}^{\infty}(\theta_w\beta)^i\left[\mu^w\left(\frac{W_t^*}{W_{t+i}}\right)^{-\varepsilon^w\eta}\right]$$

where $MRS_{t+i} = \tilde{C}_{t+i} H^{\eta}_{t+i}$ is the marginal rate of substitution between consumption and leisure for households and $\mu^w = \varepsilon^w/(\varepsilon^w - 1)$ is the steady-state wage markup.

Log-linearizing and solving for w^*_t gives the optimal reset wage equation:

$$w^*_t = \frac{(1-\theta_w\beta)}{(\varepsilon^w\eta + 1)} E_t \sum_{i=0}^{\infty} (\theta_w\beta)^i \Big(\chi mrs_{t+i} + \varepsilon^w \eta w_{t+i} + p_{t+i} \Big), \tag{27}$$

where $\chi \equiv W/MRS\mu^w$.[15]

Combining Eq. 27 with the log-linearized aggregate wage index (26) gives the aggregate sticky wage equation:

$$\begin{aligned} \hat{w}_t &= \Phi\hat{w}_{t-1} + \Phi\beta E_t \hat{w}_{t+1} + \Phi^*(\varepsilon^w \eta \hat{w}_t + \chi mrs_t) \\ &\quad + \Phi\beta E_t \pi_{t+1} - \Phi\pi_t - \Phi\theta_w\beta\gamma_w\pi_t + \Phi\gamma_w\pi_{t-1}, \end{aligned} \tag{28}$$

where $\Phi^* = (1-\theta_w)(1-\theta_w\beta)/(1+\theta_w^2\beta)(1+\varepsilon^w\eta)$ and $\Phi = \theta_w/(1+\theta_w^2\beta)$.

3.6 Monetary policy and market clearing conditions

The monetary authority follows a Taylor-type interest rate rule

$$I_t = (I_{t-1})^{\kappa_i} \left(\frac{\Pi_t}{\Pi^{target}} \right)^{\kappa_\pi(1-\kappa_i)} \left(\frac{Y_t}{Y_{t-1}} \right)^{\kappa_y(1-\kappa_i)} \xi_{i,t} \tag{29}$$

where κ_i is the weight on the lagged policy rate, κ_π is the weight on inflation, and κ_y is the weight on output growth. $\xi_{i,t}$ is the monetary policy shock following an AR(1) stochastic process.

The aggregate resource constraint for the economy is

$$Y_t = C_t + C^e_t + V_t + \delta_B \frac{K^B_{t-1}}{P_{t-1}}, \tag{30}$$

where $\delta_B K^B_{t-1}$ represents the banks' management cost in terms of bank capital.

Similar to Iacoviello (2005), we close the model by including the entrepreneur flow of funds constraint

$$\frac{Y_t}{X_t} + \frac{L^e_t}{P_t} = C^e_t + \frac{I^e_{t-1} L^e_{t-1}}{P_t} + \frac{W_t}{P_t} H_t + V_t + Adj^e_t + \frac{\zeta_\psi Q^\psi_{t-1} \Psi^e}{P_t}. \tag{31}$$

4 Estimation

We estimate the model with Bayesian techniques using U.S. data over the sample period 1982Q02−2012Q03. The full sample covers the recession periods 1990Q03−1991Q02, 2001Q01−2001Q04 and 2007Q04−2009Q02; and we define the Great Moderation period from 1982Q02−2006Q04.[16] Since the model has a total of 10 shocks, our data set contains 10 observable variables: output, inflation (GDP deflator), equity price,

[15] $MRS = CH^\eta$ and $\tilde{c}_t = c_t - \phi c_{t-1}$.

[16] NBER U.S. recession data is available at http://www.nber.org/cycles/cyclesmain.html. For the initial structural break of the Great Moderation see, for example, Stock and Watson (2003, p.173). The model is estimated using Dynare developed by Michel Juillard and his collaborators at CEPREMAP.

household loans, entrepreneur loans, household assets, 3-month Treasury Bill rate, Fed funds rate, mortgage rate, and Baa corporate bond rate. All variables except inflation and interest rates are converted in real terms using the GDP deflator. Prior to estimation, we take the log-difference of real per capita variables.

For the estimation of the model, monetary authority funds in the repo market plus household deposits make up aggregate household safe-assets in the banking sector. Our motivation for this aggregation is twofold. For the model setup (Section 3.1.1), it satisfies the arbitrage assumption from unlimited access to monetary authority funds and zero frictions between short-term safe-asset classes. On the empirical side, the recent surge in monetary authority funds between 2008−2011, resulting from the large-scale recapitalization of the banking sector, largely offset the significant shortage of household deposits during that time. Therefore, it would be misleading to view household deposits as the sole measure of bank liabilities (or available bank funding) when trying to observe the transmission mechanism of financial intermediation. As a consequence of this assumption we use the 3-month Treasury Bill rate as the short-term safe-asset rate (i.e. the policy rate). For the interbank rate, we average the Fed funds rate with the 3-month AA financial commercial paper rate, to measure the additional financial stress exposure in the recent recession; which was not exhibited in the 2001 or 1990 recession periods. (For similar conclusions see, e.g., Woodford (2010) and Adrian and Shin (2011), Gertler and Kiyotaki (2011))[17]

4.1 Calibrated parameters and prior distributions

Table 1 lists the parameters that are calibrated prior to estimation. In the first block, discount factors $\{\beta_h, \beta_e, \beta_B\}$ fall in the interval $[0.95, 0.99]$, where $\beta_h = 0.97$ is the mean of saver and borrower household discount factors 0.99 and 0.95 (see, Iacoviello, 2005, p.751). We derive the entrepreneur and bank discount factors (β_e, β_B) from the reciprocal of their relevant steady-state markups over the steady-state quarterly safe-asset rate ($R = 1.01$). For example, using a steady-state quarterly gross real return to entrepreneur loans $R_e = 1.0383$, and satisfying the binding borrowing constraint condition $(1/R_e - \beta_e) > 0$, we set $\beta_e = 0.955$. This ensures a similar value for both the household and entrepreneur binding constraint conditions. The inverse of the Frisch elasticity (η) is set to 1. The capital-output share α is set to 0.33, and the physical capital depreciation rate δ_e is set to 0.025. A steady-state gross markup of $X = 1.10$ implies a price elasticity of demand for differentiated retail goods (ε^p) of 11. The price elasticity of demand for different types of labor ε^w is fixed at 5, implying a steady-state wage markup (μ^w) of 25%. Lastly, based on well-established estimates (eg. Smets and Wouters, 2003, 2007), we assume a high degree of wage indexation (0.8) and let the probability of resetting an optimal wage $(1 - \theta_w)$ approximate an average length of wage contracts of one year.

The second block reports the steady-state aggregate ratios and the relevant U.S. banking sector conditions. The elasticities of substitution for household loans (ε^h) and entrepreneur loans (ε^e) equal 1.441 and 1.353. The target capital requirement ratio τ equals 11%, reflecting the recent U.S. banks' balance sheet condition. The bank capital depreciation rate (δ_B) equals 0.1044.[18] Parameter ϕ_ψ is the ratio of the

[17] For example, the 10-year Treasury Bill−Baa corporate bond spread is an often watched financial markets indicator of retail borrowing conditions (Woodford, 2010).

[18] We assume that there are no undivided profits in the steady-state equilibrium, and therefore derive the value from the net

Table 1: Calibrated parameters

Parameter	Description	Value
β_h	Household discount factor	0.97
β_e	Entrepreneur discount factor	0.955
β_B	Bank discount factor	0.986
η	Inverse of the Frisch elasticity	1
α	Capital share in the production function	0.33
δ_e	Capital depreciation rate	0.025
ε^p	Price elasticity of demand for goods	11
ε^w	Price elasticity of demand for labor	5
θ_w	Wage stickiness	0.75
γ_w	Degree of wage indexation	0.8
τ	Capital requirement ratio	0.11
ε^h	Elasticity of substitution for household loans	1.441
ε^e	Elasticity of substitution for entrepreneur loans	1.353
δ_B	Sunk costs for bank capital management	0.1044
ϕ_ψ	Ratio of market capitalization of bank equity to bank capital	0.25
L^h/L	Households' share of total loans	0.46
L^e/L	Entrepreneurs' share of total loans	0.54
C/Y	Consumption-output ratio	0.679
K^B/Y	Total bank capital-output ratio	0.171
ϕ_w	Weight on wages in borr. constraint	0.8
ϕ_k	Weight on physical capital in borr. constraint	0.8

market capitalization of bank equity to bank capital, which captures the pass-through effect of equity price changes on bank capital accumulation. We set ϕ_ψ to 0.25, based on our preliminary estimations. Shares of household and entrepreneur loans to total bank loans, the consumption-output ratio, and the total bank capital-to-output ratio are calculated from the data means over the sample period. We restrict any other steady-state ratios in the banking sector to be consistent with the balance sheet definition and capital requirement. Finally, based on stable preliminary estimations, the weights on wages (ϕ_w) and physical capital (ϕ_k) in the borrowing constraints are set to 0.8. This implies that, for example, a negative 10% shock to equity prices will directly reduce household and entrepreneur creditworthiness by 2%.

