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Real Effects of Bank Shocks

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Abstract

What are the effects of a bank shock – or a decline in bank loan repayments – in an economy featuring bank-firm lending relationships and what is the propagation mechanism? I answer these questions in this paper and build a dynamic general equilibrium model in which collateral-constrained entrepreneurs have endogenously-persistent credit relationships with banks. Credit relationships play a dual role of shock amplifier and stabilizer in this environment. In presence of credit relationships, a bank shock in this model drives up credit spread at impact, causing bank credit to fall and paving the way for a downturn in macroeconomic activity. Economic activity recovers later on as spread falls, resulting in a rebound in bank loans and investment. When credit relationships are turned off, the model shows prolonged fall in bank loans and a persistent slowdown in investment, consumption and output as spread remains continually elevated, making bank credit expensive. A more persistent bank shock leads to a sustained decline in output even in the presence of lending relationships while a more volatile shock causes protracted slump in output in absence of credit relationships but not when they are present.

Keywords

bank shocks, lending relationships, economic activity

JEL Classification

E32, E44

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1 Introduction

This paper represents the first attempt in the literature to examine the effects of bank shocks – defined as an exogenous decline in bank loan repayments – in an environment that features bank-firm lending relationships. It sheds light on how these shocks interact with borrower-lender credit relationships, affect financial variables and transmit to the real sector. Bank-firm credit relationships are pervasive, however, their implications for bank shocks has eluded attention. This paper addresses this gap.

I present four results in this paper. First, in absence of bank-firm lending relationships, a bank shock leads to a persistent fall in macroeconomic activity caused by a prolonged decline in bank credit. When bank-firm credit relationships are present, the initial effects of bank shocks are magnified but later on, macroeconomic activity recovers faster. Second, the effects of bank shocks are increasing in the borrower hold-up which is captured by intensity and persistence of lending relationships. Third, a more volatile bank shock has larger initial impact in the case of bank-firm credit relationships versus when it's not taken into account. However, economic activity largely recovers after initial impact wears off. This is not true when bank-firm credit relationships are absent. In that case, macroeconomic activity displays more persistent slowdown. Fourth, a more persistent bank shock causes a prolonged economic slump even in the presence of lending relationships, however, its effects are more pronounced in the case when borrower-creditor relationships are not present.

A bank shock in this model takes the form of a negative shock to loan repayments and leads to an impairment of bank assets (loans). I show that in presence of bank-firm credit relationships, these shocks lead to large jumps in spread which cause a drop in credit extended to entrepreneurs. This is followed by a downturn in investment which ripples across output, consumption and other macroeconomic variables. The initial effects are much larger in the case of borrower-lender credit relationships. Later, bank credit recovers faster which jumpstarts the economy after initial impact of these shocks wear off, leading to a faster economic recovery.

Bank-firm lending relationships in this paper are modelled using deep habits in banking (Aliaga-Díaz and Olivero, 2010; Melina and Villa, 2014, 2018; Ravn, 2016; Airaudo and Olivero, 2019; Shapiro and Olivero, 2020) in a framework characterized by monopolistic competition. Deep habits can be interpreted as representing the existence of switching costs for borrowers in a parsimonious way. The reason why bank shocks in this framework lead to larger initial effects but faster recovery later on is related to borrower "hold-up" effect. The underlying idea is that through monitoring their borrowers, banks get an information monopoly over their customers' credit worthiness which leads to switching costs of changing banks for borrowers or a borrower hold-up (Boot, 2000). During recessions, when borrowers are perceived to be at greater risk of failure, the information monopoly allows banks to hold up borrowers for higher interest rates. Several well-known studies in banking as well as recent papers lend empirical support for the mechanism rooted in deep habits (Diamond, 1984; Sharpe, 1990; Rajan, 1992; Von Thadden, 1995; Dell'Ariccia, 2001; Santos and Winton, 2008; Ioannidou and Ongena, 2010; Cahn, Girotti, and Salvadè, 2024). The discussion in Section 2 also points towards this[1].

Because of deep habits in banking, spread spikes when a negative bank shock materializes. Banks realize that their loan repayments are going to decline and they scramble to protect their margins, leading to a rise in spread. This raises the cost of bank credit and as a result, investment falls which has negative effects on capital stock, consumption and output. After a while, spread starts falling as banks realize that by lowering their interest rates, they can lure more borrowers and because of deep habits in banking, these borrowers will be with them also in the future. This causes the spread to fall and overshoot the previous equilibrium where it stays for some time before beginning to come back to previous equilibrium. This makes it cheaper to access bank credit and gives rise to an investment boom. As a consequence, decline in capital stock stops and consumption and output start to recover.

In the version of the model in which these credit relationships are turned off, a bank shock causes a prolonged downturn in investment, capital, aggregate consumption and output. These effects of financial disruptions are well-documented in the literature (Peek and Rosengren, 1997, 2000; Dell'Ariccia, Detragiache, and Rajan, 2008; Reinhart and Rogoff, 2009a,b; Bernanke, 2018; Amiti and Weinstein, 2018; Queralto, 2020; Schmitz, 2021; Bonciani, Gauthier, and Kanngiesser, 2023). My paper contributes to the literature by proposing a new channel that shows how negative shocks to bank loan repayments can lead to persistent economic slump and how these

[1] Hale and Santos (2009) show that firms are able to borrow from banks at lower interest rates after they issue for the first time in public bond market. They interpret this as evidence that banks indeed price their information monopoly. Schenone (2010) investigates whether banks exploit their lending relationships and extract rents from their locked-in customers. Tracking a firm's lending relationships across the IPO year, they find that banks indeed exploit their information advantage and seek rents while the firm faces high switching costs and is locked into the relationship. Similar effects have been reported when borrowing firms voluntarily disclose their information (Bird, Karolyi, and Ruchti, 2019). Chodorow-Reich (2014) construct a dataset of 2,000 non-financial US firms and empirically document the importance of banking relationships and cost to borrowers of switching lenders. Saidi and Žaldokas (2021) document that hold-up by incumbent lenders declines when more information about corporate innovation (patents) becomes publicly available.

economic dynamics change in presence of borrower-lender credit relationships. Papers such as Queralto, 2020; Schmitz, 2021 and Bonciani, Gauthier, and Kanngiesser, 2023, among others, focus on worsening of agency frictions in the financial markets and productivity growth to explain persistent negative effects of financial disruptions. I abstract from these issues and instead focus on shocks coming from the banking sector and explaining its interaction with bank-firm lending relationships.

How do bank shocks lead to such macroeconomic effects, absent bank-firm credit relationships? Spread rises in the wake of a bank shock, causing the bank credit to fall since it becomes costlier to get bank loans. Spread persistently remains elevated which results in the cost of bank credit remaining persistently high. This means that bank loans fall less compared to the version which considers the presence of bank-firm lending relationships because the spike in spread is comparatively smaller. But the bank credit recovers very slowly and it doesn't reach its previous equilibrium even after half a decade. This points towards highly persistent negative effects of bank shocks in absence of bank-firm lending relationships and highlights how a bank shock can cause prolonged slump in provision of bank credit to the real sector. As provision of bank credit slowly improves, investment gradually recovers. Because of slow pace of recovery in investment (it takes more than half a decade to reach its previous steady state), stock of capital displays prolonged decline and wages remain depressed for an extended period. This has the result that aggregate consumption falls at impact and remains depressed for a long period and output persistently remains below its previous equilibrium. These findings emphasize that bank shocks can have large and persistent effects on real economy. This also highlights that bank-firm lending relationships can play an important role in determining the impact of bank shocks.

There is one precedence for the way I introduce bank shocks in my model. Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez, and Vardoulakis (2015) analyze the effects of bank shocks on macroeconomic activity. However, existing literature ignores presence of bank-firm lending relationships. These credit ties are pervasive and have been extensively documented (Rajan, 1994; Ongena and Smith, 2000a,b; Kosekova, Maddaloni, Papoutsi, and Schivardi, 2023). It is, therefore, highly relevant and useful to analyze the economic consequences of bank shocks when borrower-lender relationships matter. Another very important reason for this study is that models that assume away these features of financial markets and conjure up a fictional world where none of these banking sector imperfections exist, do not capture the true magnitude and nature of various macroeconomic shocks. This buttresses the argument in favor of models that take this aspect of banking sector seriously. This work makes progress towards this direction. The novelty of this paper is to present a model in which bank shocks interact with borrower-lender credit relationships and it's different from current workhorse models of financial frictions such as Bernanke, Gertler, and Gilchrist (1999) and Gertler and Karadi (2011).

A model that abstracts away from these empirically-documented lending relationships not only misses important macroeconomic dynamics but also underestimates large movements in financial variables such as spread and bank credit which have implications for not only real activity but also financial stability. A model devoid of a role for bank-firm credit relationships, misses the massive spike in spread after a bank shock and a subsequent large fall in bank credit. These events then have a ripple effect on wider macroeconomic activity. These findings suggest that credit relationships play a highly important role in shaping the macroeconomic effects of bank shocks and further underscore the importance of taking them seriously in macroeconomic models. This paper makes progress towards better understanding economic implications of bank shocks when these lending relationships are considered.

Relationship with Literature

This work speaks to both macroeconomics and finance literature. It is connected to the body of work on macroeconomic effects of financial frictions or shocks including, among others, Benanke and Gertler (1989); Bernanke, Gertler, and Gilchrist (1996, 1999); Kiyotaki and Moore (1997); Jermann and Quadrini (2012); Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez, and Vardoulakis (2015) and Becard and Gauthier (2022). These papers often focus on shocks coming from borrower's side (for instance, feedback from the fall in collateral value to borrowing capacity as in Kiyotaki and Moore, 1997 and Bernanke, Gertler, and Gilchrist, 1999). Other papers such as Gertler and Karadi (2011) introduce a moral hazard problem and assume that banks divert a fraction of available funds to their households. By contrast, my work emphasizes the impairment of bank assets (loans) caused by bank shocks and illustrates how it can affect economic activity. The framework in this paper does not rely upon the Costly State Verification (CSV) setup developed by Townsend (1979) and used later by Benanke and Gertler (1989) and others, nor does it use the moral hazard device of Gertler and Karadi (2011).

Most of these papers (Benanke and Gertler, 1989; Bernanke, Gertler, and Gilchrist, 1996, 1999; Kiyotaki and Moore, 1997; Jermann and Quadrini, 2012; Christiano, Motto, and Rostagno, 2014; Becard and Gauthier, 2022) do not include a formal banking system and therefore cannot speak to the macroeconomic implications of bank shocks when bank-firm lending relationships matter. Differently from them, a related strand of literature incorporates banks into their model (e.g. Van den Heuvel, 2008; Gerali, Neri, Sessa, and Signoretti, 2010; Devereux and Sutherland, 2011; Kollmann, Enders, and Müller, 2011 and Kollmann, 2013) and discusses the aftermath of a negative shock to bank capital. My paper, on the other hand, follows the tradition in the deep habits in banking literature and abstracts from the role of bank capital and instead focuses on negative shocks to bank loan repayments[2]. Further and very importantly, the aforesaid papers have no place for bank-firm credit relationships which are extensively documented in the literature (see, for example, Ongena and Smith, 2000a,b and more recently, Kosekova, Maddaloni, Papoutsi, and Schivardi, 2023). My paper takes into account this economic reality and advances the current literature by building a model in which bank shocks interact with borrower-lender credit relationships and affect macroeconomic outcomes.

My paper also contributes to the literature that focuses on macroeconomic implications of bank-firm lending relationships. Existing papers that examine the macroeconomic effects of borrower-lender relationships using deep habits framework as I do in this paper, such as works by Aliaga-Díaz and Olivero (2010); Aksoy, Basso, and Coto-Martinez (2013); Melina and Villa (2014, 2018); Ravn (2016); Airaudo and Olivero (2019) and Shapiro and Olivero (2020) do not study the economic effects of bank shocks[3]. These papers focus on how presence of bank-firm lending relationships impact the effects of TFP shocks (Aliaga-Díaz and Olivero, 2010), monetary policy (Aksoy, Basso, and Coto-Martinez, 2013), fiscal policy (Melina and Villa, 2014), interest rate policy in the face of lending growth (Melina and Villa, 2018), bank competition on collateral (Ravn, 2016), optimal monetary policy (Airaudo and Olivero, 2019) and labor market dynamics (Shapiro and Olivero, 2020). To the best of my knowledge, this is the first paper that investigates the macroeconomic consequences of bank shocks in a model of lending relationships between banks and firms and analyzes their impact and transmission mechanism. In order to do so, I build a model in the vein of previous papers with deep habits in banking and introduce a time-varying shock to repayment of bank loans as in Clerc, Derviz, Mendicino, Moyen, Nikolov,

[2] See the discussion in Section 3.3 where I discuss the bank's problem in detail.

[3] This work is also connected to currently ongoing papers such as Sharma (2023a,b,c) that examine the effects of various macroeconomic shocks (such as shocks to collateral value, credit shocks defined as sudden spike in loans relative to deposits, and financial shocks defined as shocks to substitution of loan varieties) and how they interact with bank-firm credit relationships. None of these and other papers, however, study the effects of impairment of banks assets (loans in this case) by bank shocks when borrower-lender relationships matter.

Stracca, Suarez, and Vardoulakis (2015) who incorporate a bank shock in a model à la Bernanke, Gertler, and Gilchrist (1999) and focus on capital regulation of financial intermediaries. My work does not concern capital regulation and instead, focuses on macroeconomic consequences of a shock to bank loan repayments when bank-firm lending relationships are considered.

