Credit Expansion, Bank Liberalization, and Structural Change in Bank Asset Accounts

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January 5, 2021

Abstract

This paper studies the links among credit supply expansion, commercial bank asset account structures, and the housing boom preceding the 2007-2009 financial crisis. We propose a real business cycle model with a housing market and financial intermediaries (banks) subject to leverage constraints. In our model, banks channel funds to firms for production and provide collateralized loans to mortgage borrowers; thus, banks determine their asset account structures endogenously. We show that a credit supply expansion to banks can account for four key facts that characterize the housing boom: (1) an increase in real house prices; (2) an increase in the mortgage-to-GDP ratio; (3) a decrease in the real mortgage interest rate; and (4) an increase in the ratio of mortgages to firm loans in commercial bank asset accounts. In our model, a credit supply expansion to banks can also generate a boom-bust cycle through the collateral value channel via mortgage borrowers. Asset-side bank regulations that reduce excessive mortgage issuance during a credit boom can help to dampen the subsequent economic downturn.

Keywords: Credit expansion; Bank liberalization; Bank balance sheet; Business cycle

1 Introduction

Before the 2007-2009 financial crisis, the US economy experienced an unprecedented housing and mortgage boom. The following three empirical facts have been observed regarding this boom: first, housing prices increased dramatically; second, the mortgage-to-GDP ratio increased in parallel with house prices; third, the real mortgage interest rate decreased during the period (see Panels (a)-(c) in Figure 1). The above stylized facts are more indicative of an increase in credit supply (Favara and Imbs, 2015). Although these facts have been well documented in the credit-cycle literature (e.g., Mian and Sufi, 2018 and Justiniano et al., 2019), most dynamic general equilibrium models have encountered difficulty in reconciling these facts.

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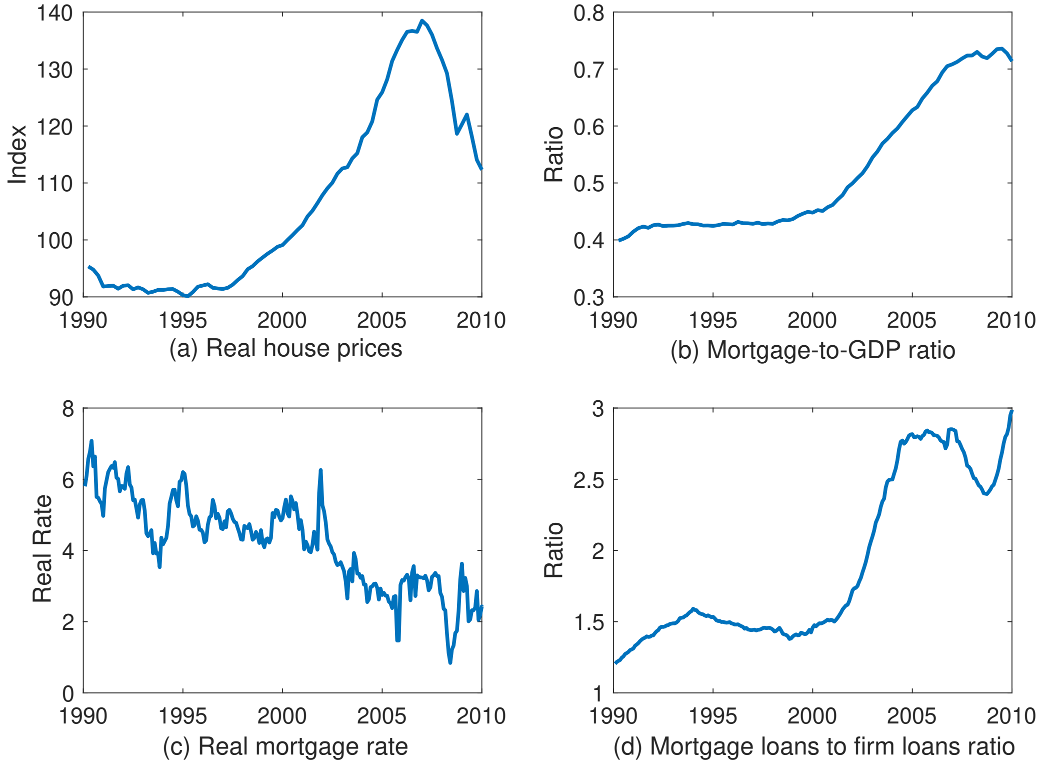

Figure 1: Stylized facts during the housing boom: (a) real house prices increased; (b) the mortgage-to-GDP ratio increased. (c) the real mortgage rate decreased; (d) the ratio of real estate loans to commercial and industrial loans increased.

This paper builds a dynamic stochastic general equilibrium (DSGE) model with financial intermediaries and a housing market to capture these facts. We attempt to link the housing boom with the bank credit expansion because banks played a central role during the housing boom. First, they were the main issuers of home mortgages to facilitate borrowers' house purchases. Second, the rapid growth of mortgage securitization by banks attracted numerous investors to fund mortgage-backed securities (MBSs), which in turn fueled the housing boom. In addition, we observe a dramatic change in the structure of commercial bank asset accounts during the credit boom. Figure 1 (d) shows the dynamics of the ratio of real estate loans to commercial and industrial loans of all US commercial banks during 1990-2010. The ratio almost doubled from 2000 to 2006 and remained at that level until immediately before the Great Recession started[1]. We show that our framework can capture the three stylized facts, as well as the change in bank asset account structures, during the boom.

In our model, banks absorb deposits from savers, lend funds to firms for production, and provide collateralized loans to borrowers for house purchases, during which processes the banks determine their asset account structures. Borrowers face borrowing constraints

[1]Off-balance-sheet activities, such as purchases of asset-backed commercial paper, are not considered in Figure 1(d). However, if we consider shadow banking, the increase in the ratio of mortgage loans to firm loans is even larger.

à la Kiyotaki and Moore (1997) and Iacoviello (2005) such that their borrowing is limited by the value of their houses. We further assume that the funds that banks can obtain from savers are limited by the banks' internal net worth (Gertler and Karadi, 2011). Such setting is based on a more realistic assumption. More importantly, when banks face endogenous financial constraints and have limited funds to issue loans, their decisions about asset account structures have an impact on business cycles.

We show that our model can capture the above stylized facts when there is a credit expansion to banks (which we call "bank liberalization" hereafter). Bank liberalization mirrors the effect of securitization, that is, the pooling and tranching of bank assets to convert mortgages into mortgage-backed securities. These financial innovations, together with financial deregulation, reduce the financial friction between short-term investors and banks and allow banks to absorb more funds (Brunnermeier, 2009). Through bank liberalization, savers become willing to provide more funds to banks, so banks can invest more in both loans to firms and mortgages. This causes the return on loans to firms and the mortgage interest rate to decrease. Bank credit expansion also leads to a higher level of household borrowing and higher house prices. The increased house prices and decreased mortgage rates further relax home buyers' borrowing constraints via the collateral value channel, so banks are inclined to lend more funds to mortgage borrowers compared to firms. As a result, the ratio of mortgage loans to firm loans increases. Our theoretical framework is, to the best of our knowledge, the first attempt to explain the change in bank asset account structures during the housing boom.

Moreover, the positive bank credit supply in our model causes nonmonotonic economic fluctuations, mainly through changes in the asset accounts of bank balance sheets. We show that the economy experiences a short-run boom and then suffers a downturn afterward when there is a positive credit supply to banks. Both the collateral constraints faced by borrowers and the financial constraints faced by banks play important roles in generating such boom-bust cycles. Since banks obtain more funds from a positive credit supply, additional funds are initially invested in loans to firms because borrowers face collateral constraints, leading to an increase in investment and output. However, once the increase in house values and the decrease in the mortgage rates relax borrowers' collateral constraints, banks invest more in mortgages vis-à-vis their funding of firms. Since banks are financially constrained, the collateral value channel of mortgages has a "crowding out" effect on firms' investment and capital purchases, predicting a subsequent decline in output. Our model illustrates a positive credit supply as a source of business cycles, consistent with the recent empirical findings of Mian and Sufi (2009), Glick and Lansing (2010), and Martin and Philippon (2017).

Bank credit expansions cause boom-bust cycles mainly through changes in the bank asset accounts, and this mechanism has important implications for policymakers aiming to limit economic recessions after booms. In our counterfactual experiments, we introduce an asset-side bank regulation: the policymaker taxes bank mortgage holdings and uses the revenue to subsidize loans to firms; the tax rate is proportionate to the mortgage-to-firm loan ratio. This regulation encourages banks to issue more loans to firms and fewer mortgages during the credit boom. The results show that such an asset-side bank regulation can mitigate economic decline at the cost of reducing the size of the preceding boom. The normative analysis shows that the asset-side bank regulation improves welfare by stabilizing credit cycles. Our results emphasize the importance of monitoring the structures of bank asset accounts during credit booms, which is complementary to macroprudential policies that focus on the other side of bank balance sheets, e.g., bank capital requirements or countercyclical capital buffers.

The rest of the paper is organized as follows. The remainder of the introduction focuses on a review of the literature. Section 2 describes our model, Section 3 shows the quantitative calibration of the model and the effect of an increase in credit supply, Section 4 conducts some numerical experiments for policies and welfare analysis, and Section 5 concludes the paper. The appendix contains a simple extension of our baseline model with housing investment and sensitivity analysis.

Related Literature

There have been a number of recent papers on credit supply expansion and business cycles[2]. Our paper builds on yet differs from the literature investigating the macroeconomic effect of financial frictions in the following ways: The vast majority of literature dates back to Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Bernanke et al. (1999). These authors introduced traditional financial accelerator models to study how financial frictions amplify the effect of shocks from the entrepreneurial side. Our paper connects two strands of recent developments originating from these works. One strand of the literature studies the interaction of financial frictions and housing values, as in Iacoviello (2005), Rubio (2011), Kiyotaki et al. (2011), etc. Another strand of the literature focuses on the importance of financial frictions and leverage constraints on financial intermediaries, such as Holmstrom and Tirole (1997), Gertler and Karadi (2011), Gertler and Kiyotaki (2010), and Nuño and Thomas (2017). Our model combines these two strands of the literature by incorporating the key elements of both types of models: home buyers who borrow using housing as collateral and financial intermediaries subject to financial constraints. Our paper emphasizes the importance of both mortgages and banking during housing booms.