4.2 Prior distributions and posterior estimates

The prior distribution of the structural parameters are reported in columns $3-5$ in Tables 2 and 3. We assume the household's coefficient of relative risk aversion γ follows an inverse-gamma distribution with a mean of 3 and a standard deviation of 0.5. Meanwhile, the entrepreneur's relative risk aversion is assumed to be much less than the household ($\gamma_e = 0.9$), which implies a preference for current period consumption gains. The prior on habit formation parameter ϕ is set at 0.65 with a standard deviation of 0.03, which is consistent with the literature (eg. Christiano et al., 2005). Parameters in the Phillips curve are based on the estimates from Smets and Wouters (2003) and Christiano et al. (2010). The parameters describing the monetary policy reaction function are chosen within the context of financial frictions literature, based on the estimates of Christiano et al. (2010). We choose a reasonable value of 0.6 as the prior mean for

income data of all U.S. commercial banks (FDIC, 2012).

Table 2: Structural parameters

	Parameter	Prior Distribution Type	Mean	Std.dev	Posterior Distribution Mean	2.5%	Median	97.5%
Preferences								
γ	Household RRA	Inv.Gamma	3	0.5	4.910	4.088	4.866	5.659
γ_e	Entrepreneur RRA	Inv.Gamma	0.9	0.1	1.087	0.888	1.073	1.279
ϕ	Habit formation	Beta	0.65	0.03	0.708	0.672	0.707	0.749
Prices								
θ_R	Price stickiness	Beta	0.8	0.03	0.923	0.914	0.924	0.932
γ_p	Degree of price indexation	Beta	0.5	0.03	0.511	0.464	0.510	0.554
Monetary policy rule								
κ_i	Coefficient on lagged policy rate	Beta	0.65	0.05	0.615	0.570	0.616	0.661
κ_π	Coefficient on inflation	Gamma	1.5	0.05	1.612	1.529	1.612	1.697
κ_y	Coefficient on output change	Beta	0.25	0.02	0.261	0.228	0.260	0.292
Credit and banking								
ν_h	Households' LTV ratio	Beta	0.6	0.03	0.580	0.531	0.580	0.630
ν_e	Entrepreneurs' LTV ratio	Beta	0.6	0.03	0.722	0.693	0.722	0.752
ν_B	Interbank LTV ratio	Beta	0.5	0.05	0.424	0.361	0.423	0.485
κ_h	HH loan rate adjust. cost	Gamma	5	2	15.22	11.87	15.07	18.51
κ_e	Entrep. loan rate adjust. cost	Gamma	5	2	6.890	5.720	6.890	8.072
κ_k	Leverage deviation cost	Gamma	5	2	1.255	1.038	1.254	1.443
Physical capital								
κ_v	Capital adjust. costs	Gamma	2	0.5	2.292	1.847	2.263	2.689
K^e/Y	Capital-output ratio	Gamma	10.7	0.2	10.78	10.46	10.78	11.11

both households' LTV (ν_h) and entrepreneurs' LTV (ν_e). We set the prior mean of the interbank LTV ratio (ν_B) to 0.5 with a standard deviation of 0.05. The interest rate adjustment cost parameters $\{\kappa_k, \kappa_h, \kappa_e\}$ are assumed to follow a gamma distribution with a mean of 5 and a standard deviation of 2 (see also, Gerali et al., 2010). Analogous to the entrepreneur investment schedule in Iacoviello (2005, p.752), we set the prior mean of the physical capital adjustment cost parameter κ_v to 2. The prior mean of the capital-output ratio is set to 10.7 based on its steady-state value. Lastly, the prior distributions for the AR(1) coefficients and the standard deviations of the shocks are reported in columns 3-5 in Table 3.

The estimated posterior statistics for the structural parameters are reported in columns 6-9 in Tables 2 and 3. Parameters for preferences, prices, and the monetary policy rule all conform well within the literature consensus. Shocks for monetary policy, loan rate markups to households and entrepreneurs, and the price markup are not persistent, while the rest are strongly persistent. The LTV ratio for households (0.58) is lower than that of entrepreneurs (0.722), which suggests that entrepreneurs can more easily collateralize their loans (see also, Iacoviello, 2005, p. 752). In fact, high estimates for ν_h and ν_e implies that changes to household financial wealth and entrepreneur net worth have strong and persistent effects on aggregate demand. An estimated interbank LTV of 0.42 also highlights the importance of bank market power by giving a large weight to retail loan rate markups (see Eq. 7). Corresponding to the persistence of retail credit spread movements, large posterior means for the entrepreneur and household loan rate adjustment cost parameters ($\kappa_e = 6.89$ and $\kappa_h = 15.22$) implies a large degree of retail loan rate stickiness—a result further confirmed by the recent relatively sharper changes to the entrepreneur spread, that is, $\kappa_e < \kappa_h$ (see also, Gerali et al.,

Table 3: Exogenous processes

	Parameter	Prior Distribution Type	Mean	Std.dev	Posterior Distribution Mean	2.5%	Median	97.5%
AR coefficients								
ρ_z	Technology	beta	0.98	0.005	0.981	0.979	0.981	0.984
ρ_i	Monetary policy	beta	0.2	0.05	0.431	0.347	0.433	0.513
ρ_b	Household asset	beta	0.97	0.005	0.970	0.967	0.971	0.973
ρ_e	Entrep. loan markup	beta	0.3	0.05	0.422	0.352	0.423	0.493
ρ_h	Household loan markup	beta	0.2	0.05	0.269	0.180	0.268	0.347
ρ_{ν_h}	Households' LTV	beta	0.95	0.005	0.951	0.943	0.951	0.960
ρ_{ν_e}	Entrepreneurs' LTV	beta	0.55	0.05	0.618	0.561	0.620	0.680
ρ_ψ	Equity	beta	0.8	0.05	0.871	0.835	0.872	0.906
ρ_p	Price markup	beta	0.3	0.05	0.373	0.292	0.373	0.461
ρ_t	Capital-asset ratio	beta	0.85	0.05	0.782	0.722	0.782	0.843
Standard deviations								
ϵ_z	Technology	Inv.Gamma	0.02	inf	0.016	0.014	0.016	0.017
ϵ_i	Monetary policy	Inv.Gamma	0.01	inf	0.008	0.007	0.008	0.009
ϵ_b	Household asset	Inv.Gamma	0.01	inf	0.008	0.007	0.008	0.009
ϵ_e	Entrep. loan markup	Inv.Gamma	0.08	inf	0.114	0.086	0.114	0.144
ϵ_h	Household loan markup	Inv.Gamma	0.08	inf	0.210	0.153	0.206	0.273
ϵ_{ν_h}	Households' LTV	Inv.Gamma	0.03	inf	0.021	0.019	0.021	0.024
ϵ_{ν_e}	Entrepreneurs' LTV	Inv.Gamma	0.03	inf	0.029	0.023	0.028	0.034
ϵ_ψ	Equity	Inv.Gamma	0.01	inf	0.005	0.004	0.005	0.006
ϵ_p	Price markup	Inv.Gamma	0.002	inf	0.001	0.001	0.001	0.001
ϵ_t	Capital-asset ratio	Inv.Gamma	0.015	inf	0.012	0.010	0.012	0.014

2010, p.124). A value of 1.255 for the leverage deviation cost, on the other hand, is significantly smaller. However, this value is based on the closely mimicked relationship between the short-term policy rate and the short-term interbank rate. As shown in our results below, and contrary to Gerali et al. (2010) for the Euro area, we find a clear role for the sticky-rate structure in commercial banking for both business cycle dynamics and credit spread variability.

5 Model results

In this section, we assess our baseline New-Keynesian DSGE model (Base hereafter) using the observed variables discussed. Our focus here is to establish the validity of our Base model with the literature and to highlight the properties of financial factors in credit spread variability. In the first stage of our analysis, we examine the dynamics of the baseline model in response to monetary and technology shocks against three variant versions of the model. Thereafter, we compare the posterior distributions of the estimated parameters to gain more valuable insights from the model and perform robustness analysis.