Roadmap

The structure of this paper is as follows. Section 2 briefly presents evidence on bank-firm lending relationships. Section 3 lays out the model. Section 4 discusses the model solution and parameterization. Section 5 presents and discusses the results. Section 7 concludes.

2 Evidence on Bank-Firm Lending Relationships

Ongena and Smith (2000a,b) document significant prevalence of bank-firm lending relationships across European countries and note that firms maintain multiple banking relationships. More recently, Kosekova, Maddaloni, Papoutsi, and Schivardi (2023, KMPS hereafter) use data from Eurosystem credit registry, AnaCredit[4], and document the structure of bank-firm relationships across eleven Euro area countries which together accounted for about 95% of Euro area nominal GDP in 2019 and 97.0% of the total outstanding bank credit in the Euro area at the end of 2019[5].

KMPS document that across Euro area countries, three clusters of banking relationships exist. In countries such as Italy, Spain and Portugal firms rely on multiple banks and large firms in these countries borrow on the average from four to five banks. The second group consists of countries like Germany, Austria, France, Greece, Finland and Belgium median large firm borrows from two banks. In the third group which includes countries like the Netherlands and Ireland, large firms borrow from one bank. These patterns hold true also for other size classes. They also note that consistent with the pattern documented before, the extent to which firms rely on the main bank which is measured by share of the credit of the main bank over total credit, is lowest for the first cluster and highest for the third. They report that across countries, long term instruments through which firms obtain credit such as loans and non-revolving credit

[4]AnaCredit is a new credit registry recently developed by the Eurosystem that covers all bank loans to corporations larger than Euro 25,000.

[5]These countries are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain.

lines are substantially cheaper and they find that reliance on long-term credit varies between more than 80% in France to less than 60% in Greece.

In terms of loan maturity, KMPS find very large cross-country differences. They report that large Dutch firms borrow at the longest maturity of 15 years while Irish firms borrow at the shortest maturity of 5 years. They also find that the relationship lending does not lead to lower rates which could be explained by the finding in the theoretical literature (Rajan, 1992) that main bank extracts part of the surplus that the relationship creates by charging higher rates.

Petersen and Rajan (1994, 1995) document presence of bank-firm lending relationships in the US. Further evidence for bank-firm lending relationships in the US comes from the market for syndicated loans which is roughly 50% of the corporate loans and it accounts for nearly two-thirds of lending with a maturity larger than 365 days (Chodorow-Reich, 2014). The average number of lenders in a syndicated loan in the US is 8 (Sufi, 2007).

3 Model

I build a discrete-time DSGE model and it bears resemblance to the setup in Iacoviello (2005), Liu, Wang, and Zha (2013) and Justiniano, Primiceri, and Tambalotti (2015). The departure from these papers is inclusion of a banking sector with borrower-lender credit relationships. It has (patient) households who consume, supply labor and make deposits with banks. Households are the ultimate owners of the banks and receive their profits. The (impatient) entrepreneurs, in turn, consume non-durable consumption good and run all the firms in the economy. They are subject to a collateral constraint which limits their borrowing to a fraction of expected value of their assets which include productive capital and land. The entrepreneurs borrow from banks and have endogenously-persistent credit relationships with them. Lending relationships in this paper are modelled using the deep habits framework which has been used in several papers such as Aliaga-Díaz and Olivero (2010); Aksoy, Basso, and Coto-Martinez (2013); Melina and Villa (2014, 2018); Ravn (2016); Airaudo and Olivero (2019) and Shapiro and Olivero (2020). Banks in this model raise deposits from households which is their only source of funding and lend them to entrepreneurs who combine them with productive capital to produce output. I introduce a bank shock to loan repayments in this model that can impair banks' assets (loans) and reduce their income[6][7]. In what follows, I describe each agent's optimization problem.

3.1 Households

Households have the utility function of the following form:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\beta^P\right)^t \left\{ \log\left(C_{i,t}^P - \gamma^P C_{i,t-1}^P\right) - \frac{N_{i,t}^{\eta}}{\eta} + \varsigma \log H_{i,t}^P \right\} \tag{1}$$

where $C_{i,t}^P$, $N_{i,t}$ and $H_{i,t}^P$ denote consumption, labor and housing respectively of the households, $\beta^P \in (0,1)$ is a discount factor, γ^P measures the degree of habit formation in consumption, η is Frisch elasticity of labor supply and ς is a weight on housing. The superscript P denotes (patient) households. The household faces the following budget constraint

$$C_{i,t}^P + Q_t^H \left(H_{i,t}^P - H_{i,t-1}^P\right) + \int_0^1 D_{ik,t} \mathrm{d}k \leq W_t N_{i,t} + \int_0^1 \Pi_{ik,t} \mathrm{d}k + R_{t-1}^D \int_0^1 D_{ik,t-1} \mathrm{d}k \tag{2}$$

where Q_t^H is the price of one unit of housing in terms of consumption goods, W_t is the real wage and R_{t-1}^D is the gross risk-free interest rate on the stock of deposits $D_{ik,t-1}$ of household i in bank k at the end of period $t-1$. I assume housing does not depreciate. Profits obtained by household i from bank k are denoted by $\Pi_{ik,t}$. After imposing symmetric equilibrium, FOCs of the households can be written as

$$\frac{1}{C_t^P - \gamma^P C_{t-1}^P} - \beta^P \mathbb{E}_t \frac{\gamma^P}{C_{t+1}^P - \gamma^P C_t^P} = \lambda_t^P \tag{3}$$

$$\beta^P \mathbb{E}_t \lambda_{t+1}^P = \frac{\lambda_t^P}{R_t^D} \tag{4}$$

$$\frac{\varsigma}{H_t^P} + \beta^P \mathbb{E}_t \left(\lambda_{t+1}^P Q_{t+1}^H\right) = \lambda_t^P Q_t^H \tag{5}$$

$$N_t^{\eta-1} = \lambda_t^P W_t \tag{6}$$

[6]The model here is not intended to capture large-scale financial crises or periods of severe distress in the financial markets. These times are usually characterized by massive losses suffered by financial intermediaries and highly nonlinear dynamics. There are models in the literature that are more appropriate for this kind of analysis which is not the focus of this study (see, for instance, Gertler and Kiyotaki, 2015 and Gertler, Kiyotaki, and Prestipino, 2020 for examples of discrete-time models and Brunnermeier and Sannikov, 2014 for an example of a continuous-time model). The model in this paper is solved using log-linear approximation around the steady state which rules out large, discontinuous shifts in economic dynamics.

[7]Because of the presence of this shock, bank's optimization problem in this model becomes very different from those in the previous papers which have used deep habits in banking. I elaborate more on this in Section 3.3.

where λ_t^P is the Lagrange multiplier associated with household's budget constraint (2). One can combine household's first-order conditions with respect to consumption (3) and bank deposits (4) to obtain their Euler equation. Equation (5) describes household's Euler equation for housing and links today's housing price to the utility it provides plus the expected capital gain. Equation (6) describes household's consumption-leisure tradeoff. First order conditions of the problem are derived in the Appendix A.

3.2 Entrepreneurs

Following Iacoviello (2005) and Liu, Wang, and Zha (2013), entrepreneur j maximizes the utility obtained from consuming the non-durable consumption goods

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\beta^E\right)^t \log\left(C_{j,t}^E - \gamma^E C_{j,t-1}^E\right) \tag{7}$$

where β^E and γ^E are as defined before. I assume that entrepreneurs are more impatient than the (patient) households, that is, $\beta^E < \beta^P$. Entrepreneurs face a collateral constraint as in Kiyotaki and Moore (1997) that limits the borrowing of each entrepreneur to a fraction of their assets

$$l_{jk,t} \leq \frac{1}{R_{k,t}^L} \theta a_{j,t} \tag{8}$$

Here, $l_{jk,t}$ denotes entrepreneur j's loan from bank k, expected value of entrepreneur's assets is $a_{j,t}$, θ is an LTV ratio and $R_{k,t}^L$ is the bank-specific lending rate. Expected valued of entrepreneur's assets $a_{j,t}$ is given by

$$a_{j,t} = \mathbb{E}_t\left(Q_{t+1}^H H_{j,t}^E + Q_{t+1}^K K_{j,t}\right) \tag{9}$$

In the above equation, Q_t^K denotes the value of installed capital in units of consumption goods, $K_{j,t}$ is stock of capital and $H_{j,t}^E$ stock of land or real estate[8].

Entrepreneurs have deep habits in banking relationships and I let $x_{j,t}$ denote entrepreneur j's effective or habit-adjusted borrowing. Given the continuum of banks in the economy who

[8] Chaney, Sraer, and Thesmar (2012) and Liu, Wang, and Zha (2013) emphasize the importance of real estate as collateral for business loans.

compete under monopolistic competition[9], this can be written as[10]

$$x_{j,t} = \left[\int_0^1 \left(l_{jk,t} - \gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k\right]^{\frac{\xi}{\xi-1}} \tag{10}$$

where stock of habits $s_{k,t-1}$ evolves according to[11]

$$s_{k,t-1} = \rho_s s_{k,t-2} + (1-\rho_s)\, l_{k,t-1} \tag{11}$$

Here, $\gamma^L \in (0,1)$ denotes the degree of habit formation in demand for loans and $\rho_s \in (0,1)$ measures the persistence of these habits. The term $\gamma^L s_{k,t-1}$ is intended to capture the borrower hold-up effect. The parameter ξ denotes the elasticity of substitution between loans from different banks and is thus a measure of the market power of each individual bank[12].

Given his total need for financing $x_{j,t}$, each entrepreneur chooses $l_{jk,t}$ to solve the following problem

$$\min_{l_{jk,t}} \int_0^1 R^L_{k,t} l_{jk,t} \mathrm{d}k \tag{12}$$

subject to collateral constraint (8) and his effective borrowing (10). The first order condition associated with this problem gives entrepreneur j's optimal demand for loans from bank k

$$l_{jk,t} = \left(\frac{R^L_{k,t}}{R^L_t}\right)^{-\xi} x_t + \gamma^L s_{k,t-1} \tag{13}$$

where $R^L_t \equiv \left[\int_0^1 (R^L_{k,t})^{1-\xi} \mathrm{d}k\right]^{\frac{1}{1-\xi}}$ is the aggregate lending rate. Equation (13) has an intuitive

[9]Extensive evidence points towards product differentiation in banking that makes financial services from different banks imperfectly substitutable from borrowers' point of view. Aliaga-Díaz and Olivero (2010) explain that bank can differentiate their loans by including with it other financial services that they provide together with the loan towards the particular sector of economic activity. These can include services such as firm monitoring, valuation of collateral and investment project evaluation. In addition, banks can also choose various quality characteristics to build reputation and differentiate from competitors like equity ratios, size and loss avoidance (Kim, Kristiansen, and Vale, 2005). Also, lenders use various product packages and the extensiveness and location of their branches (Northcott, 2004), personalized services, accessibility to bank executives, hours of operation and ATM, and remote access availability (Cohen and Mazzeo, 2004) to differentiate their services from those of competitors.

[10]Notice that when $\gamma^L = 0$, Equation (10) reduces to $x_{j,t} = \left[\int_0^1 (l_{jk,t})^{\frac{\xi-1}{\xi}} \mathrm{d}k\right]^{\frac{\xi}{\xi-1}}$.

[11]When $\rho_s = 0$, Equation (11) reduces to $s_{k,t-1} = l_{k,t-1}$, meaning that deep habit term entering Equation (10) reduces to the last period aggregate amount of loans from the bank k.

[12]Fama (1985) shows that, in absence of some degree of market power in lending, banks would be driven out of a competitive credit market by institutions with a lower cost of funds such as the market for commercial papers. There is extensive evidence for market power in loans market including, among others, Shaffer (1982); Nathan and Neave (1989); Molyneux, Lloyd-Williams, and Thornton (1994); Bikker and Groeneveld (2000); Hondroyiannis, Lolos, and Papapetrou (1999); De Bandt and Davis (2000); Bikker and Haaf (2002); Hempell (2002); Gelos and Roldos (2004); Claessens and Laeven (2004) and Matthews, Murinde, and Zhao (2007).

economic meaning and states that $l_{jk,t}$ is higher, the cheaper is borrowing from kth bank (i.e., lower $\frac{R^L_{k,t}}{R^L_t}$) and/or the stronger bank-firm relationship established with that bank (i.e., larger γ^L and/or $s_{k,t-1}$).