As demonstrated in the existing literature, most dynamic general equilibrium models have encountered difficulty in reconciling an increase in house prices, an increase in the mortgage-to-GDP ratio, and a decline in the real mortgage rate. Of particular interest is Iacoviello (2005), whose model had two different types of households and borrower credit limited by home values. For simplicity, an exogenous increase in the loan-to-value (LTV) ratio can be used as a simple modeling device to generate an increase in the credit supply. However, in contrast to what we observe in the data, an exogenous increase in the LTV ratio leads to an increase in the interest rate in such classes of models. The main reason is that this type of model usually specifies a single interest rate for lending and borrowing, which is natural when savers lend funds directly to borrowers in the credit market. Although the credit demand of borrowers is limited by collateral constraints, the price of credit in equilibrium is determined on the supply side of credit; that is, the interest rate equals the marginal rate of substitution between consumption for today and tomorrow in savers' intertemporal consumption decisions. When mortgage borrowers' collateral constraints are relaxed by a higher LTV ratio, the equilibrium interest rate moves alongside the upward-sloping credit supply curve. As a result, recent studies have shown that an additional force is needed to

[2]See Schularick and Taylor (2012), Mian and Sufi (2009, 2011, 2015), Jordà et al. (2015), Mian et al. (2017), Baron and Xiong (2017), and Kaplan et al. (2020). Mian and Sufi (2018) surveyed the literature on this topic.

combine the increase in credit supply and housing prices with a drop in the mortgage rate[3]. Our model manages to reconcile these stylized facts through the channel of a positive credit supply to banks.

Our paper is also related to studies of the macroeconomic effect of housing, e.g., Iacoviello (2005, 2015), Landvoigt (2014), Favilukis et al. (2017), Greenwald (2018), and Garriga et al. (2019). Favilukis et al. (2017) studied the relaxation of borrower financial constraints and housing prices in a general equilibrium model. Aggregate business cycle risk and bequest heterogeneity were introduced to explain the large increase in housing prices. Greenwald (2018) showed that payment-to-income constraints are an important channel influencing macroeconomic dynamics. Garriga et al. (2019) studied the housing price boom in a model with segmented financial markets. The above three papers used a relaxation of the loan-to-value or payment-to-income ratio as a positive credit supply shock and introduced a simultaneous decrease in the interest rate to reconcile the three empirical facts. Landvoigt (2014) developed a model with lenders, borrowers, and financial intermediaries to study household debt and housing booms. In the quantitative exercise in his model, laxer collateral constraints were combined with an underestimation of mortgage risks by lenders to generate a quantitatively plausible boom-bust cycle in household debt. Instead, our paper introduces Gertler-Kiyotaki-type financial intermediaries, generating endogenous leverage constraints with a countercyclical risk premium and allowing for quantitatively different movements in the mortgage rate and deposit rate.

Another novelty of this paper is its introduction of a framework to study the interaction between housing market booms and business cycles through banks' balance-sheet decisions. By allowing banks to invest their funds in mortgages and loans to firms, the model shows that the combination of bank financial constraints and their balance-sheet decisions can introduce a new channel that generates business cycles. Our paper is related to the literature on credit cycles and business cycles, e.g., Eggertsson and Krugman (2012), Guerrieri and Lorenzoni (2012), and Rognlie et al. (2018). Guerrieri and Uhlig (2016) provided a comprehensive literature review of credit cycles and housing cycles. Rognlie et al. (2018) showed that overbuilding in the housing sector induces a demand-driven recession and an asymmetric recovery. Some small open-economy models have studied the determinants of the US credit supply from an international perspective, as mentioned in Bernanke (2005). Some papers, e.g., Martin and Philippon (2017) and Batini et al. (2018), have related credit cycles to sovereign risks.

The work most related to our paper is that of Justiniano et al. (2019), who built a general equilibrium model with borrowers that face collateral constraints and lenders that face lending constraints. They studied the effect of credit supply through (1) looser borrowing constraints associated with lower required collateral values and (2) looser lending constraints on lenders. They showed that the latter are essential in explaining the increase in housing prices and the decrease in the real mortgage rate. Bank liberalization in our model resembles the looser lending constraints in these authors' framework. The key difference is that our model incorporates two different types of bank assets, and it allows us to study the link between credit expansions and the change in bank asset account structures. By embedding

[3]Existing models, for example, Schmitt-Grohé and Uribe (2016), assume an exogenous reduction in the interest rate as the cause of a credit supply expansion in a small open-economy model.

financially constrained banks that make decisions about their asset account structures, our model introduces an additional force of economic fluctuations. This new element provides a new perspective to explain boom-bust cycles.

2 Model

The economy consists of five sectors: patient and impatient households, firms, capital producers, and banks. Patient households consume final goods and housing, provide labor to firms, and save money in banks. Banks absorb funds from patient households facing financial constraints and channel the funds to impatient households and firms. Impatient households borrow money from banks using their housing as collateral and therefore face collateral constraints. Firms produce final goods using labor and physical capital as inputs. They lack funds and therefore must borrow from banks to buy physical capital from capital producers. The following are the detailed descriptions for each sector.

2.1 Patient Households

The economy is populated by patient and impatient households, both infinitely lived and of measure one. The households of both types consume final goods (the numeraire) and housing and provide labor. Subscript $j = \{s, b\}$ represents patient households (savers) and impatient households (borrowers). Among patient households, a proportion f of them are workers, and the remainder $1 - f$ are bankers. The workers supply labor to firms to earn wages. The bankers work in financial intermediaries. The patient household maximizes the following utility function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_s^t U(C_{s,t}, H_{s,t}, L_{s,t}) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_s^t \left(\ln C_{s,t} + \chi_s \ln H_{s,t} - \frac{\eta_s}{1+\varphi_s} L_{s,t}^{1+\varphi_s} \right), \tag{1}$$

where $\mathbb{E}_t$ is the expectation operator given the information at time t, β_s is the time discount factor for the patient household, $C_{s,t}$ is consumption, $H_{s,t}$ is the holdings of housing, $L_{s,t}$ is labor hours, χ_s and η_s are the weight parameters of housing and labor in the utility function, respectively, and φ_s is the inverse of the Frisch labor elasticity. This household's budget constraint is

$$C_{s,t} + Q_t^h (H_{s,t} - H_{s,t-1}) + D_t = W_{s,t} L_{s,t} + R_t D_{t-1} + T_{s,t}, \tag{2}$$

where Q_t^h is the price of housing in terms of final goods, $W_{s,t}$ is the wage for the patient household workers, D_t is deposits saved in banks, R_t is the risk-free return on deposits from time $t-1$ to t, and $T_{s,t}$ is the lump-sum transfer that the patient household receives from other sectors. We define the marginal utility and stochastic discount factor by

$$U_{s,t}^c = \frac{\partial U(C_{s,t}, H_{s,t}, L_{s,t})}{\partial C_{s,t}}, \tag{3}$$

$$\Lambda_{t,t+1} = \beta_s \frac{U_{s,t+1}^c}{U_{s,t}^c}, \tag{4}$$

and the optimality conditions of the patient household's utility maximization problem give rise to the Euler equation, labor supply, and housing demand:

$$R_{t+1}\mathbb{E}_t\Lambda_{t,t+1} = 1, \tag{5}$$

$$W_{s,t} = \eta_s C_{s,t} L_{s,t}^{\varphi_s}, \tag{6}$$

$$\frac{Q_t^h}{C_{s,t}} = \frac{\chi_s}{H_{s,t}} + \beta_s \mathbb{E}_t \left(\frac{Q_{t+1}^h}{C_{s,t+1}} \right). \tag{7}$$

2.2 Impatient Households

The utility function of impatient households shares the same form as that of the patient households except that $\beta_b < \beta_s$, so they discount the future more heavily. In equilibrium, impatient households are borrowers in the economy. They choose consumption $C_{b,t}$, housing $H_{b,t}$, and labor supply $L_{b,t}$ to maximize the following utility function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t U(C_{b,t}, H_{b,t}, L_{b,t}) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t \left[\ln C_{b,t} + \chi_b \ln H_{b,t} - \frac{\eta_b}{1+\varphi_b} L_{b,t}^{1+\varphi_b} \right]. \tag{8}$$

The borrower's budget constraint is given by

$$C_{b,t} + Q_t^h (H_{b,t} - H_{b,t-1}) + R_{b,t} B_{t-1} = W_{b,t} L_{b,t} + B_t, \tag{9}$$

where $W_{b,t}$ is the wage rate for impatient workers, B_t is borrowing at the beginning of t, and $R_{b,t}$ is the interest rate that banks charge the impatient household from $t-1$ to t. It is assumed that impatient households cannot borrow directly from patient households. Instead, they borrow from banks by signing standard debt contracts. In line with the model in Kiyotaki and Moore (1997), the bank cannot force the borrower to repay debt, and the impatient household borrows money using its house as collateral. If borrowers repudiate his debt, the bank can repossess their houses with an amortization rate m_t. Therefore, for the impatient household to borrow B_t from banks, the debt obligation is limited by the value of the amortized assets:

$$B_t \leq m_t \mathbb{E}_t \left(\frac{Q_{t+1}^h H_{b,t}}{R_{b,t+1}} \right). \tag{10}$$

The amortization rate m_t is also known as the loan-to-value (LTV) ratio. The value of m_t can be affected by financial regulations or institutional changes in financial markets. When m_t increases, borrowers can borrow more from banks given the value of their real estate assets. This increase can be interpreted as laxer bank lending standards because banks are willing to lend more funds to impatient households. This idea of a credit supply expansion to households is often used by authors studying credit and housing booms, e.g., Landvoigt (2014) and Favilukis et al. (2017). We study the effect of a positive credit supply in later sections by allowing m_t to change exogenously.