Our three variant models serve to highlight three key issues. For the first variant model we assume flexible rate adjustments on retail loan rate setting, that is, there are no quadratic retail loan rate adjustment costs ($\kappa_h = \kappa_e = 0$). This flexible interest rate model (FI hereafter) highlights the role of bank market power through sticky retail rate adjustment; we therefore still observe the influence of balance sheet adjustments on the interbank rate and the stochastic markups of commercial banks. For the second variant version (TS hereafter) we use the 10-year Treasury Bill as the observed data for the interbank rate. Introducing the term spread between the 3-month and 10-year Treasury Bills gives a significantly larger weight to the influence of monetary policy over long-term interest rates. In doing so, we establish the feasibility of our credit spread transmission mechanism (as defined in Section 2). For the third variant version, in line with the conventional approach (e.g., Smets and Wouters, 2007; Christiano et al., 2010), we use the federal funds rate as the observed variable for the policy rate (FF hereafter) and, importantly, we use no observed variable for the interbank rate. The main objective here is to find out how the model, absent any observed data for the interbank rate, will compare to the dynamics and posterior estimates of the other versions.

5.1 Nominal and real shocks

Fig. 1 shows the impulse responses of the observed variables, credit spreads and bank capital-asset ratio to a positive technology shock.[19] For the Base model, the responses of inflation, output, policy rate, and equity price conform to the findings in Castelnuovo and Nistico (2010). Initially, up to the ninth quarter, we observe a counter-cyclical capital-asset ratio, after which a persistently positive equity market improves the capital position of banks. A bullish equity market, improved creditworthiness and wider profit margins for financial intermediation (i.e., net credit spreads) propagate the dynamics of the model through both the usual financial accelerator and bank funding channels (see also, Christiano et al., 2010, p.55-58).[20] Under a technology shock, the effect of the FI model on total loans and inflation is small. The most significant effect of flexible retail rate adjustment is observed through larger retail credit spreads. Indeed, relative to the other model versions, the increased profitability on loans offsets the decline in bank capital from lower equity prices. Both the FF and TS models follow the dynamics of the baseline model more closely. Yet again, the most significant differences in the impulse responses are observed in net credit spreads and equity prices. That said, credit spread variability corresponds to levels of financial stress which is inversely related to equity returns. Therefore, the larger the net credit spreads of each model version relative to the baseline model should correspond with lower equity prices. Both the FI and TS models confirm this relationship, whereas the more closely following net credit spreads for the FF model corresponds with a closer equity price response.

Fig. 2 shows the impulse responses to a contractionary monetary policy shock. In the baseline model, output falls, while the demand for safe-assets increases and credit extension declines (see also, Christiano et al., 2010, p.119). We importantly observe a counter-cyclical capital-asset ratio, and therefore, lower bank leverage from weak credit supply Meh and Moran (see also, 2010). A higher nominal policy rate is negligibly offset through inflation, and therefore closely reflects the rise in the real interest rate. Interest rates on household and entrepreneur loans increase sluggishly compared to the policy rate, initially pushing credit spreads below steady-state. Specifically, to curb future lower retained earnings from reduced total bank assets (total loans), banks impose persistence in the cost of credit to stabilize their capital-asset ratios (see also, Meh and Moran, 2010). And, indeed, banks initially increase retail loan rates less than the policy rate to minimize the reduction in credit supply. The results therefore indicate that imperfect bank competition

[19] For conciseness, we report total loans instead of household and entrepreneur loans individually.

[20] As the investment bank manages the capital position of the whole bank unit, combining the interbank spread with the retail credit spreads gives the profitability of each additional type of loan in financial intermediation (see Sec. 3.1.2). Therefore, net credit spreads in the baseline model are positive for approximately 15 quarters.

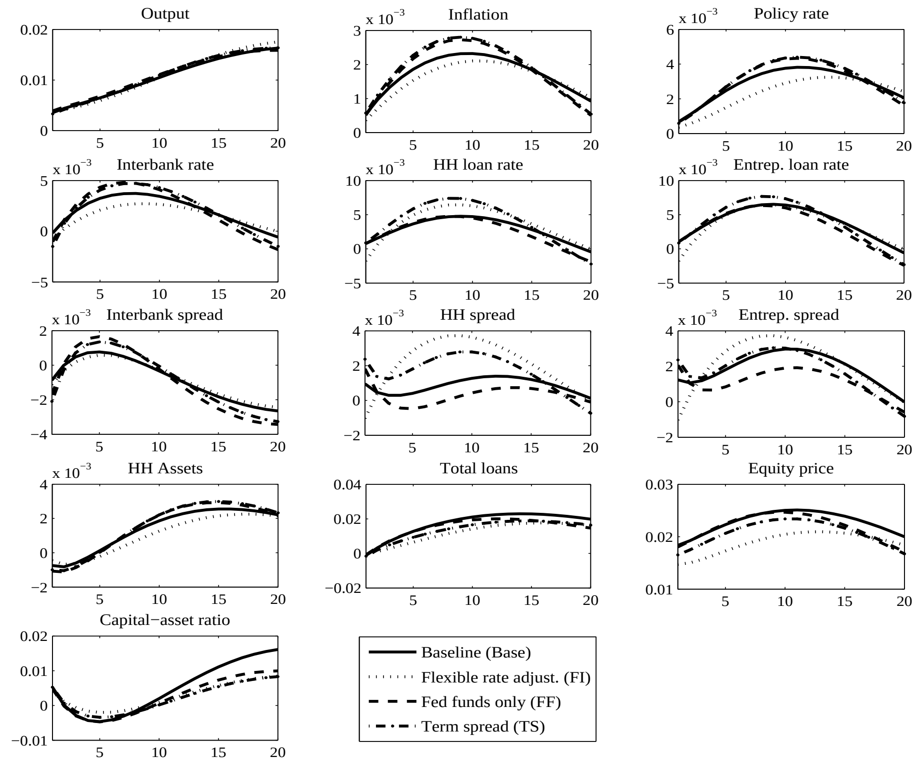

Figure 1: IRFs to a positive technology shock

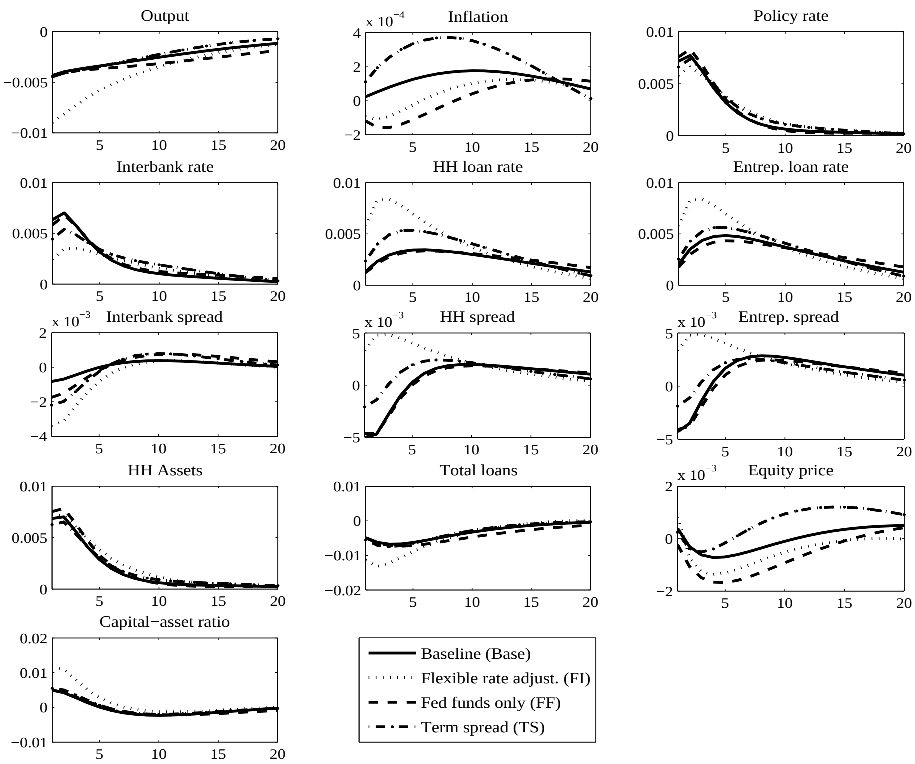

Figure 2: IRFs to a contractionary monetary policy shock

attenuates the effects of monetary policy through sticky rate adjustments and bank balance sheet adjustments (see also, Goodfriend and McCallum, 2007; Gerali et al., 2010). For example, the FI model clearly shows the importance of sticky rate adjustment in financial intermediation. Higher loan rates, compared to the Base model, significantly reduce total loans, which exacerbates the decline in output. Although there is a large decline in total bank assets, bank capital-asset ratios are strengthened through significantly larger retail credit spreads. Indeed, contrary to the lesser role of bank balance sheet adjustment in Gerali et al. (2010), larger capital-asset ratios coincide with amplified business cycle fluctuations (see de Walque et al., 2010). We therefore find an important role for sticky rate adjustments and bank balance sheet adjustments: whereby, during the onset of a recession, imperfect bank competition would stifle efforts of the monetary authorities to stimulate aggregate demand through the conventional interest rate channel.