Production function of each entrepreneur is

$$Y_{j,t} = A_t \left(N_{j,t}\right)^{1-\alpha} \left\{ \left(H^E_{j,t-1}\right)^{\phi} \left(K_{j,t-1}\right)^{1-\phi} \right\}^{\alpha} \tag{14}$$

where $Y_{j,t}$ is output, $N_{i,t}$ is labor input and $\alpha, \phi \in (0,1)$ are factor shares. TFP A_t follows the process

$$\log A_t = (1-\rho_A)\log A + \rho_A \log A_{t-1} + \sigma_A \epsilon_{A,t} \tag{15}$$

with iid innovation $\epsilon_{A,t}$ following a normal process with standard deviation σ_A where $A > 0$ and $\rho_A \in (0,1)$. The evolution of capital obeys the following law of motion

$$K_{j,t} = (1-\delta) K_{j,t-1} + \left[1 - \frac{\Omega}{2}\left(\frac{I_{j,t}}{I_{j,t-1}} - 1\right)^2\right] I_{j,t} \tag{16}$$

where $I_{j,t}$ is firm j's investment level, $\delta \in (0,1)$ the rate of depreciation of capital stock and $\Omega > 0$ is a cost adjustment parameter. The entrepreneur faces the following budget constraint

$$C^E_{j,t} + \int_0^1 R^L_{k,t-1} l_{jk,t-1} \mathrm{d}k \leq Y_{j,t} - W_t N_{j,t} - I_{j,t} - Q^H_t \left(H^E_{j,t} - H^E_{j,t-1}\right) + x_{j,t} \tag{17}$$

After imposing symmetric equilibrium, the FOCs of the entrepreneurs are

$$\lambda^E_t = \frac{1}{C^E_t - \gamma^E C^E_{t-1}} - \beta^E \mathbb{E}_t \frac{\gamma^E}{C^E_{t+1} - \gamma^E C^E_t} \tag{18}$$

$$\lambda^E_t = \beta^E \mathbb{E}_t \lambda^E_{t+1} R^L_t + \mu^E_t R^L_t \tag{19}$$

$$W_t = (1-\alpha)\frac{Y_t}{N_t} \tag{20}$$

$$\lambda^E_t Q^H_t = \beta^E \mathbb{E}_t \left[\lambda^E_{t+1}\left(Q^H_{t+1} + \alpha\phi \frac{Y_{t+1}}{H^E_t}\right)\right] + \mu^E_t \theta \mathbb{E}_t Q^H_{t+1} \tag{21}$$

$$\kappa^E_t = \alpha(1-\phi)\beta^E \mathbb{E}_t\left(\frac{\lambda^E_{t+1} Y_{t+1}}{K_t}\right) + \beta^E (1-\delta)\mathbb{E}_t \kappa^E_{t+1} + \mu^E_t \theta \mathbb{E}_t Q^K_{t+1} \tag{22}$$

$$\lambda^E_t = \kappa^E_t \left[1 - \frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \Omega \frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right)\right] + \beta^E \Omega \mathbb{E}_t \left[\kappa^E_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 \left(\frac{I_{t+1}}{I_t} - 1\right)\right] \tag{23}$$

where μ_t^E, κ_t and λ_t^E are Lagrange multipliers associated with entrepreneur's collateral constraint (8), law of motion of capital (16) and entrepreneur's budget constraint (17). Entrepreneur's first order conditions with respect to consumption (18) and loans (19) may be combined to derive his Euler equation for consumption. Equation (20) describes entrepreneur's optimal demand for labor. Entrepreneur's Euler equation for land is described by (21) which relates its price today to its expected resale value tomorrow plus the payoff obtained by holding it for a period as given by its marginal productivity and its ability to serve as a collateral. Likewise, (22) is entrepreneur's Euler equation for capital and it links price of capital today to its price tomorrow and the expected payoff from keeping it for a period as given by its marginal productivity and its ability to serve as a collateral. Finally, entrepreneur's Euler equation for the investment is given by (23). All the derivations of first order conditions have been relegated to Appendix A.

3.3 Banking Sector

Banks in this model accept deposits from households and make loans to entrepreneurs. Banks take the interest rate on deposits R_t^D as given. Each individual bank k chooses its lending rate $R_{k,t}^L$ and its total amount of lending $L_{k,t}$. Its profit function is given by

$$\Pi_{k,t} = \Psi_t R_{k,t-1}^L L_{k,t-1} + \int_0^1 D_{ik,t} \mathrm{d}i - L_{k,t} - R_{t-1}^D \int_0^1 D_{ik,t-1} \mathrm{d}i \tag{24}$$

I assume that bank loan repayments are subject to a time-varying exogenous shock as in Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez, and Vardoulakis (2015). I call it a bank shock and it follows an AR(1) process given by Equation (25). It enters bank's profit function, making it different from those in other papers in the deep habits in banking literature such as Aliaga-Díaz and Olivero (2010); Aksoy, Basso, and Coto-Martinez (2013); Melina and Villa (2014, 2018); Ravn (2016); Airaudo and Olivero (2019) and Shapiro and Olivero (2020). The presence of this shock profoundly alters bank's optimization problem and as I show later in this section, changes the bank's behavior as governed by its two FOCs (28) and (29).

The bank shock here is a reduced-form way of modelling forces or developments that might negatively impact loan repayments (which is synonymous with bank revenue or income as this is the only way banks make money in this model). It can capture, for instance, a rise in loans turning bad or any other situation that causes a drop in loan repayments such as cases where banks have to restructure debts and accept haircuts on them or other scenarios where banks have to absorb asset writedowns. In sum, it's supposed to capture exogenous impairment of bank assets (in this case, loans)[13]. Its law of motion is given by

$$\log \Psi_t = (1-\rho_\Psi)\log \Psi + \rho_\Psi \log \Psi_{t-1} + \sigma_\Psi \epsilon_{\Psi,t} \tag{25}$$

where $\sigma_{\Psi,t}$ is the iid innovation which follows a normal distribution with standard deviation σ_Ψ and where $\Psi > 0$ and $\rho_\Psi \in (0,1)$. The balance sheet of bank k is[14]

$$L_{k,t} = \int_0^1 D_{ik,t} \mathrm{d}i \tag{26}$$

where $L_{k,t}$ denotes total loans made by bank k to all entrepreneurs, that is, $L_{k,t} \equiv \int_0^1 l_{jk,t}\mathrm{d}j$. Each bank takes the demand for its loans as given

$$L_{k,t} = \int_0^1 l_{jk,t}\mathrm{d}j = \int_0^1 \left[\left(\frac{R^L_{k,t}}{R^L_t}\right)^{-\xi} x_t + \gamma^L s_{k,t-1}\right]\mathrm{d}j \tag{27}$$

Each bank chooses $L_{k,t}$ and $R^L_{k,t}$ to maximize its profits subject to (26) and (27). Considering a symmetric equilibrium in which all banks optimally choose the same lending rate, the FOCs for banks' optimization problem are:

$$\varrho^E_t = \mathbb{E}_t q_{t,t+1}\left[\left(\Psi_t R^L_t - R^D_t\right) + \gamma^L (1-\rho_s)\mathbb{E}_t \varrho^E_{t+1}\right] \tag{28}$$

and

$$\xi \varrho^E_t x_t \frac{1}{R^L_t} = \mathbb{E}_t q_{t,t+1} \Psi_t L_{k,t} \tag{29}$$

where ϱ^E_t is the Lagrange multiplier on demand for bank's loans (27) and can be interpreted as shadow value to the bank of lending an extra dollar. Banks are owned by households and consequently their stochastic discount factor is given by $q_{t,t+1} = \beta^P \mathbb{E}_t \frac{\lambda^P_{t+1}}{\lambda^P_t}$. The optimality condition (28) states that shadow value of lending an extra dollar is given by repayment minus cost of borrowing that extra dollar from the households. Note that the repayment is subject to

[13] Admittedly, it's an abstraction. These shocks capture – directly or indirectly – losses to the banks caused by loan defaults or debt restructuring which are not exogenous. A richer model might capture the economic distress that might lead borrowers to default or seek restructuring of their debt. Having said that, my model provides a tractable setup to capture these effects in a simple way.

[14] Doerr, Drechsel, and Lee (2021) use Federal Deposit Insurance Corporation (FDIC) data and find that deposits account for 93% of total liabilities for the average bank between 1993 and 2015. This indicates that deposits are the major funding source for the US banking system.

a realization of the shock Ψ_t. The second term on the right-hand side reflects the fact that if a given bank lends an extra dollar in this period, the borrower of that dollar will develop a habit for loans from that bank and as a result, will borrow more from it also in the subsequent period. The size of this effect depends on degree γ^L and duration ρ_s of deep habits. In absence of deep habits (that is, when $\gamma^L = \rho_s = 0$), the latter term disappears.

Equation (29) equates the profit gain from a marginal increase in bank's lending rate to the marginal cost. Bank's marginal cost is on the left-hand side and indicates a loss in its market share as it increases its lending rate. The marginal benefit of a higher lending rate appears on the right-hand side and shows the discounted gain made by repayment of loans made at higher lending rates. The repayment of loans is affected by the shock Ψ_t. Because of the presence of bank shocks, bank's optimization problem becomes fundamentally different from those in the setups that do not account for this possibility. These two FOCs reflect that and are different from the standard FOCs in papers such as Aliaga-Díaz and Olivero (2010); Aksoy, Basso, and Coto-Martinez (2013); Melina and Villa (2014, 2018); Ravn (2016); Airaudo and Olivero (2019) and Shapiro and Olivero (2020). All the derivations of FOCs are contained in Appendix A.

3.4 Aggregation and Market Clearing

Aggregate resource constraint of the economy is

$$C_t^P + C_t^E + I_t = Y_t \tag{30}$$

The clearing condition for the housing market is

$$H_t^P + H_t^E = H \tag{31}$$

where H is the total fixed supply of housing.

4 Model Solution and Parameterization

A period in the model refers to a quarter. Appendices B, C and D contain the list of equilibrium equations, the list of steady-state conditions and the system of log-linear equations, respectively. The calibration of parameters is rather standard and is summarized in Table 1. I allow for a relatively significant difference between discount factors of households and entrepreneurs so that steady-state value of μ_t^E is different from zero. The degree of habit formation in consumption is chosen to be 0.6 which is in line with empirical estimates (Smets and Wouters, 2007). The Frisch elasticity of labor supply η is chosen to be 1.01 and the value of weight on housing ς is set to 0.1 (Iacoviello, 2005).

Table 1: Parameter values

	Value	Description	Source
β^P	0.995	Discount factor, households	Iacoviello (2005)
β^E	0.95	Discount factor, entrepreneurs	Iacoviello (2005)
γ^i, $i = \{P, E\}$	0.6	Habits in consumption, households, entrepreneurs	Smets and Wouters (2007)
η	1.01	Frisch elasticity of labor	Iacoviello (2005)
ς	0.1	Weight on utility from housing	Iacoviello (2005)
α	0.3	Non-labor share of production	Iacoviello (2005)
ϕ	0.1	Land share of non-labor input	Iacoviello (2005)
Ω	1.85	Investment adjustment cost parameter	Ravn (2016)
δ	0.0285	Capital depreciation rate	Ravn (2016)
θ	0.95	Loan-to-value ratio	Iacoviello (2015)
γ^L	0.72	Deep habit formation	Aliaga-Díaz and Olivero (2010); Melina and Villa (2014, 2018); Ravn (2016); Shapiro and Olivero (2020)
ρ_s	0.85	Persistence of stock of deep habits	Aliaga-Díaz and Olivero (2010); Melina and Villa (2014, 2018); Shapiro and Olivero (2020)
ξ	190	Elasticity of substitution between banks	Aliaga-Díaz and Olivero (2010)
ρ_A	0.95	Persistence of technology shock	Smets and Wouters (2007)
Ψ	1	Steady-state value of bank shock	Normalization
ρ_Ψ	0.90	Persistence of bank shock	See Text
σ_A	0.0014	Standard deviation of technology shock	Standard
σ_Ψ	0.01	Standard deviation of bank shock	See Text

The labor income share is 0.3 which implies a steady-state capital-output ratio of 1.15, in line with US data (Liu, Wang, and Zha, 2013). The input share of land in production is close to the value estimated in Liu, Wang, and Zha (2013) and Iacoviello (2005). The investment adjustment cost parameter is given a value of 1.85 (Ravn, 2016). The literature contains estimates which range from 0 (Liu, Wang, and Zha, 2013) to above 26 (Christiano, Motto, and Rostagno, 2010). The capital depreciation rate implies a steady-state ratio of non-residential investment to output slightly above 0.13 as in Beaudry and Lahiri (2014). I set the LTV ratio θ to 0.95 which is close the value 0.90 used in Iacoviello (2015).

For the parameters in the banking sector, I rely on Aliaga-Díaz and Olivero (2010) and other papers in the literature. As a baseline only, I set the deep habit parameter in lending γ^L to 0.72 (Aliaga-Díaz and Olivero, 2010; Melina and Villa, 2014; Ravn, 2016; Melina and Villa, 2018; Shapiro and Olivero, 2020) and the autocorrelation parameter in stock of habits in lending ρ_s to 0.85 used by Aliaga-Díaz and Olivero (2010); Melina and Villa (2014, 2018) and Shapiro and Olivero (2020). I later conduct two exercises in which I vary both the deep habit parameter in lending γ^L and the autocorrelation parameter in stock of habits ρ_s. These exercises allow me to capture in a transparent manner how changing intensity and persistence of lending relationships impact the effects of the bank shocks.

For elasticity of substitution between different loan varieties ξ, the literature contains a range of values from 190 (Aliaga-Díaz and Olivero, 2010) to 425 (Melina and Villa, 2014). Other values used in the literature are 230 (Ravn, 2016) and 396 (Melina and Villa, 2018). This is higher than elasticity of substitution typically used in models of monopolistic competition in goods market (for instance, Ravn, Schmitt-Grohé, and Uribe, 2006 use 5.3). However, as Aliaga-Díaz and Olivero (2010) argue, loans from different banks are likely to be much better substitutes than goods produced by different firms. This is also reflected in smaller observed markups (Ravn, 2016). This indicates that elasticity of substitution among different loan varieties should indeed be higher. I pick the value 190 as used in Aliaga-Díaz and Olivero (2010) which is towards the lower side of the numbers used in the literature.