The condition of $\beta_b < \beta_s$ ensures that the impatient household's borrowing constraint (10) is binding. The optimality conditions of the impatient household's problem are

$$W_{b,t} = \eta_b C_{b,t} L_{b,t}^{\varphi_b}, \tag{11}$$

$$\frac{\chi_b}{H_{b,t}} - (Q_t^h - m_t \frac{\mathbb{E}_t Q_{t+1}^h}{R_{b,t+1}}) \frac{1}{C_{b,t}} + \beta_b (1 - m_t) \mathbb{E}_t \left(\frac{Q_{t+1}^h}{C_{b,t+1}} \right) = 0, \tag{12}$$

$$B_t = m_t \mathbb{E}_t \left(\frac{Q_{t+1}^h H_{b,t}}{R_{b,t+1}} \right). \tag{13}$$

2.3 Firms

Competitive firms use labor from patient and impatient households and physical capital as inputs to produce final goods through a Cobb-Douglas production function:

$$Y_t = A_t K_t^{\alpha} (L_{s,t}^{\gamma} L_{b,t}^{1-\gamma})^{1-\alpha}, \tag{14}$$

where A_t is the aggregate productivity level known at the beginning of time t, Y_t is final output, K_t is physical capital, and α and γ are parameters[4]. It is assumed that the firms lack funds and hence must borrow from banks. Here, we simplify the lending and borrowing between the firms and the banks by assuming that there is no friction in the transaction[5]. That is, the firms commit to paying the entire profit to the banks by issuing state-contingent firm equity. The first-order conditions with respect to patient and impatient labor are given by

$$W_{s,t} = \gamma(1 - \alpha) \frac{Y_t}{L_{s,t}}, \tag{15}$$

$$W_{b,t} = (1 - \gamma)(1 - \alpha) \frac{Y_t}{L_{b,t}}. \tag{16}$$

The gross profit per unit of capital Z_t is

$$Z_t = \frac{Y_t - W_{s,t} L_{s,t} - W_{b,t} L_{b,t}}{K_t} = \alpha \frac{Y_t}{K_t}. \tag{17}$$

Since all of the profits go to the banks via firm equity, the firms have no profits left in each period. If we normalize firm equity such that one unit of firm equity corresponds to one unit of physical capital, the ex post return on firm equity (capital) is

$$R_{k,t} = \frac{Z_t + (1 - \delta) Q_t}{Q_{t-1}} \tag{18}$$

where Q_t is the price of firm equity (capital).

4 We follow Iacoviello (2005) and Rubio (2011) and introduce patient and impatient labor. This setting implies that the labor of patient and impatient households are not perfect substitutes. This specification is analytically tractable, which allows us to obtain the close-form solution of the steady states in the model. Moreover, it is convenient to calibrate γ, the relative size of the rule-of-thumb (constrained) household group, from the data.

5 Empirical evidence shows that the credit spread faced by firms is larger than mortgage interest rate spread, which suggests that firm lending is subject to greater frictions than household borrowing. Assuming frictionless firm borrowing and frictional household borrowing (a collateral constraint) seems contradictory to conventional wisdom. However, in our model, one can also interpret patient households as "prime" households and impatient households as "subprime" households. Under that interpretation, it is more plausible that subprime mortgages are subject to more friction than corporate loans. Indeed, according to the subprime mortgage premium data in Demyanyk and Van Hemert (2011), the subprime mortgage rate is higher than the BAA-rated corporate bond yield. Investment grade loans, which include those with BBB rating and above, are the majority of newly issued corporate loans from 1996 to 2019 in the US (Data Source: SIFMA). We thank an anonymous referee for bringing this to our attention.

2.4 Capital Producers

Final goods can be invested to produce physical capital with flow-variable adjustment costs. The capital producers conduct capital production and transfer their profits back to the patient households in each period because the patient households have ownership. Specifically, the capital producers choose investment I_t to produce capital given the capital price Q_t subject to the adjustment costs

$$\max \mathbb{E}_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - I_\tau \left[1 + \Psi(\frac{I_\tau}{I_{\tau-1}}) \right] \right\}.$$

The adjustment cost function $\Psi(\cdot)$ is convex and satisfies the following condition: $\Psi(1) = 0, \Psi'(1) = 0, \Psi''(1) > 0$. The concavity of the objective function ensures that an interior solution exists. The solution shows that the marginal cost of capital production equals the price of capital Q_t.

$$Q_t = 1 + \Psi(\frac{I_t}{I_{t-1}}) + \frac{I_t}{I_{t-1}} \Psi'(\frac{I_t}{I_{t-1}}) - \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 \Psi'(\frac{I_{t+1}}{I_t}) \right]. \tag{19}$$

We use capital producers with adjustment costs to generate procyclical asset prices.

2.5 Banks

Banks have some internal net worth n_t at the beginning of time t and obtain funds from patient households by issuing risk-free debts (deposits). They have two ways to invest the borrowed funds together with their own net worth. They can either (1) lend to firms to buy physical capital for the next period of production or (2) lend funds to impatient households. Let d_t be the deposits from patient households, $\mathcal{A}_t$ be the total value of bank assets, s_t be the firm equity, Q_t be the price of the firm equity, and b_t be the amount of bank lending to the impatient households. The bank balance-sheet equation is given by

$$\mathcal{A}_t \equiv Q_t s_t + b_t = d_t + n_t, \tag{20}$$

The return on risk-free debts held by the patient households from t to $t+1$ is R_{t+1}, the return on bank lending to the impatient households is $R_{b,t+1}$, the ex post return on firm equity is $R_{k,t+1}$, and all of these returns are determined endogenously. Over time, bank net worth evolves as

$$n_{t+1} = R_{k,t+1} Q_t s_t + R_{b,t+1} b_t - R_{t+1} d_t, \tag{21}$$

As long as the risk premium is positive, i.e., $\mathbb{E}_{k,t+1} > R_{t+1}$ and $R_{b,t+1} > R_{t+1}$, banks can gain profits by issuing more deposits to patient households. To prevent banks from accumulating sufficient net worth to move away from the borrowing constraint, we assume that the bankers face exogenous probability θ of staying in the banking sector at the end of each period. When bankers are forced to exit the banking sector with a probability of $1-\theta$, they bring their net worth back to households for consumption. The risk-neutral bankers' objective is to maximize the expected discounted terminal consumption:

$$V_t = \max \mathbb{E}_t \sum_{\tau=t+1}^{\infty} \left[\Lambda_{t,\tau} \theta^{\tau-t-1} (1-\theta) n_\tau \right], \tag{22}$$

With a positive risk premium, banks would like to borrow infinitely from the patient households. Following Gertler and Karadi (2011), we impose a borrowing limit on banks. Specifically, we assume there is a moral hazard problem: after the banker collects deposits from patient households, he or she has an outside option to divert a fraction Θ_t of bank assets to his or her own family, and the remaining bank assets are not sufficient to fully repay the patient households' deposits. Knowing the possibility of diversion by the banker, the patient households limit the funds that they lend to the bank such that the banker's benefit from diverting funds does not exceed his or her payoff from not diverting:

$$V_t \geq \Theta_t \mathcal{A}_t. \tag{23}$$

This equation is the incentive compatibility constraint for bankers. The banker's optimization problem is to choose (s_t, b_t) to maximize Eq. (22) subject to the budget constraint (21) and the moral hazard constraint (23). We define bank leverage ϕ_t by

$$\phi_t = \frac{\mathcal{A}_t}{n_t} = \frac{Q_t s_t}{n_t} + \frac{b_t}{n_t} \equiv \phi_{s,t} + \phi_{b,t}, \tag{24}$$

The closed-form solution of V_t is given by:

$$V_t(n_t) = (\mu_{s,t}\phi_{s,t} + \mu_{b,t}\phi_{b,t} + \nu_t)n_t, , \tag{25}$$

where the Lagrange multipliers (LMs) in (25) are recursively defined as

$$\nu_t = \mathbb{E}_t \Lambda_{t,t+1}\Omega_{t+1}R_{t+1}, \tag{26}$$

$$\mu_{s,t} = \mathbb{E}_t \Lambda_{t,t+1}\Omega_{t+1}(R_{k,t+1} - R_{t+1}), \tag{27}$$

$$\mu_{b,t} = \mathbb{E}_t \Lambda_{t,t+1}\Omega_{t+1}(R_{b,t+1} - R_{t+1}), \tag{28}$$

$$\Omega_{t+1} = (1-\theta) + \theta(\mu_{s,t+1}\phi_{s,t+1} + \mu_{b,t+1}\phi_{b,t+1} + \nu_{t+1}). \tag{29}$$

Among the above expressions, Ω_{t+1} is the shadow price of net worth tomorrow, ν_t is the bank's private cost of issuing deposits, and $\mu_{s,t}$ ($\mu_{b,t}$) is the net profit of firm equity (mortgage loans). Since the borrowing constraint (23) is binding, by Eqs. (24) and (25), the optimal bank leverage is

$$\phi_{s,t} + \phi_{b,t} = \frac{\mu_{s,t}\phi_{s,t} + \mu_{b,t}\phi_{b,t} + \nu_t}{\Theta_t}. \tag{30}$$

We further assume that the banker can change his or her asset account structure without any cost in our baseline model. If the shadow value of firm equity is larger than that of mortgage loans, i.e., $\mu_{s,t} > \mu_{b,t}$, the banker's franchise value is larger when the bank uses funds to invest in firm equity and vice versa. In equilibrium, the banker's shadow value of firm equity equals the shadow value of lending funds to impatient households:

$$\mathbb{E}_t \Lambda_{t,t+1}\Omega_{t+1}R_{k,t+1} = \mathbb{E}_t \Lambda_{t,t+1}\Omega_{t+1}R_{b,t+1}. \tag{31}$$

Otherwise, banks would have arbitrage opportunities. From Eq. (30), bank leverage is decreasing in the fraction of diversion Θ_t so we can interpret Θ_t as the parameter of financial frictions in the banking sector. Ceteris paribus, savers are willing to lend more funds to banks for a lower level of Θ_t. Therefore, a negative shock to Θ_t can be a simple modeling device to generate an increase in credit supply to banks (bank liberalization).