The TS model and FF model follow a similar pattern as the Base model. The differences, once again, emerge more clearly through credit spread variability and the equity market.[21] In terms of the impact of monetary policy through raising interest rates to reduce credit demand (and therefore output), the difference between the TS model, FF model and Base model are small. Therefore, in favor of our Base model, introducing information on the term spread data provides no distinct advantage in the results. Furthermore, the Base model more closely mimics the implied results from the FF model with no observed variable for the interbank rate. The Base model, therefore, gives the most intuitive and robust results. Indeed, from Fig. 1 we come to the same conclusion and, in Sec. 5.2 below, the comparison of the estimated parameters between the alternative models reinforces this finding.

In summary, it is clear then from Fig. 2 that both supply- and demand-side financial accelerator effects propagate strongly through the business cycle, driving credit spread variability. However, analogous to what we observe in the technology shock (Fig. 1), credit supply-side frictions dominate financial intermediation and business cycle dynamics.

5.2 Alternative model estimated parameter comparisons

Table 4 compares the posterior estimates of the structural parameters for each alternative model. Overall, the parameter estimates are mostly consistent across models, indicating our results are robust. In contrast to the varying estimates for banking parameters $\{\nu_B, \kappa_k, \kappa_e, \kappa_h\}$, the consistency of estimates for household and entrepreneur preferences (γ, γ^e) and credit demand conditions (the LTV ratios ν_h and ν_e) reiterate the dominance of credit supply-side factors in determining credit spread variability.

Compared to the Base model, the FI model predictably gives more weight to stochastic markup volatility in retail loan rate setting (that is, ν_B declines from 0.424 to 0.158). But zero sticky retail rate adjustment is compensated for by a significant jump in the persistence of stochastic markup shocks (ρ_e, ρ_h), and a larger leverage deviation cost parameter (κ_k) creates additional imperfect rate adjustment.[22] That said, for the

[21] Compared to the other impulse responses, the varying distortions to inflation are actually small (and weakly identified—all the 90% confidence intervals, not shown here, are wide) and do not have a significant impact in the results: as price markup shocks induce insignificant variations to credit spreads (see Table 5). This is most likely the result of low and stable inflation in the Great Moderation period, when price markup shocks had minimal effects (see also, Smets and Wouters, 2007).

[22] A larger leverage deviation cost parameter (κ_k) magnifies the influence of capital-asset ratios on the interbank rate, and therefore, long-term retail rates.

Table 4: Alternative model estimated parameter comparisons

	Posterior distribution means					Posterior distribution means			
	Baseline (Base)	Flexible (FI)	Fed funds (FF)	Term spread (TS)		Baseline (Base)	Flexible (FI)	Fed funds (FF)	Term spread (TS)
Parameters					AR(1) processes				
γ	4.910	4.578	4.806	4.543	ρ_z	0.981	0.987	0.981	0.981
γ^e	1.087	0.878	1.117	0.872	ρ_i	0.431	0.337	0.433	0.409
ϕ	0.708	0.713	0.705	0.708	ρ_b	0.970	0.973	0.970	0.970
θ_R	0.923	0.924	0.907	0.908	ρ_e	0.422	0.868	0.449	0.549
γ_p	0.511	0.500	0.520	0.523	ρ_h	0.269	0.919	0.276	0.583
κ_i	0.615	0.765	0.642	0.669	ρ_{ν_h}	0.951	0.952	0.951	0.952
κ_π	1.612	1.580	1.598	1.591	ρ_{ν_e}	0.618	0.617	0.609	0.591
κ_y	0.261	0.272	0.264	0.262	ρ_ψ	0.871	0.896	0.881	0.877
ν_h	0.580	0.581	0.584	0.487	ρ_p	0.373	0.377	0.440	0.411
ν_e	0.722	0.701	0.690	0.682	ρ_t	0.782	0.861	-	0.847
ν_B	0.424	0.158	0.321	0.063	ϵ_z	0.016	0.016	0.015	0.015
κ_k	1.255	2.176	2.629	3.005	ϵ_i	0.008	0.006	0.008	0.007
κ_e	6.890	-	8.024	6.208	ϵ_b	0.008	0.008	0.008	0.008
κ_h	15.22	-	16.32	12.96	ϵ_e	0.114	0.016	0.105	0.027
κ_v	2.292	1.530	2.199	2.519	ϵ_h	0.210	0.014	0.197	0.026
K^e/Y	10.78	10.89	10.77	10.79	ϵ_{ν_h}	0.021	0.021	0.021	0.021
					ϵ_{ν_e}	0.029	0.013	0.027	0.019
					ϵ_ψ	0.005	0.004	0.005	0.005
					ϵ_p	0.001	0.001	0.001	0.001
					ϵ_t	0.012	0.009	-	0.015

Note: We exclude parameter descriptions, prior means and standard deviations (see Tables 2 and 3), and statistic confidence intervals in the table due to the limited space.

Base model, FF model and TS model, the relationship between the loan rate adjustment cost parameters ($\kappa_h > 2(\kappa_e)$) remain consistent. On the other hand, compared to the Base model, the posterior means of κ_k for both the FF and TS models are more than double (2.629 and 3.005). However, a higher value for ν_B in the Base model adjusts for the lower κ_k value by raising the influence of the interbank rate relative to the stochastic markup in retail rate setting (see Eq. 7). Conversely, a value close to zero for ν_B in the TS model significantly raises the weight on stochastic retail rate markups. Indeed, the fact that the FI model, under flexible retail rate adjustment, gives a smaller increase for κ_k (from 1.255 to 2.176) suggests that the Base model represents the influence of leverage deviation costs more accurately. Furthermore, considering the observed data used for the interbank rate and policy rate in the Base model, a smaller value corresponds well with their closely related interest rate movements over the sample period.

Overall, the parameter estimates in the baseline model closely mimic the estimates for the fed funds model. This gives compelling evidence in favor of our baseline model because the fed funds model, given no observed variable for the interbank rate, can be thought of as the implied values for financial intermediation. As the evidence from the impulse responses in Figure 1 and 2 also show, the baseline model tends to strike a balance between the advantages of using either the term spread model or fed funds model. Two further assertions reveal the importance of the baseline model. Firstly, it is far more appealing to assume that the *expected* path of monetary policy dominates the term spread, rather than only the *direct* short-term effects of both the policy rate and bank balance sheet adjustments. Secondly, it is better then to capture the influence of the interbank market on credit spread variability through short-term interbank rates—which feeds through to retail loan rate setting. The baseline model will therefore implicitly captures some portion of the term premium through stochastic markups on retail loan rates.[23] In fact, this reveals more about the probable influence of bank balance sheet adjustments on credit spread variability and the pricing of default risk (the excess bond premium) (e.g., Gilchrist and Zakrajek, 2012).

6 Applications

After having shown that the estimated Base model explains the U.S. business cycle quite well and that financial factors play a central role, we use the model to examine the driving forces behind credit spreads. Firstly, to investigate the strength and persistence of shocks to credit spread variability we tabulate their variance decompositions at different forecast horizons. Thereafter, to highlight the financial factors that influence credit spread variability over the sample period, we examine the historical decomposition of the retail and interbank credit spreads. And based on the relationship between credit spreads and financial stress during recessions, we compare the main sources of financial stress over the Great Moderation and Great Recession periods.

6.1 Historical and variance decomposition of spreads

Table 5 tabulates the conditional variance decomposition of the interbank spread and retail credit spreads based on the mean of the model's posterior distribution reported in Sec. 4.2. We report the contribution of each of the structural shocks to credit spread variance on impact and at 1-year, 2-year and 5-year horizons. This decomposition provides insight from the estimated model on the influence of financial factors on the observed variance of credit spreads.

Bank capital-asset shocks dominate interbank spread variability over the short- and medium term (30 to 33%). The direct impact of monetary policy shocks on the short-term interbank spread is persistent but mild (approx. 8%). In contrast, the average of monetary policy shocks over a 2-year forecast horizon (not shown here) accounts for 87% and 73% of the variance of the policy rate and interbank rate, respectively (see also, Smets and Wouters, 2007, p.598). The implication here is that although monetary policy has significant sway over short term rates, the majority of variability between the rates is due to bank capital-asset shocks. Shocks to technology, equity price and the entrepreneur loan markup are also persistent, but mild. Yet, as expected, only technology becomes more influential at longer horizons. Bank funding dynamics are negligible; however, a large source of variability stems from the demand side of credit in households' LTV shock. Similarly, we find that household and entrepreneur spreads are dominated by the banking sector. The impact of monetary shocks on the household spread (43.4%) is larger than that of the entrepreneur spread (27.2%). On the one hand, credit spread variability for entrepreneur's is strongly isolated in bank market power over the markup. On the other hand, the household loan markup shock has a lesser, but also highly persistent, influence on household credit spread variability.