Following Smets and Wouters (2007), I set the persistence of TFP shock to 0.95 and its standard deviation to 0.0014 which is standard in the literature. I normalize the steady-state value of bank shock Ψ to 1. For autocorrelation parameter of bank shock ρ_Ψ, I set a value of 0.90 and for standard deviation of bank shock σ_Ψ, I set a value of 0.011. I call these values baseline. Later, I run simulations with 50% higher volatility, that is, 0.0156 and a higher persistence of 0.99. These experiments show how the effects of bank shocks change at higher volatility and increased persistence and how these dynamics are affected by presence of bank-firm lending relationships.

5 Results and Discussion

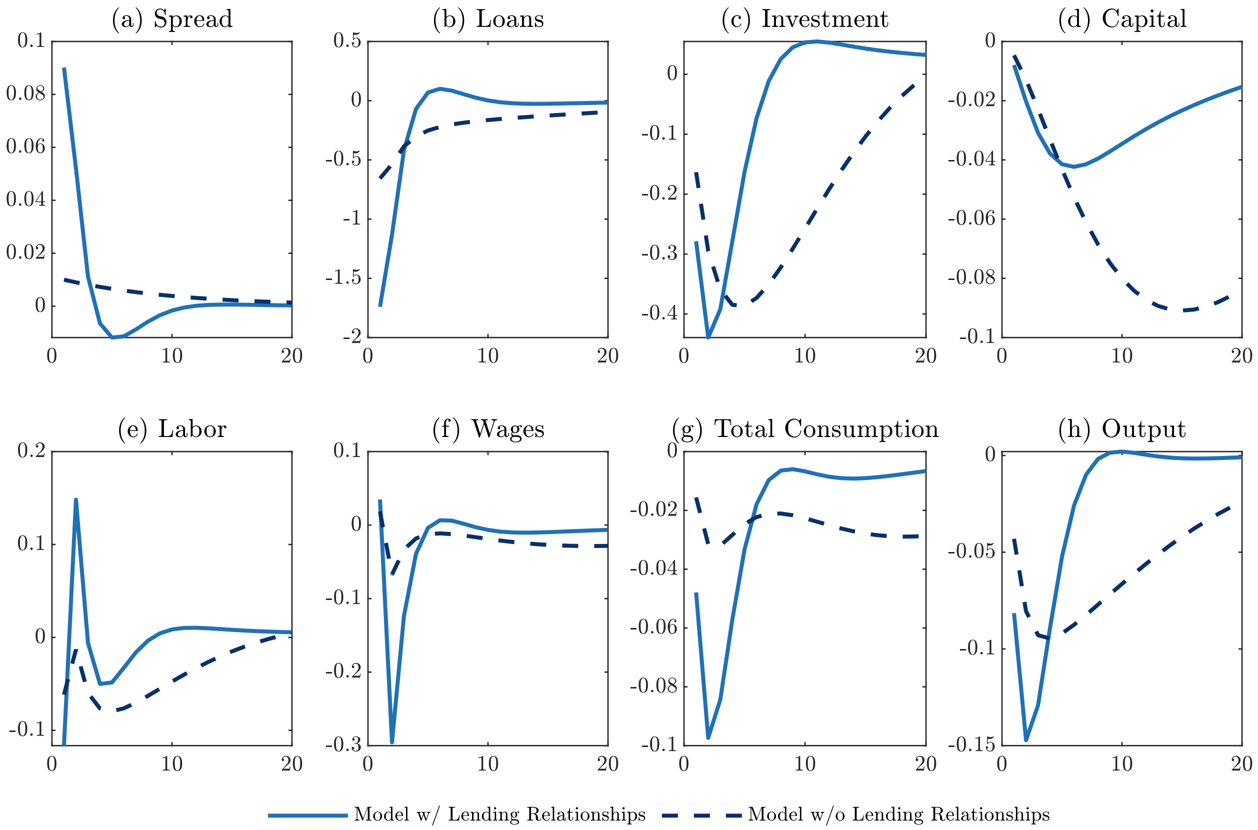
I discuss the effects of a bank shock in this section and compare the results in the two cases – when bank-firm credit relationships are considered and when they are turned off. Later, I show how changing the intensity and persistence of lending relationships affect the impact of bank shocks.

Figure 1 shows the effects of a bank shock on key macroeconomic variables. Consider first the case when credit relationships are present. After a bank shock, the spread between lending and deposit rates rises, making bank credit expensive. As a result, loans fall leading investment to decline on impact and resulting in a persistent slump in the stock of capital. This has knock-on effects on output and other macroeconomic variables. Bank credit recovers later when credit spread returns to its equilibrium, overshoots it and remains below it for several quarters. This makes bank loans cheaper and leads to a credit boom. This boosts investment, capital, consumption and output.

These dynamics are directly affected by presence of lending relationships implied by deep habits in banking. When a negative bank shock materializes, it reduces bank income. Banks respond to it by raising their interest in order to reduce their losses. Because of borrower hold-up, banks can raise interest more than the case when bank-firm lending relationships are absent (see the discussion below). This causes a spike in spread which leads to a fall in loans and investment. After initial spurt in spread, banks rapidly begin to lower their interest rate in order to lure more borrowers and "lock them in". They realize that, because of presence of deep habits in lending, these borrowers will be with them also in the future periods, yielding them higher profits. This results in spread falling below previous equilibrium and staying below it for some quarters. Because of this, bank credit becomes cheaper to obtain and it manifests itself in the form of a jump in bank loans and investment. This helps arrest the decline in capital stock precipitated by initial fall in bank loans and investment, and paves the way for the economic activity to recover.

When lending relationships are turned off (that is, $\gamma^L = \rho_s = 0$), a bank shock leads to a comparatively smaller but highly persistent jump in spread. Because the spread remains elevated for a prolonged period, bank credit becomes expensive and declines persistently. This presages a persistent decline in investment, capital, consumption and output. Unlike the previous case when bank-firm credit relationships are taken into account, macroeconomic activity does not

FIGURE 1: EFFECTS OF A BANK SHOCK



NOTE: Numbers on the horizontal axis represent quarters since the shock. Numbers on the vertical axis show percentage deviation from the steady state.

recover for a long time. Labor and wages remain depressed persistently. These effects are in line with evidence documented by numerous studies that look at effects of credit disruptions (Calvo, Coricelli, and Ottonello, 2014; Chodorow-Reich, 2014; Bernanke, 2018).

Why do bank shocks cause initially smaller but much more persistent fall in economic activity, when bank-firm credit relationships are abstracted from? The mechanism behind these differential dynamics is as follows and it is a sum of two forces. First, absent bank-firm credit relationships, banks raise interest rate after a negative bank shock, causing a spike in spread. This jump in spread, however, is comparatively smaller but persistent. Because the economy does not feature borrower hold-up in this case, banks lose the ability to raise interest rate as much as in the alternative case when bank-firm lending relationships are present. Second, because of absence of deep habits in banking, banks do not have this calculus in their mind that borrowers will be with them also in the future periods which in the previous case (of bank-firm credit relationships), leads them to lower their interest rapidly after the initial spike. Consequently, spread does not quickly return to its previous equilibrium, making bank credit persistently expensive which has snowball effects on the wider economy.

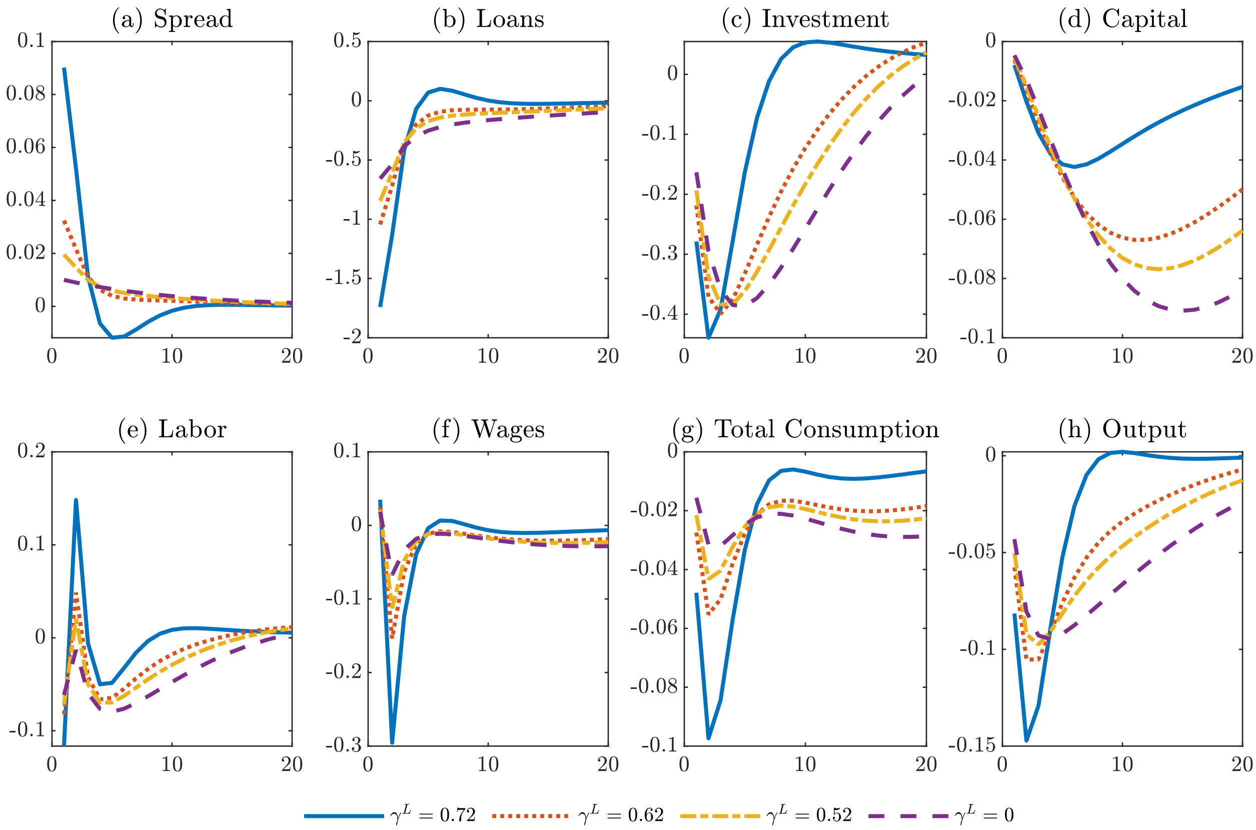
These findings indicate how bank-firm credit relationships possess dual facets. They can initially lead to an amplification of bank shocks but can also aid a faster economic recovery later on. These economic dynamics are starkly different in an economy which features no bank-firm lending relationships. In this case, bank shocks cause highly persistent economic slump and the economy witnesses a slower recovery.

I now turn to how these macroeconomic dynamics change with changing intensity and persistence of lending relationships. The purpose of this exercise is two-fold. On the one hand, it helps understand how intensity and persistence of credit relationships impact the effects of bank shocks. On the other hand, it serves as a robustness check. I perform two experiments. In the first exercise, I vary the intensity of lending relationships while keeping all other parameters fixed at their baseline value. This allows me to capture transparently the impact of changing intensity of lending relationships on effects of bank shocks. I then perform a second exercise in which I vary the persistence of lending relationships while keeping other parameters fixed at their initial value. This allows me to capture how changing persistence of lending relationships affects the impact of bank shocks.

Figure 2 show the impulse response functions after a bank shock at different levels of intensity of lending relationships. I consider four different values – 0.72 which has been used in the baseline calibration, 0.62, 0.52, and 0 which corresponds to the case of no lending relationships. It can readily be seen that the effects of bank shocks are increasing in the intensity of lending relationships with spread rising more at greater intensity of lending relationships and causing a bigger knock-on impact on loans, investment and wider economy. Why is this so? Recall that as Equation (10) shows, the borrower hold-up is given by $\gamma^L s_{k,t-1}$. A higher value of the parameter γ^L which governs the intensity of lending relationships, implies a larger borrower hold-up which is exploited by banks. This is why spread displays a larger spike at higher value of γ^L which causes knock-on effects on macroeconomic activity.