Now let us consider the evolution of aggregate bank net worth N_t. In this case, the flows of new and old bankers must be considered. At the end of period t, we assume that some new bankers enter the banking sector with some initial net worth, so the proportions of bankers and workers within the patient households remain fixed. It is assumed that the initial net worth brought by the new bankers is a fixed fraction ω of total bank assets. Aggregate bank capital evolves as

$$N_{t+1} = \theta(R_{k,t+1}Q_tS_t + R_{b,t+1}B_t - R_{t+1}D_t) + \omega\mathcal{A}_t, \tag{32}$$

where the above upper-case notations (e.g., S_t and D_t) are the aggregate counterparts of the individual variables.

2.6 Resource Constraints and Market Equilibrium

Output is divided between the patient and impatient households' consumption and investment. The resource constraint is given by

$$Y_t = C_{s,t} + C_{b,t} + \left[1 + \Psi(\frac{I_t}{I_{t-1}})\right] I_t. \tag{33}$$

Aggregate physical capital in the economy is accumulated as

$$K_{t+1} = (1-\delta)K_t + I_t. \tag{34}$$

The labor-market equilibrium implies that labor demand and supply for patient and impatient workers coincide:

$$\gamma(1-\alpha)\frac{Y_t}{L_{s,t}} = \eta_s C_{s,t} L_{s,t}^{\varphi_s}, \tag{35}$$

$$(1-\gamma)(1-\alpha)\frac{Y_t}{L_{b,t}} = \eta_b C_{b,t} L_{b,t}^{\varphi_b}. \tag{36}$$

For simplicity, we assume that the housing supply is fixed and normalized to one in our model: $\bar{H} = 1$. In this case, the change in housing prices is driven by housing demand, and we discuss the welfare implications and limitations of this assumption in Section 4. The housing market-clearing condition is

$$H_{s,t} + H_{b,t} = \bar{H}. \tag{37}$$

The following sequence of actions occurs during period t: (1) Capital K_t is given at the beginning of time t. (2) A_t, m_t, and Θ_t are realized. (3) Patient households choose $(C_{s,t}, L_{s,t}, H_{s,t}, D_t)$ given $(W_{s,t}, R_{t+1}, Q_t^h)$, impatient households choose $(C_{b,t}, L_{b,t}, H_{b,t}, B_t)$ given $(W_{b,t}, R_{b,t+1}, Q_t^h)$, firms choose $(K_t, L_{s,t}, L_{b,t})$ given $(Z_t, W_{s,t}, W_{b,t})$, capital producers choose I_t given Q_t, banks choose $(\mathcal{A}_t, B_t, D_t)$ given $(R_{t+1}, \mathbb{E}_t R_{t+1}^k)$, and $(W_{s,t}, W_{b,t}, Z_t, R_{t+1})$ are determined by the market-clearing conditions. In summary, the equilibrium of the model is defined as $(C_{s,t}, L_{s,t}, H_{s,t}, C_{b,t}, L_{b,t}, H_{b,t}, Y_t, K_t, I_t, \mathcal{A}_t, B_t, D_t, W_{s,t}, W_{b,t}, Z_t, Q_t, Q_t^h, R_{k,t+1}, R_{t+1})$ satisfying Eqs. (5)-(7), (9), (11)-(19), (20),(30), (33)-(34), and (37).

In our model, since the patient households cannot lend directly to firms or impatient households, the flow of funds goes through banks. The two main distortions come from (1) the financial constraints faced by banks when they borrow from patient households and (2) the borrowing constraints faced by impatient households when they borrow from banks. As we show in Section 3, the changes in these two credit constraints have different effects on mortgage interest rates and house prices.

3 Results

This section shows how we calibrate the model. First, section 3.1 describes how the parameter values are chosen in our baseline model. Then, we study the effect of a positive credit supply in the following two ways. We study how a permanent increase in credit supply affects the steady states of the economy in Section 3.2. Section 3.3 shows the transitional dynamics of relevant variables when the economy is affected by a positive credit supply shock. Specifically, two different channels of credit supply are evaluated in the numerical experiments: (1) looser financial constraints on banks as a result of a negative shock to Θ_t (bank liberalization) and (2) laxer collateral requirements for impatient households as a result of a positive shock to the LTV ratio m_t (LTV ratio liberalization). To study the effects of the two channels, we keep the impatient household's LTV ratio (collateral constraint) unchanged. We apply the same practice in the scenarios in which we study the effects of bank liberalization and LTV ratio liberalization, respectively.

3.1 Parameters

The parameter values are shown in Table 1. For household preferences, the time discount factor for patient households is set to $\beta_s = 0.99$ so the steady-state annual deposit rate is 4%. We choose the discount factor for impatient households ($\beta_b = 0.965$) based on the estimation in Lawrance (1991), which is in the range of $0.95 - 0.98$. We set the weight parameter of housing, the weight parameter of labor disutility, and the Frisch labor elasticity to be the same for both types of households. The weight parameters of labor disutility are chosen ($\eta_s = \eta_b = 7.41$) such that the steady-state patient labor is $\bar{L}_s = 0.3$. Following Rubio (2011) and Greenwald (2018), we choose standard values for the inverse of the Frisch labor elasticity, $\varphi_s = \varphi_b = 1$, which is consistent with what applied microeconomics studies would suggest[6]. The total housing in the economy is normalized to 1. Furthermore, we set the weight parameter of housing in the utility function to $\chi_s = 0.44$. Under such an arrangement, a realistic bank balance sheet structure can be achieved: the steady-state ratio of mortgages to firm loans broadly matches the average value of US commercial banks' asset accounts during the credit boom. The steady-state LTV ratio is set to $\bar{m} = 0.82$ to match the average

[6] By setting $\varphi_s = \varphi_b = 1$, the model inevitably generates a level of labor volatility that is lower than the aggregate data on hours worked. We acknowledge this shortcoming in our paper. As the Appendix shows, our results are robust to a choice of Frisch labor elasticity parameter (φ_s) within the range $0.2 - 1.2$. An alternative way to improve the performance of labor supply without changing the parameter $\varphi_s(\varphi_b)$ is to use the form of utility function in Greenwood et al. (1988).

Table 1: Parameter Values

patient households:		
β_s	time discount factor	0.99
χ_s	weight parameter of housing	0.44
η_s	weight parameter of labor	7.41
φ_s	inverse Frisch labor elasticity	1
impatient households:		
β_b	time discount factor	0.965
χ_b	weight parameter of housing	0.44
η_b	weight parameter of labor	7.41
φ_b	inverse Frisch labor elasticity	1
$\bar{m}$	steady state loan-to-value ratio	0.82
producers:		
α	capital share	0.3
γ	impatient labor share	0.5
δ	physical capital depreciation rate	0.025
Φ	investment adjustment cost parameter	1
banks:		
θ	survival rate of banks	0.9685
ω	the proportion of initial net worth of new bankers	0.0005
Θ	the proportion of diversion by bank managers	0.302

ratio of mortgage loans to the contract price of houses from 1994-2008 according to data from the Federal Housing Finance Agency (FHFA) and Urban Institute[7].

For firms and capital producers, the capital share for the Cobb-Douglas production function is $\alpha = 0.3$, the physical capital depreciation rate is $\delta = 0.025$, and the elasticity of investment to asset prices is set to 1. The parameter for the investment adjustment cost is chosen such that the steady-state capital price is equal to 1. These parameter values are fairly standard. Following Campbell and Mankiw (1989), we set the relative size of the rule-of-thumb (constrained) household group, γ, to be 0.5.

For banking sector parameters, we choose the steady-state fraction of banker diversion $\Theta = 0.302$ and the fraction of initial bank net worth held by new bankers to be $\omega = 0.0005$ to achieve two targets: (1) a steady-state leverage ratio close to $\bar{\phi} = 7.7$ to match the average value of the bank capital ratio (13%) in the US and (2) an annual credit spread of approximately 100 basis points. The proportion of banks remaining in the banking industry is set to $\theta = 0.9685$ such that banks survive for 10 years on average.

The exogenous credit shocks that simulate bank liberalization (Θ_t) and LTV liberalization (m_t) follow first-order autoregressive (AR) processes: $\Theta_t = \rho_\Theta \Theta_{t-1} + \varepsilon_{\Theta,t}$ and $m_t = \rho_m m_{t-1} + \varepsilon_{m,t}$. Following Benigno and Nisticò (2017), the persistence parameters of credit shocks are set to $\rho_\Theta = \rho_m = 0.85$ such that the half-live of the shock is 4 quarters and the credit shocks remain effective for 4 years. This is consistent with the evidence reported in Section 1 and corresponds to the credit supply shocks simulated in Justiniano et al. (2019).

[7]Alternatively, the LTV ratio is set to 0.89 in Iavoviello (2005), 0.8 in Damjanovic and Girdenas (2014), and 0.9 in Rubio (2014). Our result is robust to the choice of steady-state LTV ratio when it ranges from $0.8 - 0.9$.

Table 2: Steady State Values

Variables		baseline	high LTV ratio	low Θ	high LTV and low Θ
output	Y	0.860	0.865	0.868	0.873
capital	K	6.878	6.920	7.070	7.113
impatient hh borrowing	B	5.145	6.082	5.399	6.426
mortgage to bank asset ratio	B/QK	0.748	0.879	0.764	0.903
deposits	D	10.455	11.306	11.769	12.187
return on capital (%)	R_k	1.25%	1.25%	1.18%	1.18%
return on borrowing(%)	R_b	1.25%	1.25%	1.18%	1.18%
deposit return (%)	R	1.01%	1.01%	1.01%	1.01%
bank leverage ratio	ϕ	7.671	7.671	10.02	10.02
house prices	q^H	26.249	27.359	26.547	27.749
net worth	N	1.567	1.695	1.245	1.352

3.2 Steady States

3.2.1 LTV Ratio Liberalization

We show the steady states of the baseline model in the first column in Table 2. First, we change the loan-to-value ratio from $\bar{m} = 0.82$ to $\bar{m}' = 0.9$ and determine how the steady-state values change accordingly. The result is reported in the second column. The increase in the LTV ratio allows impatient households to borrow more from banks given the value of their housing, and it can be regarded as a permanent liberalization of bank lending standards. The steady-state impatient households' borrowing increases, as does the ratio of mortgages to firm loans. Impatient households' housing is higher, and their higher demand for housing leads to higher house prices. Conversely, patient households' housing decreases, but their consumption and savings increase. In the steady state, banks absorb more funds from patient households. Since the risk premium is positive, when banks lend more funds to mortgage borrowers, banks obtain a higher steady-state value of retained earnings (net worth). With higher bank net worth and bank deposits, banks' lending to firms also increases. As a result, the steady-state level of capital and output shows a slight increase over the baseline result.