Financial intermediation certainly has significant influence in the impulse responses of credit spread

[23] Essentially, this is similar to looking at the risk premium of mortgage rates or Baa corporate rates over the PRIME interest rate: although only the sample mean of the data is subtracted from the loan rates in estimation, by looking at the spread variability we extrapolate the similar trend between the policy rate and loan rates.

Table 5: Variance decomposition of credit spreads

Interbank spread

Shocks		Horizons			
		1-quart.	1-year	2-years	5-years
ϵ_z	Technology	0.097	0.099	0.156	0.569
ϵ_i	Monetary	0.079	0.084	0.079	0.033
ϵ_p	Price markup	0.006	0.005	0.022	0.054
ϵ_b	HH asset	0.001	0.002	0.013	0.030
ϵ_{ν_h}	Households' LTV	0.250	0.259	0.223	0.080
ϵ_{ν_e}	Entrepreneurs' LTV	0.063	0.058	0.050	0.063
ϵ_h	HH loan markup	0.003	0.015	0.023	0.011
ϵ_e	Entrep. loan markup	0.099	0.084	0.070	0.054
ϵ_t	Capital-asset ratio	0.311	0.327	0.302	0.085
ϵ_ψ	Equity	0.092	0.068	0.060	0.021

Household credit spread

Shocks		Horizons			
		1-quart.	1-year	2-years	5-years
ϵ_z	Technology	0.018	0.009	0.019	0.068
ϵ_i	Monetary	0.434	0.320	0.271	0.300
ϵ_p	Price markup	0.002	0.005	0.006	0.020
ϵ_b	HH asset	0.001	0.001	0.001	0.002
ϵ_{ν_h}	Households' LTV	0.028	0.015	0.012	0.011
ϵ_{ν_e}	Entrepreneurs' LTV	0.021	0.009	0.007	0.006
ϵ_h	HH loan markup	0.425	0.607	0.657	0.563
ϵ_e	Entrep. loan markup	0.029	0.013	0.010	0.009
ϵ_t	Capital-asset ratio	0.030	0.014	0.012	0.013
ϵ_ψ	Equity	0.012	0.006	0.005	0.008

Entrepreneur credit spread

Shocks		Horizons			
		1-quart.	1-year	2-years	5-years
ϵ_z	Technology	0.026	0.030	0.082	0.173
ϵ_i	Monetary	0.272	0.145	0.155	0.194
ϵ_p	Price markup	0.001	0.002	0.004	0.013
ϵ_b	HH asset	0.000	0.000	0.000	0.002
ϵ_{ν_h}	Households' LTV	0.017	0.007	0.007	0.008
ϵ_{ν_e}	Entrepreneurs' LTV	0.013	0.004	0.005	0.005
ϵ_h	HH loan markup	0.000	0.000	0.000	0.000
ϵ_e	Entrep. loan markup	0.640	0.800	0.736	0.587
ϵ_t	Capital-asset ratio	0.021	0.008	0.007	0.009
ϵ_ψ	Equity	0.009	0.004	0.003	0.007

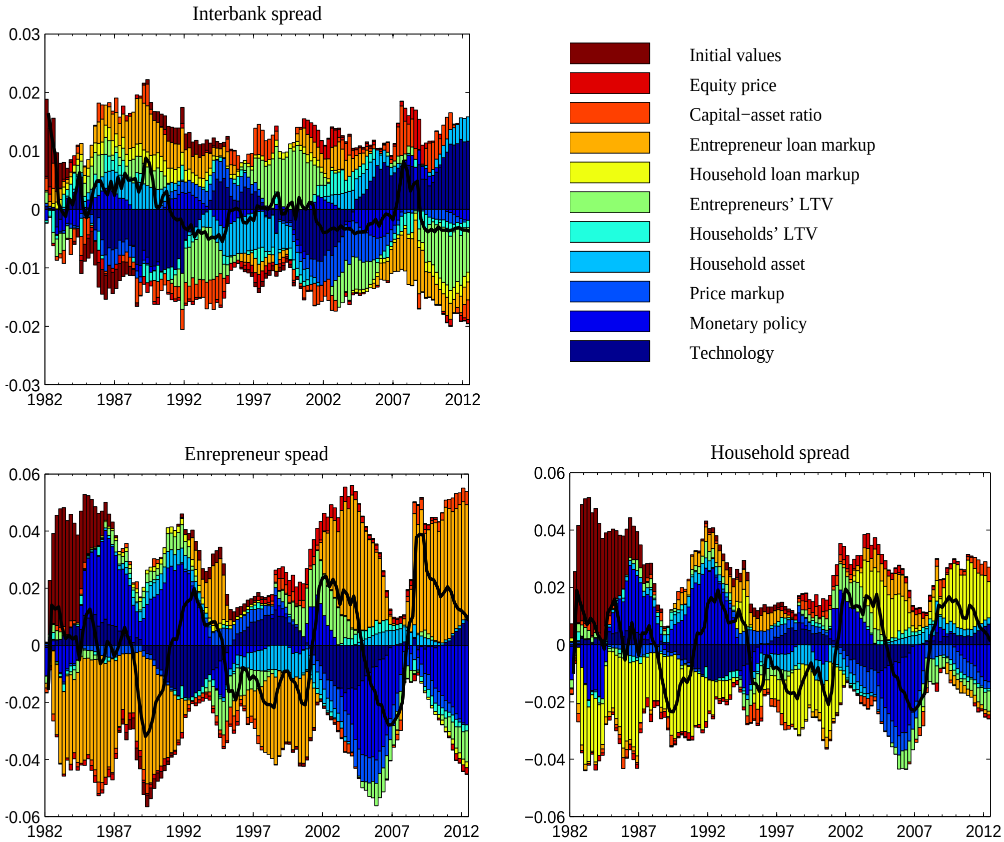

Figure 3: Historical decomposition (full-sample): interbank spread (top-left); entrepreneur spread (bottom-left); household spread (bottom-right)

variability. It is also clear that supply-side credit factors dominate the demand-side of the credit market. Banks exert significant influence over credit spread variability through profit maximizing commercial banks and bank balance sheet adjustments on capital-asset ratios. This raises two issues: direct monetary policy influence through short-term interest rates can potentially be either offset or significantly exacerbated by financial market conditions, and any indirect effect through real GDP changes tends to come with long lags; secondly, unconventional credit policies by adjusting LTV ratios (or any demand-side interventions) lack any significant influence over credit spread variability. Recapitalizing bank balance sheets, however, would be the most plausible intervention.

Figure 3 provides the historical shock decomposition of the interbank and retail credit spreads over the sample period of the data used in estimation. We do not intend to overextend our inference from the contribution of the various structural shocks to the observed historical movement of credit spreads. We rather focus on how the structural shocks predict clear patterns in the variance of credit spreads. We find that the estimated model provides coherent and well-established results, which allows us to shed light on the influence of financial factors on credit spread variability.

In the interbank market we see no clear pattern, pertaining to the business cycle, over the whole sample period. However, we can clearly see the impact of shocks to the aggregate bank capital-asset ratio in the recent crisis, which was exacerbated by the equity market collapse. Interestingly, both supply- and demand-side credit factors influence the spread with significance: the entrepreneurs' LTV is clearly positively related to movements in the interbank spread; while the entrepreneur loan markup tends to be negatively related to technology shocks. The main conclusion here is that the interbank market has clearly evolved over the Great Moderation period. On the one hand, both retail credit supply and demand factors, especially in the production sector, are still important over the whole sample period. On the other hand, if the recent crisis tells us anything, bank balance sheet adjustments can induce significant distress in the interbank market.