I now examine how changing persistence of lending relationships affects the impact of the bank shocks. Figure 3 shows the impulse response functions of select variables to a bank shock at various levels of persistence of lending relationships. I consider three different levels of persistence – 0.85 which has been used in the baseline calibration, 0.75 and 0.65. I call them high persistence, intermediate persistence and low persistence, respectively. Consistent with the observation in Figure 2, it's apparent that bank shocks have larger impact at greater persistence of lending relationships. The effects follow the usual mechanism of larger spike in spread, followed by fall

Figure 2: Bank Shock and Intensity of Lending Relationships

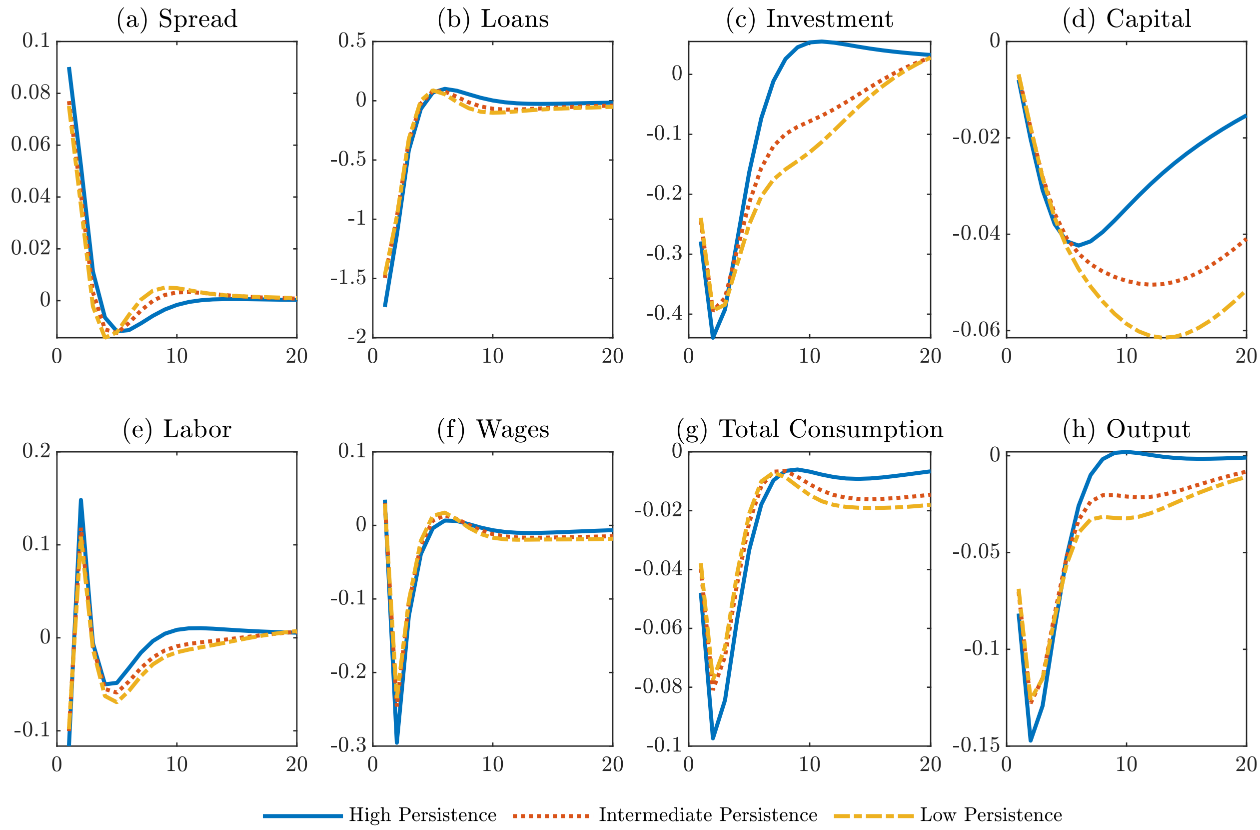


Note: Except intensity of lending relationships parameter γ^L, all other parameters held fixed at their baseline value in Table 1. Numbers on the horizontal axis represent quarters since the shock. Numbers on the vertical axis show percentage deviation from the steady state.

in bank credit, investment and economic activity. Again, the underlying logic is that greater persistence of stock of habits in borrowing ρ_s results in larger borrower hold-up given by the term $\gamma^L s_{k,t-1}$ in Equation (10). Banks exploit it when negative bank shocks materialize, causing a bigger spike in spread which has ripple effects on provision of bank credit, investment and wider economic activity.

To sum up, I have shown in this section that bank shocks cause persistent decline in macroeconomic activity in an economy which ignores the presence of bank-firm credit relationships. In the alternate version of the economy which does feature bank-firm credit relationships, bank shocks have significantly larger initial effects but the economic activity recovers faster later on boosted by a resurgence in bank loans driven by falling spread. I also run two experiments in which I show that effects of bank shocks are increasing in the intensity and persistence of bank-firm credit relationships since they increase the borrower hold-up effect.

Figure 3: Bank Shock and Persistence of Lending Relationships



Note: Except persistence of stock of habits in lending parameter ρ_s, all other parameters held fixed at their baseline value in Table 1. Numbers on the horizontal axis represent quarters since the shock. Numbers on the vertical axis show percentage deviation from the steady state.

6 Further Quantitative Exercises

So far, I have not considered how the effects of bank shocks change when its volatility or persistence changes. To answer these questions, I now conduct two additional exercises in which I vary the persistence and volatility of the bank shock. My interest here is to unveil how changing persistence and volatility of the bank shocks interact with bank-firm credit relationships and to explain resulting economic dynamics. In the first exercise, I raise the persistence of the bank shock from 0.90 to 0.99. I then simulate the model both with and without lending relationships. I then conduct a second exercise in which I raise the volatility of the bank shock by 50% from 0.01 to 0.015. I then, again simulate the model with and without lending relationships.

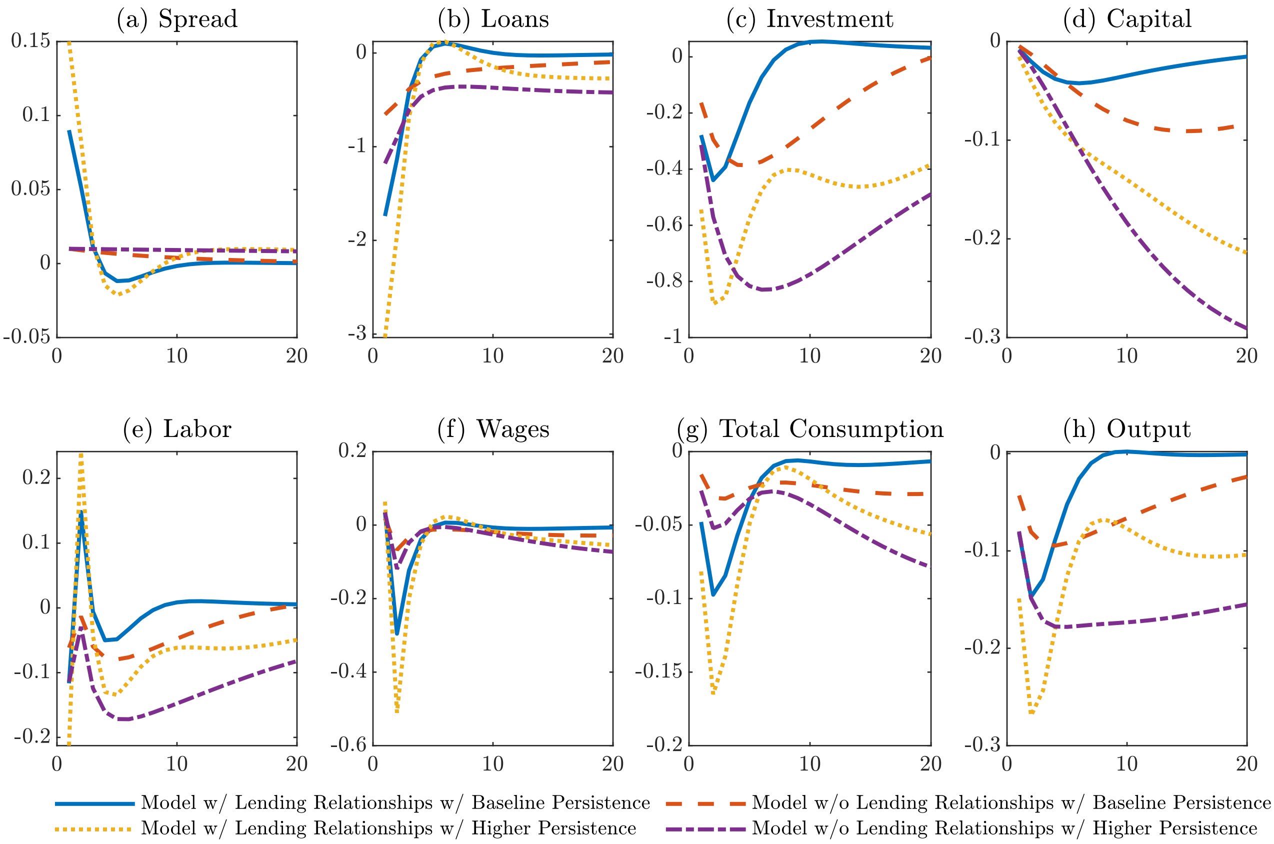
Figure 4 shows the impulse response functions of select variables. Consider first the case with lending relationships. At higher persistence of the bank shock, spread jumps more which makes bank credit prohibitively expensive. As a result, bank lending collapses which leads to a large and persistent fall in investment. This causes a highly persistent slump in capital stock. Wages initially fall before jumping back but they don't fully recover which is owing to the fact that investment and capital are persistently low. The sum of these effects manifests itself in the form of a sustained slump in aggregate consumption and output. Note that consumption and output recover at baseline persistence but at higher persistence of bank shock, these effects change and lead to a prolonged reduction in investment, capital, aggregate consumption and output. It, however, is worth noting that these effects are still cushioned by presence of bank-firm lending relationships in the sense that these effects are much larger when bank-firm lending relationships are ignored.

What explains these persistent effects? Because of presence of bank-firm credit relationships, banks initially raise their spread more after a more persistent bank shock as they scramble to protect their profits. This causes a larger fall in bank credit and investment which cascades through the economic system. Consistent with the baseline results discussed earlier, spread rapidly falls after the initial spike as banks rush to lower their interest rates to lure more borrowers. However, after spread has been low for some time, it begins to rise and remains elevated for a prolonged period. This is because after a more persistent bank shocks, banks raise their interest rates persistently to make up for the losses in their income. This prolonged surge in spread then gives rise to persistent decline in bank loans, investment and other macroeconomic variables.

When bank-firm lending relationships are turned off (corresponding to the case of $\gamma^L = \rho_s = 0$), bank shocks cause a smaller but persistent spike in spread. The spread remains more elevated at greater persistence of the bank shock causing a bigger fall in bank loans and an accompanying greater fall in macroeconomic activity. Because the economy in this case features no deep habits in lending implied by bank-firm credit relationships, banks can neither raise the interest rate as much as in the case of bank-firm credit relationships, nor do they rapidly lower it after initial spike to lure and lock in more customers. This causes spread to remain persistently high with its attendant negative economic consequences.

I now investigate how changes in volatility of bank shocks interact with bank-firm lending relationships and affect macroeconomic outcomes. Figure 5 plots the impulse response functions of select variables both at the baseline and at higher volatility of the bank shocks. Analogous to the previous case in which I examined effects of bank shocks both at the baseline and at higher persistence, in this case too bank shocks exhibit greater impact at higher volatility. These effects are transmitted through their impact on spread which spikes more at greater volatility of the

Figure 4: Bank Shock and Its Persistence

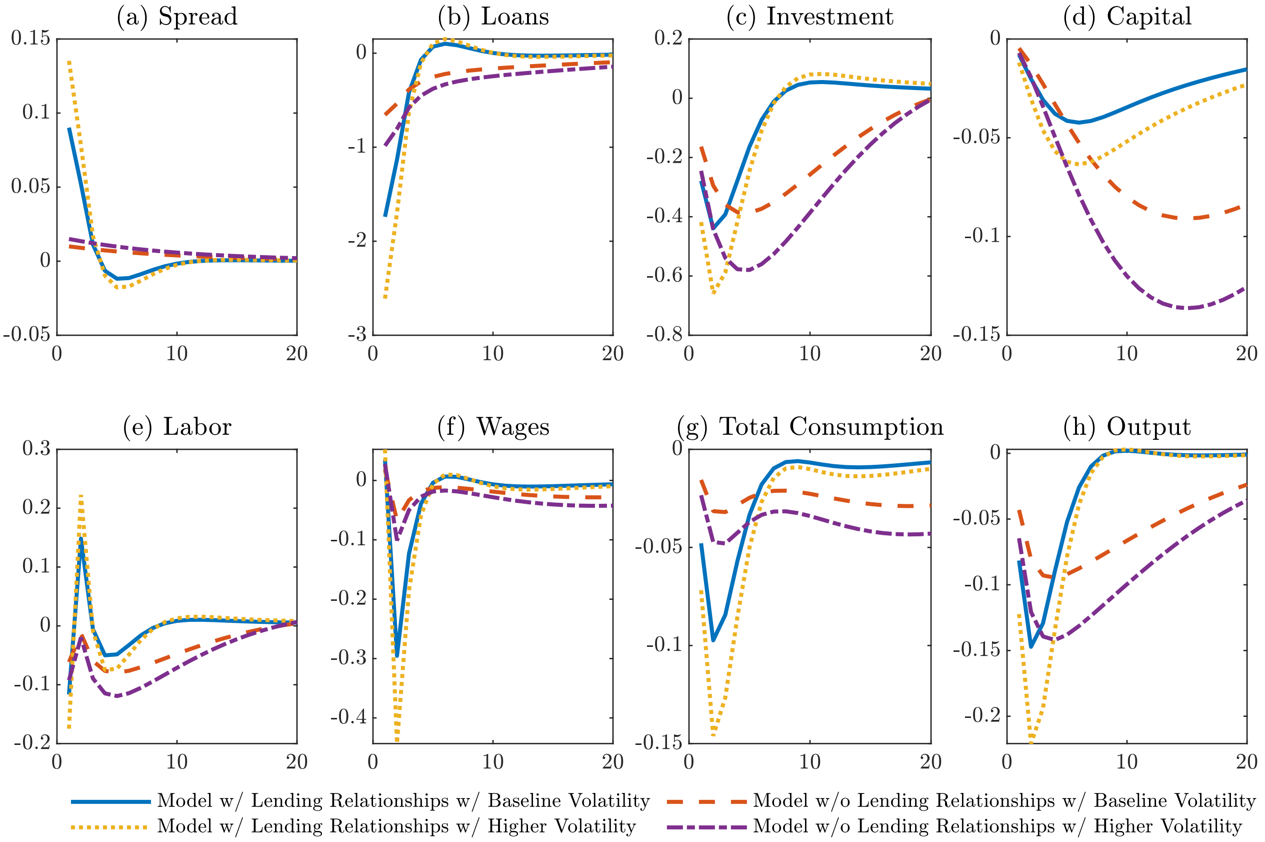


Note: Except persistence of bank shock parameter ρ_Ψ, all other parameters held fixed at their baseline value in Table 1. Numbers on the horizontal axis represent quarters since the shock. Numbers on the vertical axis show percentage deviation from the steady state.

bank shock. Interestingly, in presence of bank-firm credit relationships, macroeconomic activity almost goes back to the same equilibrium as the bank shock with baseline volatility. This is so because banks, after initial spike in spread, lower it and take it to the previous equilibrium, restoring bank credit which stabilizes the larger macroeconomy.