It is surprising that the steady-state borrowing rate for impatient households ($\bar{R}_b$) is unaffected by the change in the LTV ratio. The reasons are as follows. In our baseline model, banks are risk neutral and can adjust their bank asset structure at no cost. When they make lending decisions to firms or impatient households, the no-arbitrage condition implies that the equilibrium mortgage rate and the return on firm equity ($\bar{R}_k$) coincide. However, the return on firm equity is affected by the level of physical capital due to the diminishing marginal product of capital. The funds used for capital purchases are affected by the financial frictions in the banking sector, which are mainly captured by the fraction of diversion parameter Θ and limited bank net worth[8]. The increase in the LTV ratio does not alter such frictions. Additionally, the steady-state deposit rate is determined by the time discount factor of patient households; therefore, the steady-state credit spread is unchanged. Bank leverage is affected by the shadow values, which are further affected by the credit spread, so the steady-state bank leverage does not change either.

3.2.2 Bank Liberalization

Now, we consider bank liberalization by reducing the financial frictions between banks and depositors. It is acknowledged that securitization, financial innovations and bank deregulation reduce financial frictions between short-term investors and banks and allow banks to absorb more funds. In our model, this goal can be achieved by a decrease in the fraction of diversion parameter Θ_t. With a lower level of Θ_t, the moral hazard problem in banks is attenuated, and they have fewer incentives to divert funds, so patient households are comfortable lending more funds to these banks. Thus, bank liberalization implies a positive credit supply to banks, which further causes an increase in banks' lending to firms and impatient households. In our numerical experiment, we reduce Θ from 0.302 to 0.213 so that the steady-state bank leverage ratio increases from 7.67 to 10, mimicking the average level of bank leverage during the Great Moderation period. The result is reported in the third column of Table 2.

Compared to the result of LTV ratio liberalization, bank liberalization has a much smaller effect on impatient households' borrowing because impatient households are still affected by collateral constraints. The increase in mortgage loans is mainly due to the increase in house prices and the decrease in the mortgage rate. The steady-state firm loans are higher, and the ratio of mortgage loans to firm loans shows a moderate increase. The price of housing increases by a smaller amount. Most importantly, the reduction in financial frictions between depositors and banks causes the risk premium to decrease, so the return on firm equity and the mortgage rate are lower than those in the baseline result.

Although bank liberalization leads to a decrease in the steady-state mortgage rate, the quantitative effect on house prices and bank asset account structures is smaller than that of LTV ratio liberalization. However, if both credit supply channels occur at the same time, we can see a quantitatively more plausible result, shown in the 4th column. A higher steady-state house price level and mortgage-to-firm loan ratio come mainly from LTV ratio liberalization, and the decrease in the mortgage rate comes from the bank liberalization.

To the best of our knowledge, the only existing theoretical model in the literature that mimics the reduction of the mortgage rate as a consequence of a positive credit supply is that of Justiniano et al. (2019). In their model, the reduction in the borrowing rate can be achieved when lenders are limited by exogenous lending constraints and when such constraints are relaxed. The relaxed financial frictions in banks in our model are similar to the laxer lending constraints in their model. Our model differs from their framework in two aspects. First, in Justiniano et al. (2019), lenders lend directly to borrowers in the financial market when lenders (borrowers) face lending (collateral) constraints. However,

[8]Bank net worth depends crucially on the probability of banks dying out in each period $1 - \theta$. If θ is large, bank net worth is higher, and the risk premium decreases. The same implication applies to the same types of banking models, such as those of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010).

both constraints are rarely binding at the same time in equilibrium. When the laxer lending constraints affect the equilibrium interest rate, the lending constraints are binding and the borrowing constraints are not. However, according to mortgage data from Fannie Mae, the effect of collateral constraints on the borrowed amount is obvious. In our model, both banks' financial constraints and borrowers' collateral constraints are binding. Second, our model creates a new link between credit supply and business cycles by allowing banks to choose to invest in loans to firms and mortgages. In the next section, we show that bank liberalization can cause boom-bust cycles.

3.3 Credit Supply and Business Cycles

This section studies the transitional effect of a positive credit supply shock by examining the impulse response functions of some key variables. In the following numerical experiments, we assume a 1% decrease in Θ_t as a bank liberalization shock and 0.165% increase in m_t as an LTV ratio liberalization shock. We normalize the size of the shock on m_t such that the peak responses of bank assets caused by both shocks are the same. The results in Figure 2 show that bank liberalization decreases the mortgage rate, increases mortgage-to-output ratio, and increases the mortgage-to-firm loan ratio. By contrast, LTV ratio liberalization increases the mortgage rate. Moreover, we show that bank liberalization first leads to an increase in output, but output decreases subsequently. Both banks' financial constraints and borrowers' collateral constraints are important in generating such boom-bust cycles.

3.3.1 Bank Liberalization and Economic Cycles

When Θ_t decreases, patient households are willing to lend more funds to banks. This can be interpreted as the effect of bank liberalization due to technological improvements or institutional changes in the financial sector, such as securitization, bank deregulation, and credit enhancement, during the credit boom[9]. Therefore, the bank leverage ratio increases. Since impatient households still face collateral (LTV) constraints, banks do not initially lend the additional funds to borrowers. Instead, they invest these additional funds in firm loans, causing an increase in investment and capital. According to the diminishing marginal product of capital (MPK), the return on capital (equivalently the return on firm loans) decreases. The no-arbitrage condition of bankers in Eq. (31) implies that the mortgage rate also decreases in parallel with the return on firm equity. The decrease in the mortgage rate relaxes impatient households' collateral constraints because borrowers can now borrow more when they must repay less in the next period. Therefore, mortgage loans start to increase gradually. With more funds, impatient households increase their demand for housing, leading to an increase in house prices[10]. The increase in the holding of housing by impatient households further relaxes

[9]In the financial market, it is common to see that securitization, credit derivatives, tranching, etc. made some investors come to believe that their lending was secure. Our model takes Gertler and Karadi's borrowing constraint for banks, and we use an exogenous reduction in the banker's fraction of diversion parameter (admittedly parsimonious) to model a positive credit supply to banks. The mechanism behind the emergence of a positive credit supply shock is beyond the scope of this paper.

[10]In Figure 2, house prices decrease subsequently because the housing demand of patient households decreases as they save more in banks. This channel can be shut down if we assume an inelastic housing demand for savers. See similar results in Greenwald (2018).

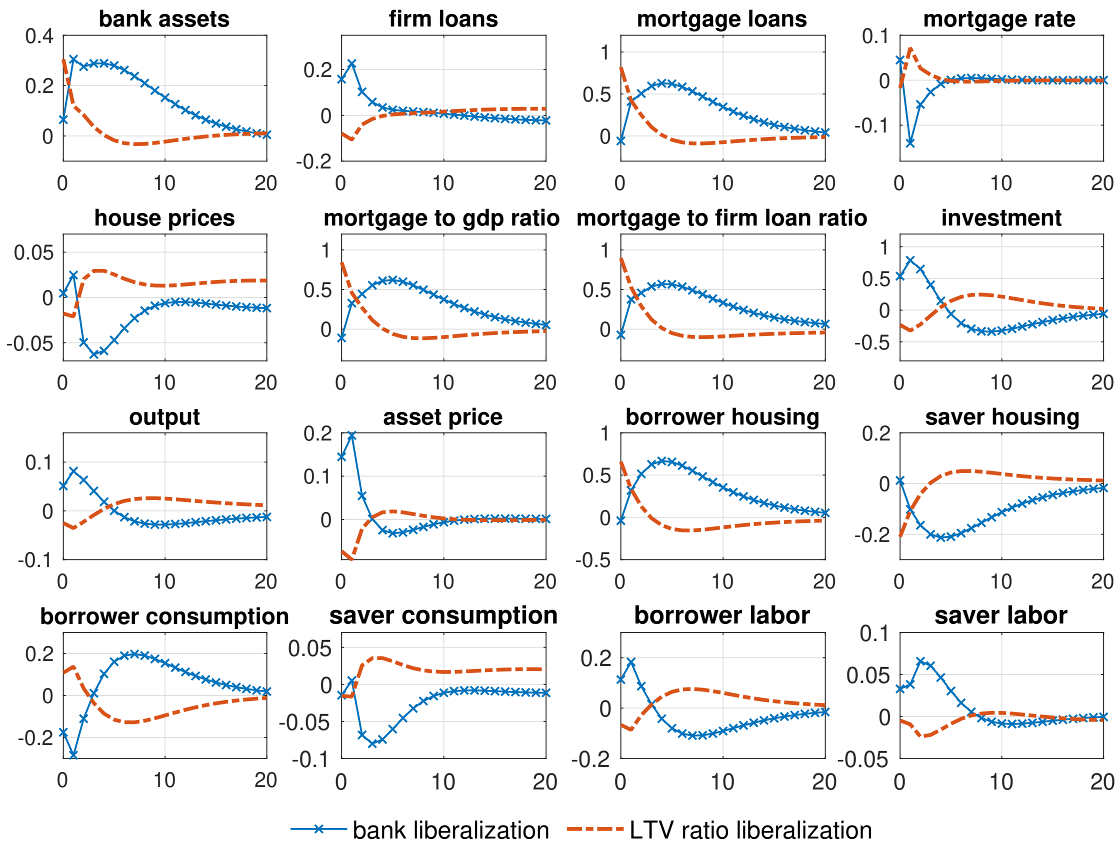

Figure 2: Impulse response functions of bank liberalization (a 1% decrease in Θ_t) v.s. LTV ratio liberalization (a 0.165% increase in m_t)

collateral constraints, so mortgage loans continue to increase. The results demonstrate the effect of "the collateral value channel": the increase in the impatient households' housing, the decrease in the mortgage rate, and the increase in house prices all relax borrowing constraints. Such an effect is common in the financial frictions and financial acceleration literature. Also, a decrease in firm loan rate reduces MPK and strengthens investment by increasing both patient and impatient labor.