For retail credit spreads we observe a clear pattern both over the whole sample period and between entrepreneur and household credit spreads. Firstly, the widening of credit spreads in each of the three previous U.S. recessionary periods (1990Q03−1991Q02, 2001Q01−2001Q04 and 2007Q04−2009Q02) correspond exactly with each movement of retail spreads above steady-state to their respective peaks. This reflects the observation from interest rate data that credit spreads become increasingly narrow toward the end of boom phases of the business cycle, and conversely widen in recession periods (see also, Gilchrist and Zakrajek, 2012, p.1696). While monetary policy tends to lead the movement of spreads (which highlights the lag of the conventional interest-rate channel), the persistence of credit spread widening or narrowing is driven by bank market power over retail loan rate markups. There is however one clear exception. Leading up to the August 2007 crisis, monetary policy has an extremely persistent effect on narrowing retail credit spreads—more than offsetting the loan markups of banks. This observation gives credence to the evidence that monetary authorities kept the policy rate too low from 2002 to 2005 (e.g., Taylor, 2007), inadvertently pushing the incentive for banks to seek larger profit margins from increasingly risky portfolios. Yet overall, we again observe a clear strong dominance of credit supply factors over credit spreads. We also see that monetary shocks can create significant distortions to credit spreads, and that bank capital-asset ratios seems to have greater influence over credit spreads in recent years. With these results in mind, we explore more closely the results from each recession period.

6.2 U.S. recessions comparison analysis

Although the recession periods of 1990−91 and 2001 were milder than that of 2007−09, a comparative study by Peter Ireland (2011) shows that—similar to what we observe for financial stress in Figure 3—the pattern of shocks have not changed significantly throughout the Great Moderation and Great Recession periods. In fact, Ireland (2011) finds that all three recessions exhibit a similar combination of exogenous demand and supply shocks, where the stand out difference for the Great Recession is that these adverse shocks lasted longer and were deeper.[24] (Similarly, Stock and Watson (2003); Sims and Zha (2006); Smets and Wouters (2007) find that the benign Great Moderation period cannot be attributed to changes in structural parameters—that is, the endogenous transmission mechanism of shocks—but rather a reduction in the volatility of a

[24] He goes on to add that while expansionary monetary policy helped cushion the 1990−91 and 2001 recessions, the zero lower bound on the policy rate created a *de facto* contractionary policy stance in 2009. This constraint, he finds, contributed to both the duration and deepness of the recession.

Table 6: U.S. recessions estimated parameter comparisons

	Posterior distribution means				Posterior distribution means		
	2007−09	2001	1990−91		2007−09	2001	1990−91
Parameters				AR(1) processes			
γ	4.023	3.983	4.250	ρ_z	0.98	0.98	0.98
γ^e	1.035	0.930	0.930	ρ_i	0.28	0.27	0.27
ϕ	0.672	0.691	0.671	ρ_b	0.97	0.97	0.97
θ_R	0.917	0.922	0.913	ρ_e	0.32	0.34	0.36
γ_p	0.487	0.481	0.493	ρ_h	0.31	0.34	0.31
κ_i	0.685	0.676	0.637	ρ_{ν_h}	0.79	0.89	0.80
κ_π	1.511	1.509	1.534	ρ_{ν_e}	0.63	0.59	0.58
κ_y	0.254	0.253	0.255	ρ_ψ	0.82	0.85	0.78
ν_h	0.743	0.739	0.747	ρ_p	0.32	0.30	0.31
ν_e	0.789	0.795	0.786	ρ_t	0.83	0.82	0.75
ν_B	0.365	0.368	0.383	ϵ_z	0.014	0.012	0.017
κ_k	1.382	1.575	1.955	ϵ_i	0.005	0.005	0.005
κ_e	4.965	8.435	6.096	ϵ_b	0.008	0.006	0.006
κ_h	11.06	13.31	8.29	ϵ_e	0.117	0.095	0.083
κ_v	2.073	1.588	2.008	ϵ_h	0.114	0.115	0.118
K^e/Y	10.71	10.76	10.77	ϵ_{ν_h}	0.019	0.016	0.022
				ϵ_{ν_e}	0.020	0.023	0.036
				ϵ_ψ	0.007	0.005	0.007
				ϵ_p	0.001	0.001	0.001
				ϵ_t	0.010	0.008	0.010

Note: We exclude parameter descriptions, prior means and std. dev., and statistic confidence intervals in the table due to the limited space. However, Tables 2 and 3 are a good guide.

similar combination of exogenous shocks). While Ireland's paper made use of a small-scale model based on the core New-Keynesian building block (an IS curve, a Phillips curve and a monetary policy rule), we use our medium-scale New-Keynesian model with a central role for financial intermediation to ask a similar question: does the recent 2007−09 recession show any clear difference in its sources of influence over credit spread variability (i.e. financial market stress), and hence, could this have contributed to the persistence and severity of the crisis?

We re-estimate our baseline model using sub-samples of our data set. We take a 5-year period before and after each recessions' peak and trough: 1985Q03−1996Q02; 1996Q01−2006Q04; and 2002Q04−2012Q03.[25] The model is correspondingly re-calibrated to reflect the steady-states of each period. We first present the results of the estimated parameters from each U.S. recession period, to highlight any key structural breaks in the parameters. Secondly, we look at two shocks common to each period: a monetary policy shock and a bank capital-asset ratio shock. Here we specifically want to see the role of financial intermediation in propagating the shocks, and whether the variability of credit spreads differs. Lastly, following the analysis in the previous section we compare the historical and variance decomposition of credit spread variability in each recession period.

Table 6 reports the estimated parameter comparisons for each of the U.S. recession sub-samples, labeled: 2007−09, 2001 and 1990−91. The persistence of shocks and their standard deviations are consistent across models. One interesting exception is that the posterior means for the standard deviation of the household

[25] We only include data for three years and one quarter after the 2007−09 recession. The sample period is therefore 40 observations, compared to 44 observations for the 1990−91 and 2001 recession sub-samples.

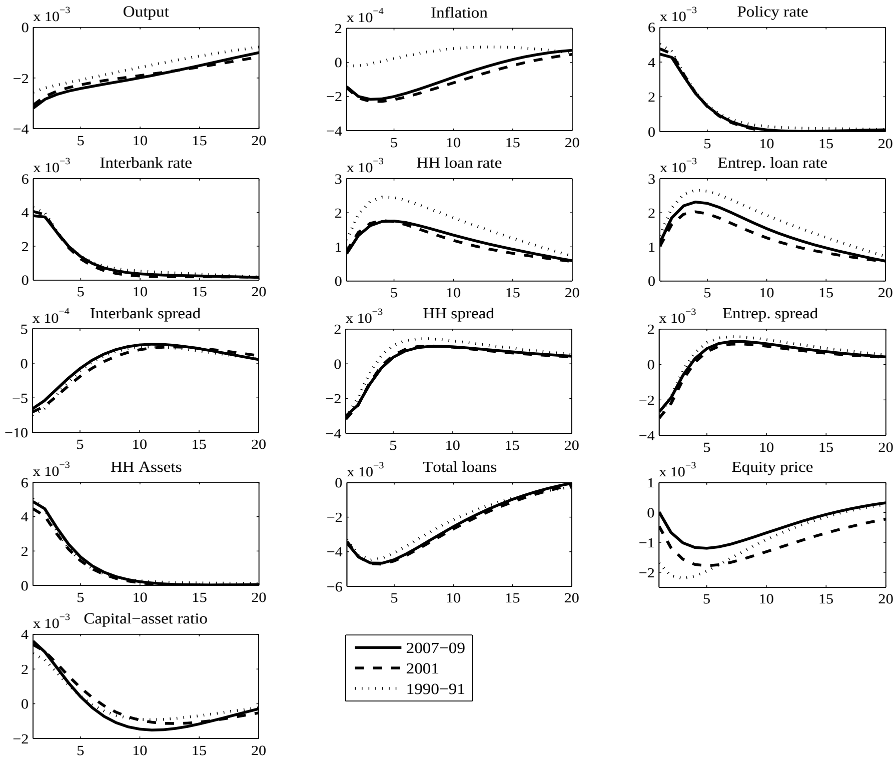

Figure 4: IRFs to a contractionary monetary policy shock

and entrepreneur LTV shocks (ϵ_{ν_h} and ϵ_{ν_e}) have declined since 1990−91, while the standard deviation for the entrepreneur loan rate markup shock (ϵ_e) has steadily increased. This indicates a slight shift in emphasis from the demand-side to the supply-side of the credit market. Structural parameters for preferences, the Phillips curve, monetary policy and LTV ratios are closely consistent across each sub-sample period. The quadratic interest rate adjustment cost parameters $\{\kappa_k, \kappa_e, \kappa_h\}$ vary slightly across the sub-samples, but the relative relationships are consistent. Although the investment schedule parameter κ_v is lower for 2001, there seems to be little evidence of a strong structural change in the estimated parameters for each sub-sample period of U.S. recessions.

For each recession period, figure 4 shows the impulse responses of the observed variables to a contractionary monetary policy shock. Both 2001 and 2007−09 give slightly exacerbated responses for output and inflation. Equity prices respond significantly more to the policy rate in the 1990−91 and 2001 recession periods, which suggests the source of the equity market collapse over 2007−09 is less rooted in the response of market interest rates. Overall, however, the results are quite similar, indicating that the policy rate exhibits little variation in the propagation or exacerbation of the variables. Although household and loan rate adjustments in 1990−91 are visibly larger, the difference in spread variability is minimal.