Absent bank-firm credit relationships, however, the bank shocks have sizable and persistent effects on economic activity at greater volatility. In this case also, the effects are transmitted through jump in spread which, though comparatively smaller, remains elevated for a prolonged period. This causes a sustained decline in provision of bank credit which leaves pernicious impact on macroeconomic activity. Absence of deep habits in banking in this case means that banks do not lower their interest rates, and do not make attempts to lure and lock in more borrowers. As a consequence, spread remains persistently high causing a prolonged slump in economic activity.

Figure 5: Bank Shock and Its Volatility



Note: Except volatility of bank shock parameter σ_Ψ, all other parameters held fixed at their baseline value in Table 1. Numbers on the horizontal axis represent quarters since the shock. Numbers on the vertical axis show percentage deviation from the steady state.

7 Concluding Remarks

It is known that credit disruptions have significant and persistent negative impact on the macroeconomy (Reinhart and Rogoff, 2009a; Bernanke, 2018). This paper examines how shocks originating in the financial sector can have severe consequences for both financial variables and real activity and how the effects of these shocks are impacted by the pervasive presence of credit relationships between banks and firms. I show that shocks that affect bank loan repayments or 'bank shocks', can have profound implications for economic activity. Using a parsimonious model that takes into account presence of borrower-lender credit relationships, I show that a bank shock causes huge surge in credit spread as banks scramble to compensate for loss in their revenues. Bank loans fall significantly as bank credit becomes prohibitively expensive. In the version of the model in which credit relationships are turned off, economic activity displays a persistent slowdown or a scarring effect. When bank-firm lending relationships are present, bank credit recovers after falling more initially. Faster recovery in provision of credit to real sector boosts investment which results in a faster macroeconomic recovery. These effects are starkly different in the version of the model that ignores borrower-lender credit relationships.

The results in this paper highlight the important role that bank-firm credit relationships can play in shaping macroeconomic outcomes after a bank shock. They also suggest that these lending relationships can affect macroeconomic activity in interesting and important ways. In this study, they play dual role – they both amplify the initial negative impact of the bank shocks but then also assist the macroeconomic recovery later on. This indicates that models that abstract from this pervasive characteristic of the banking sector may underestimate the impact and nature of these shocks and might miss important economic dynamics.

My goal in this paper has been to build a simple and tractable model that shows transparently the forces at play. In order to do this and to keep the analysis focussed, there are many other important issues in the banking sector that I abstract from in this work. These are interesting questions such as presence of other financial intermediaries, lending relationships between banks and households, and effects of other shocks. I leave these questions for future work.

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Appendix (For Online Publication)

Real Effects of Bank Shocks

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Contents

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A Derivation of FOCs

A.1 Households

The Lagrangian of patient households is

$$\mathscr{L}_t = \mathbb{E}_t \left\{ \sum_{t=0}^{\infty} \left(\beta^P\right)^t \left[\begin{array}{c} \log\left(C_{i,t}^P - \gamma^P C_{i,t-1}^P\right) - \frac{N_{i,t}^{\eta}}{\eta} + \varsigma \log H_{i,t}^P \\ -\lambda_{i,t}^P \left[\begin{array}{c} C_{i,t}^P + Q_t^H \left(H_{i,t}^P - H_{i,t-1}^P\right) + \int_0^1 D_{ik,t} \mathrm{d}k \\ -W_t N_{i,t} - \int_0^1 \Pi_{ik,t} \mathrm{d}k - R_{t-1}^D \int_0^1 D_{ik,t-1} \mathrm{d}k \end{array} \right] \end{array} \right] \right\} \tag{A.1}$$

The problem yields the following first order conditions (here, I ignore all the i's denoting individual patient households):

$$\frac{\partial \mathscr{L}}{\partial C_t^P} : \frac{1}{C_t^P - \gamma^P C_{t-1}^P} - \beta^P \mathbb{E}_P \frac{\gamma^P}{C_{t+1}^P - \gamma^P C_t^P} = \lambda_t^P \tag{A.2}$$

$$\frac{\partial \mathscr{L}}{\partial D_t} : \beta^P \mathbb{E}_t \lambda_{t+1}^P = \frac{\lambda_t^P}{R_t^D} \tag{A.3}$$

$$\frac{\partial \mathscr{L}}{\partial H_t^P} : \frac{\varsigma}{H_t^P} + \beta^P \mathbb{E}_t \left(\lambda_{t+1}^P Q_{t+1}^H\right) = \lambda_t^P Q_t^H \tag{A.4}$$

$$\frac{\partial \mathscr{L}}{\partial N_t^P} : N_t^{\eta-1} = \lambda_t^P W_t \tag{A.5}$$

A.2 Entrepreneurs

Entrepreneur's optimization problem features two parts. The first part consists of choosing how much to borrow from each individual bank, $l_{jk,t}$ to minimize his total interest rate expenditure. This problem can be framed as

$$\min_{l_{jk,t}} \left[\int_0^1 R_{k,t}^L l_{jk,t} \mathrm{d}k\right] - \chi_t^E \left[x_{j,t} - \left(\int_0^1 \left(l_{jk,t} - \gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k \right)^{\frac{\xi}{\xi-1}} \right] \tag{A.6}$$

The first order condition for this problem is

$$R_{k,t}^L = -\frac{\xi}{\xi-1} \chi_t^E \left(\int_0^1 \left(l_{jk,t} - \gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k \right)^{\frac{1}{\xi-1}} \frac{\xi-1}{\xi} \left(l_{jk,t} - \gamma^L s_{k,t-1}\right)^{-\frac{1}{\xi}} \tag{A.7}$$

This can be rewritten as

$$
\begin{aligned}
R_{k,t}^{L} &= -\chi_t^E \left(\int_0^1 \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k\right)^{\frac{1}{\xi-1}} \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{-\frac{1}{\xi}} \\
R_{k,t}^{L}\left(l_{jk,t}-\gamma^L s_{k,t-1}\right) &= -\chi_t^E \left(\int_0^1 \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k\right)^{\frac{1}{\xi-1}} \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \\
\int_0^1 R_{k,t}^{L}\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)\mathrm{d}k &= -\chi_t^E \left(\int_0^1 \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k\right)^{\frac{1}{\xi-1}} \int_0^1 \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k \\
\int_0^1 R_{k,t}^{L}\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)\mathrm{d}k &= -\chi_t^E \left(\int_0^1 \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k\right)^{\frac{\xi}{\xi-1}} \qquad \text{(A.8)}
\end{aligned}
$$

Now, using $\left(\int_0^1 \left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}} \mathrm{d}k\right)^{\frac{\xi}{\xi-1}} = x_{j,t}$, the previous equation can be written as

$$
x_{j,t} = -\frac{1}{\chi_t^E}\left[\int_0^1 R_{k,t}^{L}\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)\mathrm{d}k\right] \qquad \ddagger
$$

Define the aggregate lending rate as $R_t^L \equiv \left[\int_0^1 \left(R_{k,t}^L\right)^{1-\xi}\right]^{\frac{1}{1-\xi}}$ and note that at the optimum, the following condition must hold

$$
R_t^L x_{j,t} = \int_0^1 R_{k,t}^{L}\left(l_{jk,t}^E-\gamma^L s_{k,t-1}^E\right)\mathrm{d}k
$$

Now, ‡ can be rewritten as

$$
\begin{aligned}
x_{j,t} &= -\frac{1}{\chi_t^E}\left[R_t^L x_{j,t}\right] \\
-\chi_t^E &= R_t^L
\end{aligned}
$$

Inserting this in first order condition (A.8)

$$
\begin{aligned}
R^L_{k,t} &= -\frac{\xi}{\xi-1}\chi^E_t\left(\int_0^1\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}}\mathrm{d}k\right)^{\frac{1}{\xi-1}}\frac{\xi-1}{\xi}\left(l_{j,t}-\gamma^L s_{k,t-1}\right)^{-\frac{1}{\xi}}\\
R^L_{k,t} &= R^L_t\left(\int_0^1\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)\mathrm{d}k\right)^{\frac{1}{\xi-1}}\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{-\frac{1}{\xi}}\\
R^L_{k,t} &= R^L_t\left(x_t\right)^{\frac{1}{\xi}}\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{-\frac{1}{\xi}}\\
\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{1}{\xi}} &= \left(x_t\right)^{\frac{1}{\xi}}\frac{R^L_t}{R^L_{k,t}}\\
l_{jk,t} &= \left(\frac{R^L_t}{R^L_{k,t}}\right)^{\xi}x_t+\gamma^L s_{k,t-1}\\
l_{jk,t} &= \left(\frac{R^L_{k,t}}{R^L_t}\right)^{-\xi}x_t+\gamma^L s_{k,t-1}
\end{aligned}
$$

The second part of entrepreneur's optimization problem can be written as

$$
\mathscr{L}_t = \mathbb{E}_t\left\{\sum_{t=0}^{\infty}\left(\beta^E\right)^t\left[\begin{array}{c}
\log\left(C^E_{j,t}-\gamma^E C^E_{j,t-1}\right)\\
-\lambda^E_{j,t}\left[\begin{array}{c}C^E_{j,t}+R^L_{k,t-1}\int_0^1 l_{jk,t-1}\mathrm{d}k-Y_{j,t}+W_tN_{j,t}+I_{j,t}\\ +Q^H_t\left(H^E_{j,t}-H^E_{j,t-1}\right)-x_{j,t}\end{array}\right]\\
-\mu^E_{j,t}\left[R^L_{k,t}\int_0^1 l_{jk,t}\mathrm{d}k-\int_0^1\theta\mathrm{d}k\mathbb{E}_t\left(Q^H_{t+1}H^E_{j,t}+Q^K_{t+1}K_{j,t}\right)\right]\\
-\kappa^E_{j,t}\left[K_{j,t}-\left(1-\delta\right)K_{j,t-1}-\left\{1-\frac{\Omega}{2}\left(\frac{I_{j,t}}{I_{j,t-1}}-1\right)^2\right\}I_{j,t}\right]\\
-\epsilon^E_{j,t}\left[x_{j,t}-\left\{\int_0^1\left(l_{jk,t}-\gamma^L s_{k,t-1}\right)^{\frac{\xi-1}{\xi}}\mathrm{d}k\right\}^{\frac{\xi}{\xi-1}}\right]
\end{array}\right]\right\} \tag{A.9}
$$

where $Y_{j,t} = A_t\left(N_{j,t}\right)^{1-\alpha}\left\{\left(H^E_{j,t-1}\right)^{\phi}\left(K_{j,t-1}\right)^{1-\phi}\right\}^{\alpha}$ may be inserted for $Y_{j,t}$ in the budget constraint. Solving entrepreneur's optimization problem, the first order conditions are (I ignore all

j's here):

$$\frac{\partial \mathcal{L}}{\partial C_t^E}: \frac{1}{C_t^E - \gamma^E C_{t-1}^E} - \beta^E \mathbb{E}_t \frac{\gamma^E}{C_{t+1}^E - \gamma^E C_t^E} = \lambda_t^E \tag{A.10}$$

$$\frac{\partial \mathcal{L}}{\partial x_t}: \lambda_t^E = \epsilon_t^E \tag{A.11}$$

$$\frac{\partial \mathcal{L}}{\partial l_t}: \epsilon_t^E = \beta^E \mathbb{E}_t \lambda_{t+1}^E R_t^L + \mu_t^E R_t^L \tag{A.12}$$

$$\frac{\partial \mathcal{L}}{\partial N_t}: W_t = (1-\alpha)\frac{Y_t}{N_t} \tag{A.13}$$

$$\frac{\partial \mathcal{L}}{\partial H_t^E}: \lambda_t^E Q_t^H = \beta^E \mathbb{E}_t \left\{ \lambda_{t+1}^E \left(Q_{t+1}^H + \alpha\phi \frac{Y_{t+1}}{H_t^E} \right) \right\} + \mu_t^E \theta \mathbb{E}_t Q_{t+1}^H \tag{A.14}$$

$$\frac{\partial \mathcal{L}}{\partial K_t}: \kappa_t^E = \alpha (1-\phi) \beta^E \mathbb{E}_t \left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t} \right) + \beta^E (1-\delta) \mathbb{E}_t \kappa_{t+1}^E + \mu_t^E \theta \mathbb{E}_t Q_{t+1}^K \tag{A.15}$$

$$\frac{\partial \mathcal{L}}{\partial I_t}: \lambda_t^E = \kappa_t^E \left\{ 1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \Omega \frac{I_t}{I_{t-1}} \left(\frac{I_t}{I_{t-1}} - 1 \right) \right\} + \beta^E \Omega \mathbb{E}_t \left\{ \kappa_{t+1}^E \left(\frac{I_{t+1}}{I_t} \right)^2 \left(\frac{I_{t+1}}{I_t} - 1 \right) \right\} \tag{A.16}$$