As more funds are lent to impatient households and because banks face financial constraints, fewer funds are channeled to firms for capital purchases. It is also worth mentioning that the decreases in the firm loan rate and mortgage rate tighten bank financial constraints slightly because the decrease in the credit spread has a negative effect on banks' shadow values and profitability, and it also dampens the increase in the bank leverage ratio. By the time that mortgage loans increase through the collateral value channel, firm loans start to decrease. Therefore, there is an increase in the ratio of mortgage loans to firm loans.

A bank liberalization shock captures the empirical facts that are observed during the housing boom. Plus, it generates an economic cycle itself. When bank liberalization relaxes bank financial constraints, banks initially lend the additional funds to firms since mortgage borrowers face collateral constraints. Investment and capital increase in the first 4 quarters.

However, the borrowers' constraints are relaxed later through the collateral value channel, as discussed in the previous paragraph, and banks gradually lend more funds to impatient households. As a result, there is an increase in mortgage loans and subsequent decreases in investment and capital after the initial positive responses. When physical capital for production is less funded, output decreases. A decrease in labor supply during that period aggravates the decrease in investment and output[11]. Most importantly, a positive credit supply shock causes output to increase initially and to decrease subsequently. The result is consistent with the empirical findings that credit expansions are likely to be followed by economic recessions in the credit-cycle literature, as summarized in Mian and Sufi (2018).

3.3.2 LTV Ratio Liberalization

Figure 2 also shows the responses of variables when the economy is affected by an exogenous increase in the LTV ratio. In this case, impatient households can borrow more funds from banks given their values of housing as collateral. We can see that their borrowing level increases immediately, and it affects the economy in two ways. First, when banks lend more funds to impatient households, they lend less to firms, so the mortgage-to-firm loan ratio increases. This is because banks are subject to the financial constraints, and the funds that they collect from depositors are still limited by bank net worth. As banks invest less in firm equity to buy physical capital, it induces the return on capital to increase due to the diminishing marginal product of capital. The mortgage rate also increases according to the no-arbitrage condition in Eq. (31). Second, the increase in impatient household borrowing leads to an immediate decrease in housing demand because, with a higher LTV ratio, impatient households can borrow more funds from banks given the fact that their amortization values of housing as collateral have increased. Therefore, house prices initially decrease. However, the dramatic increase in the mortgage rate tightens collateral constraints afterward and reverses the housing demand and house prices.

From the above, LTV ratio liberalization as a positive credit supply shock leads to an increase in the mortgage-to-GDP ratio and the mortgage-to-firm loan ratio. These results are consistent with the empirical evidence. However, the increase in the mortgage rate and the decrease in house prices are the opposite of what is observed in the data mainly due to the increase in the return on capital. The above result is consistent with the finding in the literature that LTV ratio liberalizations alone cannot reconcile the stylized facts during the credit boom in DSGE models. A rise in the interest rate after a positive LTV ratio shock is documented in theoretical models with Kiyotaki-Moore-type collateral constraints, e.g., Chu (2014) and Justiniano et al. (2019).

4 Counterfactual Analysis

Our experiments until this point have assumed that banks can freely change the bank asset account structures, which is arguably an important assumption during the housing boom

[11] If we isolate the effect of labor dynamics on investment by fixing labor supply (i.e., $L_{s,t} = \bar{L}_s, L_{b,t} = \bar{L}_b$), the boom-bust cycle is still present. The initial increase and subsequent decrease in patient and impatient labor play a role in boom-bust cycle but do not affect the main results of the paper.

because we observe a dramatic change in the commercial bank balance-sheet structures according to the evidence in Section 1. This section illustrates some different numerical experiments when policymakers impose some restrictions on the bank asset account structure. We call such a policy an asset-side bank regulation since it alters the asset accounts of bank balance sheets. The results show that the policy that limits bank mortgage issuance during the period of credit expansion can alleviate boom-bust cycles. Then we provide a normative analysis of this policy.

4.1 Asset-Side Bank Regulation

We show two examples of asset-side bank policy. In the first example, we simulate an extreme case in which banks must maintain a fixed ratio of mortgage loans to firm loans. Specifically, a bank maintains the ratio at the steady-sate level in the baseline model:

$$\frac{B_t}{Q_t K_t} = \frac{\bar{B}}{\bar{Q}\bar{K}}, \tag{38}$$

where the upper bar symbol denotes the steady state. We show the responses of bank liberalization in Figure 3. With such a restriction, the no-arbitrage condition of Eq. (31) no longer holds, and the mortgage rate can be different from the expected return on firm equity. For comparison, we also plot the baseline model result in the same figure. After bank liberalization, banks absorb more funds and lend these additional funds to firms and impatient households at a fixed proportion. The main difference from the baseline result is that the mortgage loans show a milder and smoother increase because banks cannot change the bank asset account structure, so they are not allowed to lend a larger proportion of funds to impatient households via the collateral value channel. Instead, the additional funds are channeled to both firms and mortgage borrowers proportionately, so the level of firm loans increases in parallel with that of mortgage loans. The subsequent decrease in firm loans in the baseline result caused by the collateral value channel is replaced by a moderate increase similar to the mortgage loans. The long-lasting yet moderate increase in firm loans implies a persistent increase in investment, and the subsequent economic downturn that would occur in the baseline model is mostly avoided.

The above experiment is the scenario in which banks face very strict regulation of their asset accounts. A more generalized asset-side bank regulation, whereby the policymaker taxes mortgage loans and subsidizes firm equity, can also be formulated:

$$(1 + \tau_{f,t}) Q_t s_t + (1 - \tau_{h,t}) b_t = d_t + n_t. \tag{39}$$

The above equation is the bank balance-sheet structure under the policy, where $\tau_{f,t}$ is the subsidy rate on each unit of firm equity, and $\tau_{h,t}$ is the tax rate on each unit of mortgage loan. We assume that $\tau_{h,t}$ is determined under the following rule:

$$\hat{\tau}_{h,t} = \tau_0 (\hat{B}_t - \hat{Q}_t - \hat{K}_t), \tag{40}$$

where $\tau_0 > 0$ is the policy parameter, and the symbol with hat is the log-deviation of this variable from its steady state. The idea of the above policy rule is that the tax rate responds

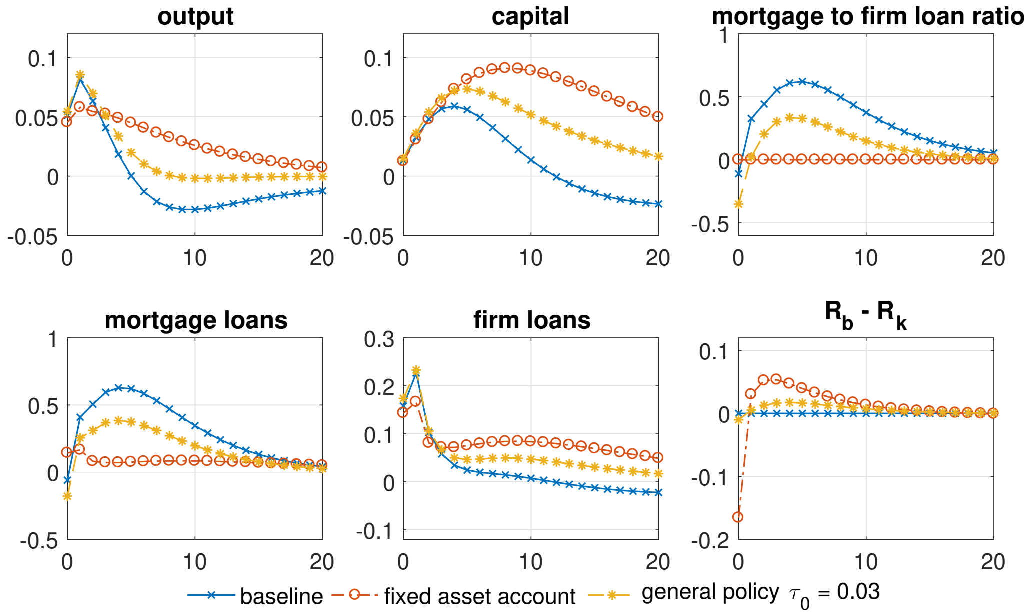

Figure 3: Counterfactual analysis: IRFs to a 1% decrease in Θ_t (bank liberalization)

positively to the change in the mortgage-to-firm loan ratio. When a credit supply shock causes the ratio to increase, the tax on mortgage loans is set to be higher, and banks are induced to issue fewer mortgages. Once $\tau_{h,t}$ is chosen, the subsidy rate $\tau_{f,t}$ is determined by the fiscal neutrality of the policy:

$$\tau_{f,t} = \frac{B_t}{Q_t K_t} \tau_{h,t}. \tag{41}$$

We further assume that the steady-state tax and subsidy are zero, so the steady states of the economy under the policy are the same as those in the baseline model. The numerical result of the policy in the case of $\tau_0 = 0.03$ is reported in Figure 3. Compared to the baseline results, the policy encourages banks to issue more firm loans and fewer mortgage loans during bank liberalization. Thus, the subsequent economic downturn is partially attenuated. The higher the value of τ_0 we choose, the larger the response of the tax rate to the credit supply shock, and the more effective the policy.

Analogously, the policy has a similar stabilizing effect on output and investment when there is an LTV ratio liberalization shock (see Figure 5 in the Appendix). Similar to bank liberalization, a positive LTV ratio liberalization shock causes an increase in the ratio of mortgage loans to firm loans. In this case, the policy limits banks to investing excessive funds in mortgages and encourages banks to issue more firm loans; therefore, the responses of output and investment are stabilized.

4.2 Welfare Analysis

The above results show that asset-side bank regulation, which prevents excessive funds from being invested in housing during a credit boom, reduces the severity of the subsequent economic downturn. However, we are left with the following questions: Does the policy improve welfare for the economy? How does the policy affect the welfare of patient and impatient households? In this section, we provide a welfare analysis based on the baseline parametrization.