Figure 5 sheds more light on the question posed here. The positive bank capital-asset ratio shock is clearly larger for output (real GDP) in the 2007−09 period. In fact, GDP deflator inflation is more deeply depressed worsening the decline in nominal gross domestic production. Credit supply is more adversely affected in the

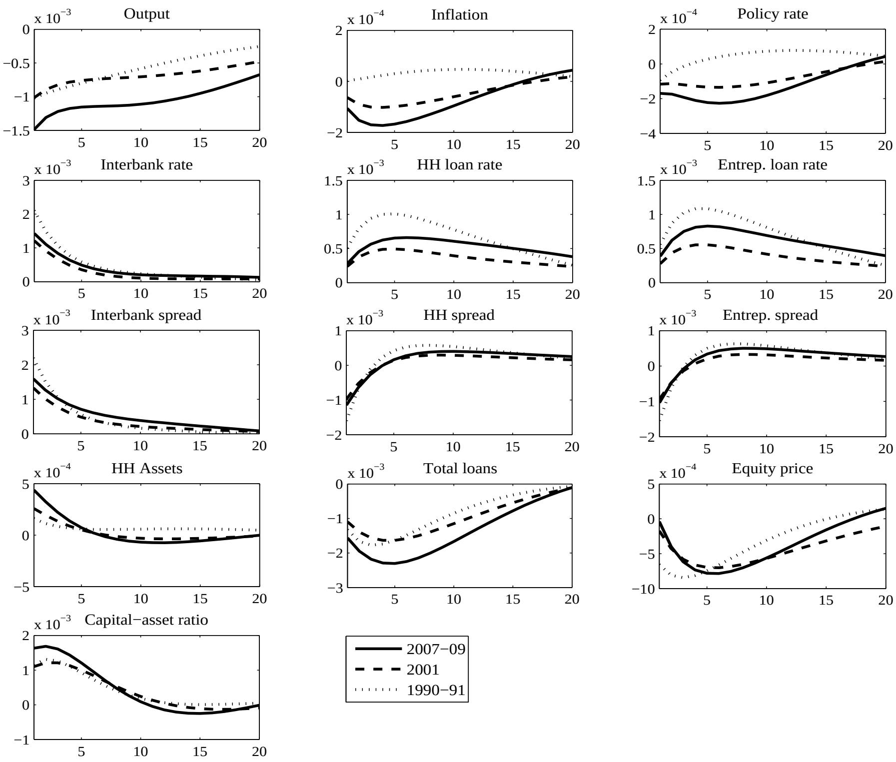

Figure 5: IRFs to a positive bank capital-asset shock

recent recession. On the other hand, equity prices are similarly depressed in each period. For each period, however, we observe a varying degree of household and entrepreneur loan rate responses, including different degrees of adjustment in the policy rate. The interesting point here is that, again, the dynamics of credit spread variability are very similar between each U.S. recession period. One clear observation we can draw across the U.S. recession periods, from Figures 5 and 4, is that shocks to the policy rate and the aggregate bank capital-asset ratio (two important shocks to interest rate movements) report no significant change in the degree of credit spread variability. Also, the fact that the capital-asset ratio shock is clearly exacerbated for the 2007−09 recession period hints to an alternative source for the excess financial stress shown in the recent crisis. As it would be overly-lengthy to assess the impact of each shock in the model on credit spread variability, we investigate the results on the historical and variance decomposition of credit spreads in each period.

6.2.1 U.S. recessions: historical and variance decomposition of spreads

Table 7 reports the variance decomposition of credit spreads from the conditional standard deviations of the structural shocks at different horizons: 1-quarter, 1-year, and 5-years. We extend our discussion in subsection 6.1 to take a closer look at the underlying change in the sources of variability, and the evidence of a shift toward the influence of financial intermediation. First, we look at the spread between the interbank rate and policy rate. For the recent recession period, technology shocks have become less influential over shorter

Table 7: Variance decomposition of credit spreads for the U.S. recession periods

Interbank spread

	2007−09: Horizons			2001: Horizons			1990−01: Horizons		
Shocks	1-quart.	1-year	5-years	1-quart.	1-year	5-years	1-quart.	1-year	5-years
ϵ_z	0.086	0.063	0.613	0.110	0.109	0.521	0.120	0.107	0.384
ϵ_i	0.039	0.046	0.015	0.055	0.072	0.032	0.065	0.091	0.057
ϵ_p	0.007	0.007	0.055	0.003	0.004	0.028	0.001	0.002	0.023
ϵ_b	0.001	0.003	0.023	0.001	0.002	0.034	0.000	0.001	0.027
ϵ_{ν_h}	0.288	0.233	0.070	0.244	0.236	0.088	0.317	0.292	0.183
ϵ_{ν_e}	0.086	0.070	0.061	0.208	0.181	0.145	0.054	0.055	0.069
ϵ_h	0.003	0.013	0.006	0.001	0.012	0.010	0.001	0.007	0.008
ϵ_e	0.073	0.068	0.022	0.097	0.094	0.032	0.020	0.019	0.013
ϵ_t	0.320	0.403	0.107	0.209	0.235	0.088	0.325	0.353	0.178
ϵ_ψ	0.099	0.093	0.030	0.073	0.055	0.020	0.097	0.072	0.057

Household credit spread

	2007−09: Horizons			2001: Horizons			1990−01: Horizons		
Shocks	1-quart.	1-year	5-years	1-quart.	1-year	5-years	1-quart.	1-year	5-years
ϵ_z	0.024	0.011	0.041	0.038	0.021	0.095	0.087	0.096	0.374
ϵ_i	0.245	0.154	0.148	0.311	0.195	0.179	0.412	0.284	0.255
ϵ_p	0.002	0.004	0.026	0.001	0.003	0.010	0.001	0.001	0.006
ϵ_b	0.001	0.001	0.001	0.001	0.001	0.002	0.000	0.000	0.002
ϵ_{ν_h}	0.080	0.038	0.025	0.050	0.025	0.018	0.088	0.049	0.027
ϵ_{ν_e}	0.048	0.021	0.015	0.091	0.039	0.028	0.024	0.013	0.017
ϵ_h	0.495	0.721	0.697	0.420	0.674	0.632	0.270	0.488	0.262
ϵ_e	0.035	0.016	0.011	0.038	0.018	0.013	0.011	0.008	0.007
ϵ_t	0.055	0.026	0.031	0.034	0.017	0.017	0.073	0.041	0.031
ϵ_ψ	0.015	0.007	0.005	0.016	0.008	0.007	0.034	0.020	0.018

Entrepreneur credit spread

	2007−09: Horizons			2001: Horizons			1990−01: Horizons		
Shocks	1-quart.	1-year	5-years	1-quart.	1-year	5-years	1-quart.	1-year	5-years
ϵ_z	0.023	0.018	0.096	0.033	0.023	0.128	0.100	0.134	0.444
ϵ_i	0.152	0.088	0.120	0.232	0.147	0.155	0.423	0.305	0.254
ϵ_p	0.001	0.002	0.027	0.001	0.002	0.009	0.001	0.001	0.006
ϵ_b	0.001	0.000	0.001	0.001	0.000	0.002	0.000	0.000	0.003
ϵ_{ν_h}	0.053	0.024	0.018	0.038	0.019	0.016	0.091	0.054	0.028
ϵ_{ν_e}	0.031	0.013	0.012	0.069	0.031	0.026	0.024	0.016	0.020
ϵ_h	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000
ϵ_e	0.693	0.833	0.692	0.588	0.758	0.641	0.248	0.421	0.197
ϵ_t	0.035	0.016	0.028	0.026	0.013	0.015	0.076	0.045	0.031
ϵ_ψ	0.011	0.005	0.004	0.013	0.007	0.006	0.037	0.023	0.018

Note: see Table 5 for shock parameter descriptions.

horizons, while the impact of monetary policy has dropped significantly over all horizons. Household and entrepreneur LTV shocks reflect the demand-side of the credit market. The influence of ϵ_{ν_h} is strong over 1-quarter and 1-year horizons for each U.S. recession period. Only 2001 highlights a role for the entrepreneur LTV. It is interesting to note that the model interprets a similar decomposition for both 2007−09 and 1990−01 recession periods. Indeed, both emphasize bank capital-asset shocks as the financial factor with the largest influence on interbank spread variance. Yet, in addition to the lesser influence of monetary policy and technology shocks for 2007−09, the recent recession gives a slightly larger weight to the entrepreneur loan rate markup. The interbank spread in 2001, on the other hand, seems to be less rooted in supply-side credit market factors. Therefore, interbank spread variability in the recent recession has its origins more strongly rooted in financial intermediation, rather than general monetary or technology shocks.