Using $\lambda_t^E = \epsilon_t^E$ from (A.11), (A.12) becomes

$$\beta^E \mathbb{E}_t \left(\lambda_{t+1}^E R_t^L \right) + \mu_t^E R_t^L = \lambda_t^E \tag{A.17}$$

A.3 Banks

The problem of banks is to choose their lending rate and the total amount of lending. The bank considers deep habits in loan demand. The bank solves the following problem

$$\max_{L_{k,t}, R_{k,t}^L} \Pi_t = \Psi_t R_{k,t-1}^L L_{k,t-1} - R_{t-1}^D L_{k,t-1} + \varrho_t^E \left(\int_0^1 \left[\left(\frac{R_t^L}{R_{k,t}^L} \right)^\xi x_t + \gamma^L s_{k,t-1} \right] \mathrm{d}j - L_{k,t} \right)$$

The first order condition for $L_{k,t}$ is

$$\mathbb{E}_t q_{t,t+1} \Psi_t R_{k,t}^L - \mathbb{E}_t q_{t,t+1} R_t^D + \gamma^L (1-\rho_s) \mathbb{E}_t \left(q_{t,t+1} \varrho_{t+1}^E \right) - \varrho_t^E = 0$$

Rearranging terms

$$\varrho_t^E = \mathbb{E}_t q_{t,t+1} \left[\left(\Psi_t R_{k,t}^L - R_t^D \right) + \gamma^L (1-\rho_s) \mathbb{E}_t \varrho_{t+1}^E \right] \tag{A.18}$$

The first order condition for $R^L_{k,t}$ is

$$\mathbb{E}_t q_{t,t+1}\Psi_t L_{k,t} + \xi \varrho^E_t \left(\frac{R^L_t}{R^L_{k,t}}\right)^{\xi-1} x_t \left(\frac{-R^L_t}{\left(R^L_{k,t}\right)^2}\right) = 0$$

Moving terms around

$$\mathbb{E}_t q_{t,t+1}\Psi_t L_{k,t} = \xi \varrho^E_t x_t \left(\frac{R^L_t}{R^L_{k,t}}\right)^{\xi-1} \left(\frac{R^L_t}{\left(R^L_{k,t}\right)^2}\right) \tag{A.19}$$

In a symmetric equilibrium all banks have the same lending rate $R^L_{k,t} = R^L_t, \forall k$ and consequently lend the same amount $L_{k,t} = L_t, \forall k$. Bank's first order condition in this case can be rewritten as

$$\varrho^E_t = \mathbb{E}_t q_{t,t+1}\left[\left(\Psi_t R^L_t - R^D_t\right) + \gamma^L\left(1-\rho_s\right)\mathbb{E}_t \varrho^E_{t+1}\right] \tag{A.20}$$

$$\frac{\xi \varrho^E_t x_t}{R^L_t} = \mathbb{E}_t q_{t,t+1}\Psi_t L_t \tag{A.21}$$

where I have imposed $L_t = l_t$ in a symmetric equilibrium.

B List of Equations

B.1 Households

$$\frac{1}{C^P_t - \gamma^P C^P_{t-1}} - \beta^P \mathbb{E}_t \frac{\gamma^P}{C^P_{t+1} - \gamma^P C^P_t} = \lambda^P_t \tag{B.1}$$

$$\beta^P \mathbb{E}_t \lambda^P_{t+1} = \frac{\lambda^P_t}{R^D_t} \tag{B.2}$$

$$\frac{\varsigma}{H^P_t} + \beta^P \mathbb{E}_t\left(\lambda^P_{t+1} Q^H_{t+1}\right) = \lambda^P_t Q^H_t \tag{B.3}$$

$$N^{\eta-1}_t = \lambda^P_t W_t \tag{B.4}$$

B.2 Entrepreneurs

$$\frac{1}{C^E_t - \gamma^E C^E_{t-1}} - \beta^E \mathbb{E}_t \frac{\gamma^E}{C^E_{t+1} - \gamma^E C^E_t} = \lambda^E_t \tag{B.5}$$

$$\beta^E \mathbb{E}_t\left(\lambda^E_{t+1} R^L_t\right) + \mu^E_t R^L_t = \lambda^E_t \tag{B.6}$$

$$W_t = (1-\alpha)\frac{Y_t}{N_t} \tag{B.7}$$

$$\lambda_t^E Q_t^H = \beta^E \mathbb{E}_t\left\{\lambda_{t+1}^E\left(Q_{t+1}^H + \alpha\phi\frac{Y_{t+1}}{H_t^E}\right)\right\} + \mu_t^E\theta\mathbb{E}_t Q_{t+1}^H \tag{B.8}$$

$$\kappa_t^E = \alpha(1-\phi)\beta^E\mathbb{E}_t\left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t}\right) + \beta^E(1-\delta)\mathbb{E}_t\kappa_{t+1}^E + \mu_t^E\theta\mathbb{E}_t Q_{t+1}^K \tag{B.9}$$

$$\lambda_t^E = \kappa_t^E\left\{1-\frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 - \Omega\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}}-1\right)\right\} + \beta^E\Omega\mathbb{E}_t\left\{\kappa_{t+1}^E\left(\frac{I_{t+1}}{I_t}\right)^2\left(\frac{I_{t+1}}{I_t}-1\right)\right\} \tag{B.10}$$

$$s_t = \rho_s s_{t-1} + (1-\rho_s) l_t \tag{B.11}$$

$$x_t = \left(l_t - \gamma^L s_{t-1}\right) \tag{B.12}$$

$$L_t = l_t \tag{B.13}$$

$$C_t^E + R_{t-1}^L l_{t-1} = Y_t - W_t N_t - I_t - Q_t\left(H_t^E - H_{t-1}^E\right) + x_t \tag{B.14}$$

$$l_t = \frac{\theta a_t}{R_t^L} \tag{B.15}$$

$$a_t = \mathbb{E}_t\left(Q_{t+1}^H H_t^E + Q_{t+1}^K K_t\right) \tag{B.16}$$

$$\kappa_t^E = \lambda_t^E Q_t^K \tag{B.17}$$

B.3 Banks

$$\varrho_t^E = \mathbb{E}_t q_{t,t+1}\Big[\left(\Psi_t R_t^L - R_t^D\right) + \gamma^L(1-\rho_s)\mathbb{E}_t\varrho_{t+1}^E\Big] \tag{B.18}$$

$$\xi\varrho_t^E x_t\frac{1}{R_t^L} = \mathbb{E}_t q_{t,t+1}\Psi_t L_t \tag{B.19}$$

$$\Pi_t = \Psi_t R_{t-1}^L L_{t-1} + D_t - L_t - R_{t-1}^D D_{t-1} \tag{B.20}$$

$$L_t = D_t \tag{B.21}$$

$$q_{t,t+1} = \beta^P\mathbb{E}_t\frac{\lambda_{t+1}^P}{\lambda_t^P} \tag{B.22}$$

B.4 Market Clearing and Resource Constraints

$$C_t^P + C_t^E + I_t = Y_t \tag{B.23}$$

$$H_t^P + H_t^E = H \tag{B.24}$$

$$Y_t = A_t (N_t)^{1-\alpha} \left\{ \left(H^E_{t-1}\right)^{\phi} (K_{t-1})^{1-\phi} \right\}^{\alpha} \tag{B.25}$$

$$K_t = (1-\delta) K_{t-1} + \left\{ 1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right\} I_t \tag{B.26}$$

C Steady State Conditions

All $i's$, $j's$ and $k's$ denoting individual household, entrepreneur and bank respectively are ignored. From household's FOC with respect to consumption (B.1) and labor (B.4), I have

$$\frac{1-\beta^P \gamma^P}{\left(1-\gamma^P\right) C^P} = \lambda^P \tag{C.1}$$

and

$$N^{\eta-1} = \lambda^P W \tag{C.2}$$

respectively. Household's FOC with respect to deposit (B.2) yields the steady-state gross interest rate

$$R^D = \frac{1}{\beta^P} \tag{C.3}$$

underscoring that the time preference of most patient individual determines the steady-state rate of interest. From (B.3), I obtain

$$\begin{aligned} \frac{\varsigma}{H^P} + \beta^P \lambda^P Q^H &= \lambda^P Q^H \\ \Rightarrow Q^H H^P &= \frac{\varsigma}{\lambda^P \left(1-\beta^P\right)} \\ \Rightarrow H^P &= \frac{\varsigma}{Q^H \lambda^P \left(1-\beta^P\right)} \end{aligned} \tag{C.4}$$

I next turn to entrepreneurs. Their consumption FOC (B.5) yields

$$\frac{1-\beta^E \gamma^E}{\left(1-\gamma^E\right) C^E} = \lambda^E \tag{C.5}$$

Entrepreneur's FOC with respect to loans (B.6) gives

$$\begin{aligned} \beta^E \lambda^E R^L + \mu^E R^L &= \lambda^E \\ \Rightarrow \mu^E &= \frac{\lambda^E \left(1-\beta^E R^L\right)}{R^L} \end{aligned} \tag{C.6}$$

The borrowing constraint for entrepreneurs binds only if μ^E is positive. This implies that β^E must be less than R^L. In the baseline calibration, β^E is set to 0.95 whereas the steady state value of R^L is 1.0219 which implies that β^E must be less than 0.9786 which is indeed the case. The production function is

$$Y = A\left(N\right)^{1-\alpha}\left[\left(H^E\right)^{\phi}\left(K\right)^{1-\phi}\right]^{\alpha} \tag{C.7}$$

From firm's labor choice for households (B.7),

$$W = \left(1-\alpha\right)\frac{Y}{N} \tag{C.8}$$

From entrepreneur's FOC with respect to housing (B.8), I have

$$\begin{aligned} \lambda^E Q^H &= \beta^E \lambda^E \left(Q^H + \alpha\phi\frac{Y}{H^E}\right) + \mu^E \theta Q^H \\ \Rightarrow \frac{Q^H H^E}{Y} &= \frac{\beta^E \alpha \phi R^L}{\left(1-\beta^E\right)R^L - \theta\left(1-\beta^E R^L\right)} \end{aligned} \tag{C.9}$$

From aggregate law of motion for capital (B.26)

$$\begin{aligned} K &= \left(1-\delta\right)K + \left[1 - \frac{\Omega}{2}\left(\frac{I}{I}-1\right)\right]I \\ \Rightarrow I &= \delta K \end{aligned} \tag{C.10}$$

I have the following steady-state resource constraints

$$Y = C^P + C^E + I \tag{C.11}$$

$$H = H^P + H^E \tag{C.12}$$

$$L = D \tag{C.13}$$

Also, I have the following steady-state version of agents' budget constraints (one of them is redundant because of Walras' Law)

$$C^P = WN - (R^D - 1)D + \Pi \tag{C.14}$$

$$C^E = Y - R^L l - WN - I - x \tag{C.15}$$

So the steady state is characterized by the vector

$$\left[Y, C^P, C^E, I, H^P, H^E, K, N, L, D, Q^H, Q^K, R^D, R^L, W, \lambda^P, \lambda^E, \mu^E\right]$$

From entrepreneur's optimal choice of capital (B.9), I have

$$\kappa_t^E = \alpha\left(1-\alpha\right)\beta^E \mathbb{E}_t\left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t}\right) + \beta^E\left(1-\delta\right)\mathbb{E}_t\kappa_{t+1}^E + \mu_t^E\theta_t\mathbb{E}_t Q_{t+1}^K$$
$$\Rightarrow \frac{\kappa^E}{\lambda^E}\left(1-\left(1-\delta\right)\beta^E\right) = \alpha\left(1-\phi\right)\beta^E\frac{Y}{K} + \frac{\left(1-\beta^E R^L\right)}{R^L}\theta Q^K \tag{C.16}$$

Entrepreneur's optimal choice of investment (B.10) yields

$$\lambda_t^E(j) = \kappa_t^E(j)\left[1-\frac{\Omega}{2}\left(\frac{I_t(j)}{I_t(j-1)}-1\right)^2 - \Omega\frac{I_t(j)}{I_t(j-1)}\left(\frac{I_t(j)}{I_{t-1}(j)}-1\right)\right]$$
$$+\beta^E\Omega\mathbb{E}_t\left[\kappa_{t+1}^E(j)\left(\frac{I_{t+1}(j)}{I_t(j)}\right)^2\left(\frac{I_{t+1}(j)}{I_t(j)}-1\right)\right]$$
$$\Rightarrow \lambda^E = \kappa^E \tag{C.17}$$

Combining this with steady state version of

$$\kappa^E = \lambda^E Q^K \tag{C.18}$$

I obtain $Q^K = 1$ in the steady state. Plugging this into (C.16), I obtain the expression for capital-to-output ratio

$$\frac{\kappa^E}{\lambda^E}\left(1-\left(1-\delta\right)\beta^E\right) = \alpha\left(1-\phi\right)\beta^E\frac{Y}{K} + \frac{\left(1-\beta^E R^L\right)}{R^L}\theta Q^K$$
$$\Rightarrow \frac{K}{Y} = \frac{\alpha\left(1-\phi\right)R^L\beta^E}{R^L\left(1-\left(1-\delta\right)\beta^E\right)-\theta\left(1-\beta^E R^L\right)} \tag{C.19}$$

Next, combining (B.15) and (B.16) yields

$$l = \frac{\theta}{R^L}\left[Q^H H^E + Q^K K\right] \tag{C.20}$$

Dividing by Y, the above expression becomes

$$\frac{l}{Y} = \frac{\theta}{R^L}\left[\frac{Q^H H^E}{Y} + \frac{Q^K K}{Y}\right]$$