Following Rubio (2011), we first solve the model by using a second-order approximation to the original structural equations for given policy rules and then evaluate welfare by comparing the utilities of both types of households. Compared to the approach of characterizing the Ramsey optimal policy, this approach enables us to separately evaluate the welfare of two different types of households and disentangle the effect of the policy. The respective welfare of patient and impatient household is defined as

$$\mathcal{W}_{s,t} = \mathbb{E}_t \sum_{j=t}^{\infty} \beta_s^{j-t} \left(\ln C_{s,j} + \chi_s \ln H_{s,j} - \frac{\eta_s}{1+\varphi_s} L_{s,j}^{1+\varphi_s} \right), \tag{42}$$

$$\mathcal{W}_{b,t} = \mathbb{E}_t \sum_{j=t}^{\infty} \beta_b^{j-t} \left(\ln C_{b,j} + \chi_b \ln H_{b,j} - \frac{\eta_b}{1+\varphi_b} L_{b,j}^{1+\varphi_b} \right). \tag{43}$$

Following Mendicino and Pescatori (2004) and Rubio (2011), social welfare is defined as a weighted sum of individual welfare values of patient and impatient households:

$$\mathcal{W}_t = (1-\beta_s)\mathcal{W}_{s,t} + (1-\beta_b)\mathcal{W}_{b,t}. \tag{44}$$

The weight parameters in Eq. (44) are set to ensure that both types of households receive the same level of utility from the same constant consumption stream.

The left panel of Figure 4 shows the respective welfare of patient and impatient households and social welfare at various parameter values τ_0 under the bank asset-side policy rule (40) in the case of bank liberalization. The welfare of impatient households is increasing in the policy parameter τ_0 because, under this policy, impatient households can obtain more funds from banks at the beginning of bank liberalization. By smoothing the borrowing constraints after the shock, the policy reduces the volatility of impatient households' consumption, labor supply, and house holdings, thus improving their welfare.

The policy affects patient households in a more complicated way. It shows that a higher level of τ_0 raises the welfare of patient households when τ_0 is small but reduces their welfare when τ_0 is large. There are two main channels through which these opposite effects on their welfare arise. First, the policy improves savers' welfare by reducing the variation in house holdings. Specifically, the overall variation in housing demand is reduced when mortgage borrowers enjoy a smoother relaxation of borrowing conditions, and it also improves the welfare of patient households by reducing the volatility of house holdings. Second, the policy reduces their welfare by amplifying the volatility of consumption and labor supply. We briefly explain the mechanism here: When there is a positive bank liberalization shock, patient households first reduce their consumption and deposit more savings in banks to fund production investment. This is the boom period. Later, banks lend more funds to impatient households via the collateral value channel, and this reduces output and consumption, leading to the bust period. Under the bank asset-side policy, patient households first reduce their consumption more to maintain a long-lasting positive investment, which in turn allows them

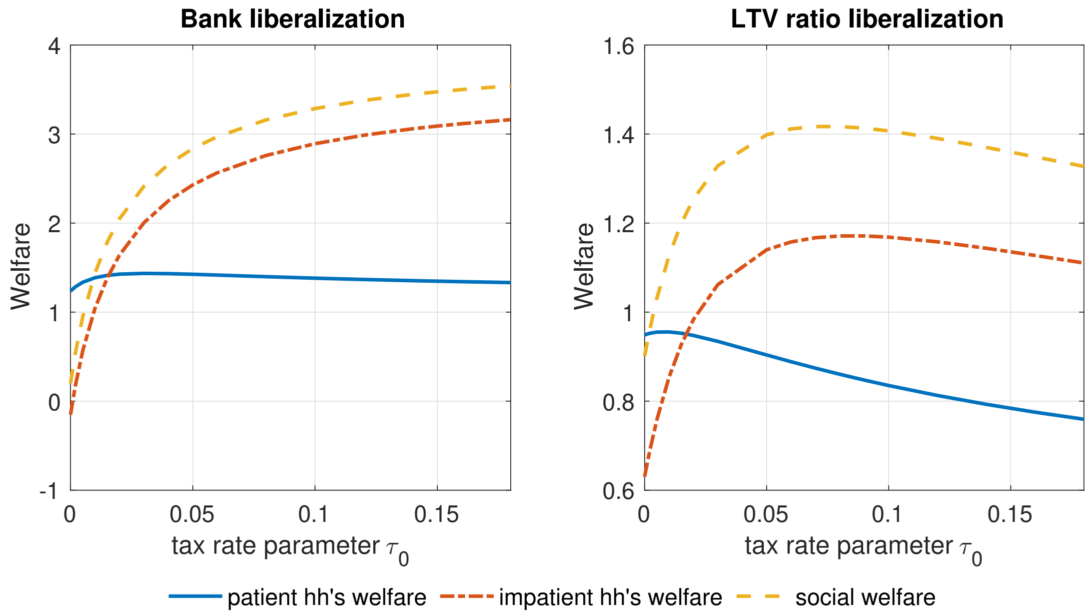

Figure 4: Welfare values (normalized) under bank asset-side policy rule (40)

to enjoy a higher consumption level later because the bust period is less severe. This reversed response of consumption caused by the policy leads to higher volatility and reduces welfare. Under our baseline parametrization, the positive effect of reducing housing volatility is large when τ_0 is small, while the negative effect of perturbing consumption smoothing is dominant when τ_0 is large.

We compare welfare under different policy parameters using consumption equivalent[12], and the results under policy rule (40) and the fixed ratio policy (38) are summarized in Table 3. Under policy rule (40), the patient households' welfare is maximized when $\tau_0 = 0.03$. When $\tau_0 < 0.03$, the policy improves the welfare of both patient and impatient households because it reduces the variation in their house holdings. When the policy parameter is large, however, there is a welfare conflict between patient and impatient households, and this welfare tradeoff is consistent with the findings in Rubio (2011) and Lambertini et al. (2013)[13]. Policy rule (40) achieves the same level of consumption equivalent as the fixed ratio policy when $\tau_0 = 1.7$. Under the baseline parametrization, social welfare is increasing in τ_0. Although making the policy more aggressive is welfare-improving, the marginal increase in social welfare diminishes.

Table 3 also reports the welfare results in the case of LTV ratio liberalization. The right panel of Figure 4 shows that when $\tau_0 < 0.08$, social welfare is improved if the policymaker

[12]More details of the welfare description are shown in the Appendix.

[13]Lambertini et al. (2013) studied how LTV ratios affect the welfare of savers and borrowers in a New Keynesian model in which borrowers face collateral constraints. Although their model did not include a financially constrained banking sector, our model shares similar welfare implications. Our model does not consider nominal rigidities, as the LTV ratio and bank leverage constraints are typically stable over business cycle frequencies, and this is not the focus of our paper.

Table 3: Welfare values for bank asset-side policy rules (consumption equivalent)

	baseline model	bank asset-side policy rule (40)			fixed ratio policy
Bank liberalization		$\tau_0 = 0.03^*$	$\tau_0 = 0.08$	$\tau_0 = 1.7$	
Social welfare	0	0.486	0.704	0.938	0.938
Patient hh's welfare	0	0.024	0.019	-0.004	-0.015
Impatient hh's welfare	0	0.653	0.973	1.344	1.352
LTV liberalization		$\tau_0 = 0.01^*$	$\tau_0 = 0.08$	$\tau_0 = 1.5$	
Social welfare	0	0.020	0.048	0.003	0.003
Patient hh's welfare	0	0.001	-0.005	-0.023	-0.027
Impatient hh's welfare	0	0.026	0.063	0.010	0.011

Note: the welfare values with asterisks indicate the cases in which the patient household's welfare is maximized.

sets the tax rate $\tau_{h,t}$ to respond more aggressively to the change in bank asset account structures. This is because the policy significantly reduces the variation in housing demand. Social welfare is maximized when $\tau_0 = 0.08$ and is decreasing in τ_0 when $\tau_0 > 0.08$. The result is different from that of bank liberalization because the policy affects impatient households in a different way during LTV ratio liberalization. A positive LTV ratio liberalization shock directly relaxes the borrowing constraints of impatient households, while the policy has the opposite effect on their credit conditions. When τ_0 is too large, the policy could harm the credit conditions of impatient households and impede their consumption smoothing. Therefore, their welfare decreases.

The above numerical experiments on bank asset account restrictions are reminiscent of macroprudential policies, although they differ from the latter in several aspects. One of the typical macroprudential policy tools, caps on the LTV ratio, has been studied in new Keynesian models, e.g., Rubio (2011) and Lambertini et al. (2013). These contributions focus on the effect of the policy on stabilizing the economy when it experiences demand shocks, such as monetary policy shocks. Our model, on the other hand, focuses on how asset-side bank regulation mitigates a potential economic downturn when the economy experiences a positive credit boom. The asset-side bank regulation is also different from other popular macroprudential policies, such as bank capital requirements or countercyclical capital buffers, because these policies focus on the other side of the bank balance sheet. In other words, the asset-side bank policy studied in this paper is complementary to the prevailing macroprudential policies. If we consider the effect of traditional supply shocks, such as productivity shocks, our model generates the same financial acceleration effect as other classical models, e.g., Iacoviello (2005) and Gertler and Karadi (2011). Thus, our findings are also complementary to studies on macroprudential policies based on these financial accelerator models.

5 Conclusion

This paper studies the effect of bank credit expansion on household credit and the housing boom before the Great Recession in a dynamic general equilibrium model. There are two channels through which the credit supply is affected. The first is laxer borrowing constraints for mortgage borrowers, and the second is bank liberalization. While both channels contribute to higher household credit and housing prices during the credit boom, bank liberalization is essential for capturing the decrease in the mortgage interest rate. In addition, bank liberalization as a positive credit supply shock can also capture the change in bank asset accounts: the ratio of mortgage loans to firm loans soared during the credit boom.