The household and entrepreneur credit spread variance decompositions are quite similar. We therefore only discuss the origins of entrepreneur credit spread variability. Analogous to the interbank spread, we

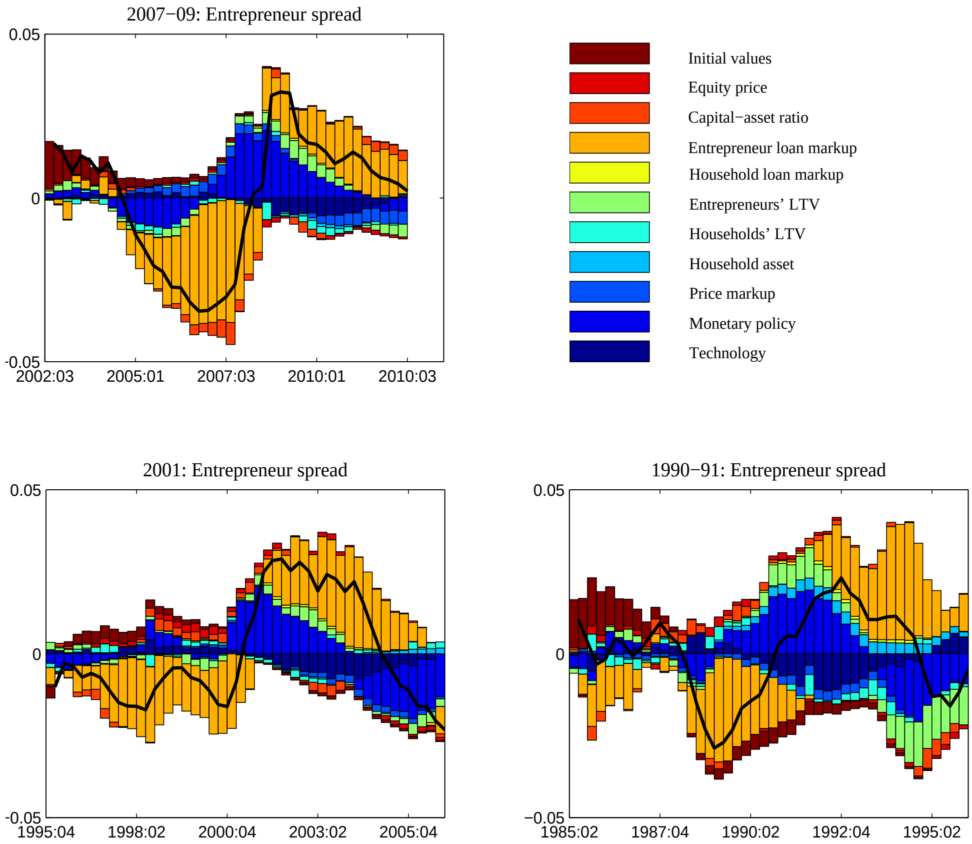

Figure 6: Historical decomposition for entrepreneur spread: 2007−09 recession (top-left); 2001 recession (bottom-left); 1990−91 recession (bottom-right)

observe a marked decline in the influence of technology and monetary shocks over the sub-sample periods. Most noticeably, from the 1990−91 to 2007−09 periods, the influence of monetary policy shocks on first quarter and one year horizons declined 27.1 and 21.7 percentage points (pp), respectively. The role of LTV shocks on the demand-side of credit are small and ambiguous across recession periods. On the other hand, we see a clear dominance of bank market power from the entrepreneur loan markup shock (ϵ_e). Moreover, from the 1990−91 period to the 2007−09 period, the first quarter, one year and five year horizons for the contribution of ϵ_e to entrepreneur spread variance increased by 44.5 pp, 46.2 pp and 49.5 pp, respectively. For the recent recession, therefore, it is quite clear that financial factors play a larger role in the origins of credit spread variability. One shortcoming from these results, however, is that the directional impact of the shocks cannot be observed: with these results in mind, we look at the historical decomposition of the entrepreneur credit spread to elucidate more about the influence of financial factors on credit spread variability.

Two important observations can be taken from the historical shock decomposition for the entrepreneur spread (see Figure 6). Firstly, compared to the full-sample historical decomposition (Figure 3) the 1990−91 and 2001 recession periods correspond closely. While the 2007−09 recession period, in the full sample, does not capture the role of bank market power in the narrowing of credit spreads leading up to the crisis. Nonetheless, policy rate adjustments consistently lead movements in the spreads, which tend to be made more persistent by bank market power over loan rate setting. Secondly, the influence of the demand-side of credit through LTV shocks has declined since 1990−91, and the bank capital-asset shock clearly played some role in exacerbated and prolonging credit spread variability in the recent recession period.

To some extent our results confirm the findings of Ireland (2011). In that, the three previous U.S. recessions exhibit similar characteristics: qualitatively, the recent recession offers no unanimously distinguishable change in the transmission mechanism of shocks. However, we do find evidence of a steady shift towards the influence of financial factors over credit spread variability, and concurrently, to the relative dominance of supply-side credit factors. Furthermore, the role of technology and monetary policy shocks has declined. It is further not clear whether the shift is a permanent feature of the growing financial sector or if, in the aftermath of the recent recession, we will see a return to a less central role for financial intermediaries in credit spread variability.

7 Concluding remarks

We develop a New-Keynesian DSGE model with rich financial market interactions to assess the influence of financial factors on credit spread variability. Large movements in credit spreads are closely linked to U.S. recessions over the Great Moderation and Great Recession periods, and hence, seen as an indicator of financial market stress. In this paper we pose two questions. To what extent does the influence of financial intermediaries over credit spread variability affect U.S. business cycle fluctuations? Is there any contributing financial factor to credit spread variability in the recent recession that can be distinguished from the 1990−91 and 2001 recession periods?

To answer the first question, the first part of our analysis deals with alternative model comparisons over the full-sample period of the Great moderation and Great Recession. Here, we find a clear role for bank market power on credit spread variability and business cycles: where both the sticky rate structure and loan markups are important. Also, bank balance sheet adjustments can cause unexpected dislocations in the conventional transmission mechanism of the policy rate. For the second question, we do a comparison analysis between the three U.S. recessions over the Great Moderation and Great Recession periods. We find evidence of a steady shift towards the influence of financial factors over credit spread variability, and a concurrent decline in the role of technology and monetary policy shocks. Relative to credit demand and bank funding factors, the role of financial intermediaries in credit supply has become the predominant force behind recent credit spread variability.

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8 Appendix: Data and sources

Data source from the Federal Reserve Bank of St. Louis (FRED):

1. RGDP: Real Gross Domestic Product, 1 Decimal (GDPC1), Billions of Chained 2005 Dollars, Quarterly, Seasonally Adjusted Annual Rate
2. Inflation: GDP Implicit Price Deflator (GDPDEF), Index 2005=100, Quarterly, Seasonally Adjusted
3. Nominal short-term interest rates: 3-Month Treasury Bill: Secondary Market Rate (TB3MS); 3-month average of the daily Effective Federal Funds Rate (FEDFUNDS); 3-Month AA Financial Commercial Paper Rate (CPF3M) (Percent, Quarterly, Not Seasonally Adjusted.)
4. Treasury rate: 10-Year Treasury Constant Maturity Rate (GS10), Percent, Quarterly, Not Seasonally Adjusted
5. Loan rate to entrepreneurs: Moody's Seasoned Baa Corporate Bond Yield (BAA), Percent, Quarterly, Not Seasonally Adjusted
6. Loan rate to households: 30-Year Conventional Mortgage Rate (MORTG), Percent, Quarterly, Not Seasonally Adjusted
7. Loans to households: Total Liabilities - Balance Sheet of Households and Nonprofit Organizations (TLBSHNO), Billions of Dollars, Quarterly, Not Seasonally Adjusted - includes mortgage sector and consumer credit sector (equivalent to CMDEBT)
8. Loans to entrepreneurs: Total Liabilities - Balance Sheet of Non-farm Nonfinancial Corporate Business (TLBSNNCB), Billions of Dollars, Quarterly, Not Seasonally Adjusted
9. Deposits: Deposits - Assets - Balance Sheet of Households and Nonprofit Organizations (DABSHNO), Billions of Dollars, Quarterly, Not Seasonally Adjusted (closely related to M2SL)
10. Equity: Standard and Poor 500 Index (SP500), Index, Quarterly, Not Seasonally Adjusted
11. US population: Civilian Noninstitutional Population (CNP16OV), Thousands of Persons, Quarterly, Not Seasonally Adjusted