Plugging in the values of $\frac{Q^H H^E}{Y}$ and $\frac{K}{Y}$ and using that $Q^K = 1$, I have

$$\frac{l}{Y} = \alpha\theta\beta^E \left[\frac{\phi}{R^L (1-\beta^E) - \theta (1-\beta^E R^L)} + \frac{(1-\phi)}{R^L (1-(1-\delta)\beta^E) - \theta (1-\beta^E R^L)} \right] \tag{C.21}$$

From entrepreneur's budget constraint (B.14)

$$C^E + R^L l = Y - WN - I + x \tag{C.22}$$

Rewriting this in ratios to output

$$\begin{aligned} \frac{C^E}{Y} + \frac{R^L l}{Y} &= 1 - \frac{WN}{Y} - \frac{I}{Y} + \frac{x}{Y} \\ \Rightarrow \frac{C^E}{Y} &= \alpha - \delta \frac{K}{Y} + \left(1 - \gamma^L - R^L\right) \frac{l}{Y} \end{aligned} \tag{C.23}$$

Dividing (C.4) by Y and then dividing it again by (C.9) gives

$$\begin{aligned} \frac{\frac{Q^H H^P}{Y}}{\frac{Q^H H^E}{Y}} &= \frac{\frac{\varsigma}{Y\lambda^P \left(1-\beta^P\right)}}{\frac{\beta^E \alpha\phi R^L}{\left(1-\beta^P\right) R^L - \theta \left(1-\beta^E R^L\right)}} \\ \Rightarrow \frac{H^P}{H^E} &= \frac{\varsigma}{Y \frac{1-\beta^P\gamma^P}{(1-\gamma^P)C^P} \left(1-\beta^P\right)} \frac{\left(1-\beta^E\right) R^L - \theta \left(1-\beta^E R^L\right)}{\beta^E \alpha\phi R^L} \\ \Rightarrow \frac{H^P}{H - H^P} &= \frac{\varsigma \left(1-\gamma^P\right)}{(1-\beta^P)(1-\beta^P\gamma^P)} \frac{\left(1-\beta^P\right) R^L - \theta \left(1-\beta^E R^L\right)}{\beta^E \alpha\phi R^L} \frac{C^P}{Y} \end{aligned} \tag{C.24}$$

From entrepreneur's stock of habits for loans (B.11)

$$\begin{aligned} s_t &= \rho_s s_{t-1} + (1-\rho_s) l_t \\ s &= l \end{aligned} \tag{C.25}$$

Entrepreneur's effective demand for loans (B.12) gives

$$\begin{aligned} x_t &= \left(l_t - \gamma^L s_{t-1}\right) \\ \Rightarrow x &= \left(1 - \gamma^L\right) l \end{aligned} \tag{C.26}$$

Total loans of entrepreneurs (B.13)

$$L = l \tag{C.27}$$

From bank's balance sheet condition (B.21), total deposits must equal total loans

$$D = L \tag{C.28}$$

Steady state version of stochastic discount factor (B.22) reads

$$q = \beta^P \tag{C.29}$$

The steady-state version of bank's first order condition (B.18) with respect to loans reads

$$\varrho_t = \beta^P \left[\Psi R^L - R^D + \gamma^L (1 - \rho_s) \varrho^E\right]$$

which can be simplified to yield

$$\varrho^E = \beta^P \frac{\Psi R^L - R^D}{1 - \beta^P \gamma^L (1 - \rho_s)} \tag{C.30}$$

The steady-state version of bank's second first order condition with respect to lending rate (B.19) writes

$$\xi \varrho^E x \frac{1}{R^L} = \beta^P \Psi L$$

Steady-state version of aggregate resource constraint (B.23) is

$$\begin{aligned} C^P + C^E + I &= Y \\ \Rightarrow \frac{C^P}{Y} &= 1 - \frac{C^E}{Y} - \delta \frac{K}{Y} \end{aligned} \tag{C.31}$$

Combining (C.1), (C.2) and (C.8) gives steady-state equilibrium condition for households

$$\begin{aligned} N^{\eta-1} &= \lambda^P W \\ \Rightarrow N^{\eta-1} &= \frac{1 - \beta^P \gamma^P}{(1 - \gamma^P) C^P} (1 - \alpha) \frac{Y}{N} \\ \Rightarrow N &= \left[\frac{\left(1 - \beta^P \gamma^P\right)(1 - \alpha)}{(1 - \gamma^P)} \left(\frac{C^P}{Y}\right)^{-1} \right]^{\frac{1}{\eta}} \end{aligned} \tag{C.32}$$

From (B.25), steady state output is

$$Y = A\left(N\right)^{1-\alpha}\left[\left(H^{E}\right)^{\phi}\left(K\right)^{1-\phi}\right]^{\alpha}$$
$$Y^{1-\alpha} = A\left(N\right)^{1-\alpha}\left[\left(\frac{H^{E}}{Y}\right)^{\phi}\left(\frac{K}{Y}\right)^{1-\phi}\right]^{\alpha}$$
$$Y^{1-\alpha} = A\left(N\right)^{1-\alpha}\left[\left(\frac{H^{E}}{Y}\right)^{\phi}\left(\frac{\alpha\left(1-\phi\right)R^{L}\beta^{E}}{R^{L}\left(1-\left(1-\delta\right)\beta^{E}\right)-\theta\left(1-\beta^{E}R^{L}\right)}\right)^{1-\phi}\right]^{\alpha} \tag{C.33}$$

From (C.4)

$$Q^{H} = \frac{\varsigma}{H^{P}\lambda^{P}\left(1-\beta^{P}\right)} \tag{C.34}$$

D System of Loglinear Equations

The system of equations log-linearized around their steady state is as below:

D.1 Optimality Conditions of Households

(A.2), (A.3) and (A.5) become

$$\beta^{P}\gamma^{P}\mathbb{E}_{t}\widehat{C}_{t+1}^{P} - \left(1+\left(\gamma^{P}\right)^{2}\beta^{P}\right)\widehat{C}_{t}^{P} + \gamma^{P}\widehat{C}_{t-1}^{P} = \left(1-\beta^{P}\gamma^{P}\right)\left(1-\gamma^{P}\right)\widehat{\lambda}^{P} \tag{D.1}$$

$$\mathbb{E}_{t}\widehat{\lambda}_{t+1}^{P} = \widehat{\lambda}_{t}^{P} - \widehat{R}_{t}^{D} \tag{D.2}$$

$$\left(\eta-1\right)\widehat{N}_{t} = \widehat{\lambda}_{t}^{P} + \widehat{W}_{t} \tag{D.3}$$

Log-linearization of (A.4) gives

$$\beta^{P}\mathbb{E}_{t}\left[\widehat{\lambda}_{t+1}^{P} + \widehat{Q}_{t+1}^{H} + \widehat{H}_{t}^{P}\right] = \widehat{\lambda}_{t}^{P} + \widehat{Q}_{t}^{H} + \widehat{H}_{t}^{P} \tag{D.4}$$

D.2 Optimality Conditions of Entrepreneurs

From (B.5) and (B.6), I have

$$\beta^{E}\gamma^{E}\mathbb{E}_{t}\widehat{C}_{t+1}^{E} - \left(1+\left(\gamma^{E}\right)^{2}\beta^{E}\right)\widehat{C}_{t}^{E} + \gamma^{E}\widehat{C}_{t-1}^{E} = \left(1-\beta^{E}\gamma^{E}\right)\left(1-\gamma^{E}\right)\widehat{\lambda}_{t}^{E} \tag{D.5}$$

and

$$\widehat{\lambda}_t^E = \widehat{R}_t^L + \beta^E R^L \mathbb{E}_t \widehat{\lambda}_{t+1}^E + \left(1 - \beta^E R^L\right) \widehat{\mu}_t^E \tag{D.6}$$

(B.7) yields

$$\widehat{W}_t = \widehat{Y}_t - \widehat{N}_t \tag{D.7}$$

From (B.8), I derive

$$\begin{aligned}\left(\widehat{\lambda}_t^E + \widehat{Q}_t^H\right) &= \beta^E \mathbb{E}_t\left(\widehat{\lambda}_{t+1}^E + \widehat{Q}_{t+1}^H\right) + \left(\frac{1}{R^L} - \beta^E\right)\theta \mathbb{E}_t\left(\widehat{\mu}_t^E + \widehat{Q}_{t+1}^H\right) \\ &+ \left[\left(1 - \beta^E\right) - \theta\left(\frac{1}{R^L} - \beta^E\right)\right]\mathbb{E}_t\left[\widehat{\lambda}_{t+1}^E + \widehat{Y}_{t+1} - \widehat{H}_t^E\right]\end{aligned} \tag{D.8}$$

(B.9) becomes

$$\begin{aligned}\widehat{Q}_t^K = &\left[1 - \beta^E(1-\delta) - \theta\left(\frac{1}{R^L} - \beta^E\right)\right]\mathbb{E}_t\left[\widehat{\lambda}_{t+1}^E - \widehat{\lambda}_t^E + \widehat{Y}_{t+1} - \widehat{K}_t\right] \\ &+ \beta^E(1-\delta)\mathbb{E}_t\left(\widehat{Q}_{t+1}^K + \widehat{\lambda}_{t+1}^E - \widehat{\lambda}_t^E\right) + \left(1 - \beta^E R^L\right)\frac{1}{R^L}\theta \mathbb{E}_t\left[\widehat{\mu}_t^E - \widehat{\lambda}_t^E + \widehat{Q}_{t+1}^K\right]\end{aligned} \tag{D.9}$$

(B.10) is approximated as

$$\widehat{Q}_t^K = \left(1 + \beta^E\right)\Omega \widehat{I}_t - \beta^E \Omega \mathbb{E}_t \widehat{I}_{t+1} - \Omega \widehat{I}_{t-1} \tag{D.10}$$

From (B.11) and (B.12), I get

$$\widehat{s}_t = \rho_s \widehat{s}_{t-1} + (1 - \rho_s)\,\widehat{l}_t \tag{D.11}$$

and

$$\widehat{x}_t = \frac{\widehat{l}_t}{1 - \gamma^L} - \frac{\gamma^L \widehat{s}_{t-1}}{1 - \gamma^L} \tag{D.12}$$

From (B.13), I obtain

$$\widehat{L}_t = \widehat{l}_t \tag{D.13}$$

(B.14) becomes

$$C^E \widehat{C}_t^E + R^L l\left(\widehat{R}_{t-1}^L + \widehat{l}_{t-1}\right) = Y\widehat{Y}_t - WN\left(\widehat{W}_t + \widehat{N}_t\right) - I\widehat{I}_t - Q^H H^E\left(\widehat{H}_t^E - \widehat{H}_{t-1}^E\right) + x\widehat{x}_t \tag{D.14}$$

(B.15) gives

$$\widehat{l}_t = \widehat{a}_t - \widehat{R}^L_t \tag{D.15}$$

(B.16) yields

$$\widehat{a}_t = \frac{Q^H H^E}{Q^H H^E + Q^K K}\mathbb{E}_t\left(\widehat{Q}^H_{t+1} + \widehat{H}^E_t\right) + \frac{Q^K K}{Q^H H^E + Q^K K}\mathbb{E}_t\left(\widehat{Q}^K_{t+1} + \widehat{K}_t\right) \tag{D.16}$$

Linearized versions of (B.17) is

$$\widehat{\kappa}^E_t = \widehat{\lambda}^E_t + \widehat{Q}^K_t \tag{D.17}$$

D.3 Optimality Conditions of Banks

From (B.18), I obtain

$$\frac{\varrho^E}{\beta^P}\widehat{\varrho}^E_t - \varrho^E\gamma^L(1-\rho_s)\mathbb{E}_t\widehat{\varrho}^E_{t+1} = \left[\Psi R^L - R^D + \varrho^E\gamma^L(1-\rho_s)\right]\mathbb{E}_t\widehat{q}_{t,t+1} + \Psi R^L\left(\widehat{\Psi}_t + \widehat{R}^L_t\right) - R^D\widehat{R}^D_t \tag{D.18}$$

Log-linearization of (B.19) yields

$$\xi\varrho^E x\left(\widehat{\varrho}^E_t + \widehat{x}_t\right) = \beta^P R^L \Psi L\left(\widehat{R}^L_t + \widehat{\Psi}_t + \widehat{L}_t + \mathbb{E}_t\widehat{q}_{t,t+1}\right) \tag{D.19}$$

From (B.21), I get

$$\widehat{L}_t = \widehat{D}_t \tag{D.20}$$

Linearized versions of (B.22) is

$$\widehat{q}_{t,t+1} = \widehat{\lambda}^P_{t+1} - \widehat{\lambda}^P_t \tag{D.21}$$

D.4 Market Clearing and Resource Constraints

(B.23) and (B.24) yield

$$\widehat{Y}_t = \frac{C^P}{Y}\widehat{C}^P_t + \frac{C^E}{Y}\widehat{C}^E_t + \frac{I}{Y}\widehat{I}_t \tag{D.22}$$

and

$$H^P\widehat{H}^P_t + H^E\widehat{H}^E_t = 0 \tag{D.23}$$

From (B.25), I have

$$\widehat{Y}_t = \widehat{A}_t + (1-\alpha)\,\widehat{N}_t + \alpha\phi\widehat{H}^E_{t-1} + \alpha\,(1-\phi)\,\widehat{K}_{t-1} \tag{D.24}$$

(B.26) gives

$$\widehat{K}_t = (1-\delta)\,\widehat{K}_{t-1} + \delta\widehat{I}_t \tag{D.25}$$