The financial frictions faced by banks are essential not only for studying the effect of bank liberalization, but also for generating the subsequent economic fluctuations after bank credit expansion. When mortgage borrowers' funds are limited by collateral constraints, more bank credit can boost investment in firm production. Conversely, when collateral constraints for mortgage borrowers are relaxed, it can restrain investment in firm production since bank credit is limited by financial frictions. Many empirical studies have shown that there are predictable economic downturns after household credit booms, and this paper provides a new perspective on credit supply as a source of business cycles.

From a normative perspective, we find that an asset-side bank regulation that prevents excessive investment in mortgages during a credit boom could help to attenuate the potential subsequent economic downturn and improve welfare. As both bank liberalizations and LTV ratio liberalizations increase the mortgage-to-firm loan ratio, the policy (a tax on mortgage loans) can be welfare-improving for both types of credit expansions when it responds moderately to the change in bank asset account structures. In line with previous studies, we find that there is a welfare conflict between patient and impatient households.

However, there are some caveats. In our framework, the housing supply is fixed, and housing production is absent. We also abstract from the role of housing in firm production[14]. When studying the roles of credit constraints and housing demand in business cycles and macroeconomic dynamics, these are arguably very useful simplifications and are quite conventional assumptions in the literature[15]. We acknowledge that the above assumptions weaken the importance of housing in economic activities, and such simplifications would magnify the boom-bust cycles generated by credit expansions. If we were to introduce housing investment into our model, for example, the boom-bust patterns of output and physical capital investment caused by credit supply shocks would both be weakened because funds are used for physical capital investment and housing investment. However, it would nevertheless remain true that as borrowers begin to get additional funds from banks via the collateral value channel, firms would obtain less funds regardless of whether they invest in physical capital or houses[16]. The effect of allowing house production, however, may depend

[14]Bahaj et al. (2020) showed that the housing of firm owners is an important source of financing for small and medium-sized enterprises. Both directors' homes and firms' properties as collateral are important sources of fluctuations in aggregate investment demand.

[15]See Iacoviello (2005, 2015), Justiniano et al. (2019), Greenwald (2018), Rubio (2011), Damjanovic and Girdenas (2014), etc.

[16]In the Appendix, we present an extended version of our model with housing investment. The results of the main text still hold under the baseline parametrization, and the welfare implications of bank asset-side

on what types of firms borrow from banks: final goods producers, capital goods producers, or house producers. We leave further investigation in this direction to future research.

Acknowledgments

We thank Thomas Sargent, Tatiana Damjanovic, Yoske Igarashi for discussions. We also thank the participants from Xiamen University Macroeconomics Workshop and internal seminars for helpful comments.

policies are consistent with the baseline model.

References

[1] Bahaj, S., Foulis, A., Pinter, G. (2020). Home values and firm behavior. *American Economic Review*, 110(7), 2225-70.

[2] Baron, M., Xiong, W. (2017). Credit expansion and neglected crash risk. *The Quarterly Journal of Economics*, 132(2), 713-764.

[3] Batini, N., Melina, G., Villa, S. (2018). Fiscal buffers, private debt, and recession: The good, the bad and the ugly. *Journal of Macroeconomics*.

[4] Benigno, P., Nisticò, S. (2017). Safe assets, liquidity, and monetary policy. *American Economic Journal: Macroeconomics*, 9(2), 182-227.

[5] Bernanke, B. S. (2005). The global saving glut and the US current account deficit. Speech at the Sandridge Lecture, Virginia Association of Economists, Richmond, Virginia.

[6] Bernanke, B., Gertler, M. (1989). Agency costs, net worth and business fluctuations. *American Economic Review*, 79, 14-31.

[7] Bernanke, B. S., Gertler, M., Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In *Handbook of Macroeconomics*, 1, 1341-1393.

[8] Brunnermeier, M. K. (2009). Deciphering the liquidity and credit crunch 2007-2008. Journal of Economic Perspectives, 23(1), 77-100.

[9] Campbell, J. Y., Mankiw, N. G. (1989). Consumption, income, and interest rates: Reinterpreting the time series evidence. *NBER Macroeconomics Annual*, 4, 185-216.

[10] Chu, Y. (2014). Credit constraints, inelastic supply, and the housing boom. *Review of Economic Dynamics*, 17(1), 52-69.

[11] Clerc, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Vardoulakish, A. P. (2015). Capital regulation in a macroeconomic model with three layers of default. *International Journal of Central Banking*, 40, 9–63.

[12] Damjanovic, T., Girdenas, S. (2014). Quantitative easing and the loan to collateral value ratio. *Journal of Economic Dynamics and Control*, 45, 146-164.

[13] Demyanyk, Y., Van Hemert, O. (2011). Understanding the subprime mortgage crisis. *The Review of Financial Studies*, 24(6), 1848-1880.

[14] Eggertsson, G. B. and P. Krugman (2012). Debt, deleveraging, and the liquidity trap: a Fisher-Minsky-Koo approach, *The Quarterly Journal of Economics*, 127(3), 1469-1513.

[15] Favara, G. and Imbs, J. (2015). Credit supply and the price of housing. *American Economic Review*, 105(3), 958-992.

[16] Favilukis, J., Ludvigson, S. C., Van Nieuwerburgh, S. (2017). The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium. *Journal of Political Economy*, 125(1), 140-223.

[17] Foote, C. L., Gerardi, K., Goette, L., Willen, P. (2008). Subprime facts: What (we think) we know about the subprime crisis and what we don't. *FRB of Boston Public Policy Discussion Paper*, (08-2).

[18] Garriga, C., Manuelli, R., Peralta-Alva, A. (2019). A macroeconomic model of price swings in the housing market. *American Economic Review*, 109(6), 2036-72.

[19] Gertler, M., Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1), 17-34.

[20] Gertler, M., Kiyotaki, N. (2010). Financial intermediation and credit policy in business cycle analysis. In *Handbook of Monetary Economics* (Vol. 3, pp. 547-599). Elsevier.

[21] Gertler, M., Kiyotaki, N., Queralto, A. (2012). Financial crises, bank risk exposure and government financial policy. *Journal of Monetary Economics*, 59, S17-S34.

[22] Glick, R., Lansing, K. J. (2010). Global household leverage, house prices, and consumption. *FRBSF Economic Letter*, 1, 1-5.

[23] Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission. Working paper.

[24] Greenwood, J., Hercowitz, Z., Huffman, G. W. (1988). Investment, capacity utilization, and the real business cycle. *The American Economic Review*, 402-417.

[25] Guerrieri, V., Lorenzoni, G. (2017). Credit crises, precautionary savings, and the liquidity trap. *The Quarterly Journal of Economics*, 132(3), 1427-1467.

[26] Guerrieri, V., Uhlig, H. (2016). Housing and credit markets: booms and busts. In *Handbook of Macroeconomics* (Vol. 2, pp. 1427-1496). Elsevier.

[27] Holmstrom, B., Tirole, J. (1997). Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics*, 112(3), 663-691.

[28] Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3), 739-764.

[29] Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics*, 18(1), 140-163.

[30] Jordà, Ò., Schularick, M., Taylor, A. M. (2015). Betting the house. *Journal of International Economics*, 96, S2-S18.

[31] Justiniano, A., Primiceri, G. E., Tambalotti, A. (2019). Credit supply and the housing boom. *Journal of Political Economy*, 127(3), 1317-1350.

[32] Kaplan, G., Mitman, K., Violante, G. L. (2020). The housing boom and bust: Model meets evidence. *Journal of Political Economy*, 128(9), 3285-3345.

[33] Kiyotaki, N., Michaelides, A., Nikolov, K. (2011). Winners and losers in housing markets. *Journal of Money, Credit and Banking*, 43(2-3), 255-296.

[34] Kiyotaki, N., Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2), 211-248.

[35] Lambertini, L., Mendicino, C., Punzi, M. T. (2013). Leaning against boom–bust cycles in credit and housing prices. *Journal of Economic Dynamics and Control*, 37(8), 1500-1522.

[36] Landvoigt, T. (2016). Financial intermediation, credit risk, and credit supply during the housing boom. Working paper.

[37] Lawrance, E. C. (1991). Poverty and the rate of time preference: evidence from panel data. *Journal of Political Economy*, 99(1), 54-77.

[38] Martin, P., Philippon, T. (2017). Inspecting the mechanism: Leverage and the great recession in the eurozone. *American Economic Review*, 107(7), 1904-37.

[39] Mendicino, C., Nikolov, K., Suarez, J., Supera, D. (2018). Optimal dynamic capital requirements. *Journal of Money, Credit and Banking*, 50(6), 1271-1297.

[40] Mendicino, C., Pescatori, A. (2004). Credit frictions, housing prices and optimal monetary policy rules. Mimeo.

[41] Mian, A., Sufi, A. (2009). The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis. *The Quarterly Journal of Economics*, 124(4), 1449-1496.

[42] Mian, A., Sufi, A. (2011). House prices, home equity-based borrowing, and the US household leverage crisis. *American Economic Review*, 101(5), 2132-56.

[43] Mian, A., Sufi, A. (2015). House of debt: How they (and you) caused the Great Recession, and how we can prevent it from happening again. University of Chicago Press.

[44] Mian, A., Sufi, A., Verner, E. (2017). Household debt and business cycles worldwide. *The Quarterly Journal of Economics*, 132(4), 1755-1817.

[45] Mian, A., Sufi, A. (2018). Finance and business cycles: the credit-driven household demand channel. *Journal of Economic Perspectives*, 32(3), 31-58.

[46] Nuño, G., Thomas, C. (2017). Bank leverage cycles. *American Economic Journal: Macroeconomics*, 9(2), 32-72.

[47] Rognlie, M., Shleifer, A. and Simsek, A. (2018). Investment hangover and the great recession. *American Economic Journal: Macroeconomics*, 10(2), 113-153.

[48] Rubio, M. (2011). Fixed-and variable-rate mortgages, business cycles, and monetary policy. *Journal of Money, Credit and Banking*, 43(4), 657-688.

[49] Schmitt-Grohé, S., Uribe, M. (2016). Downward nominal wage rigidity, currency pegs, and involuntary unemployment. *Journal of Political Economy*, 124(5), 1466-1514.

[50] Schularick, M., Taylor, A. M. (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *American Economic Review*, 102(2), 1029-61.

Appendix

5.1 IRFs: LTV Ratio Liberalization

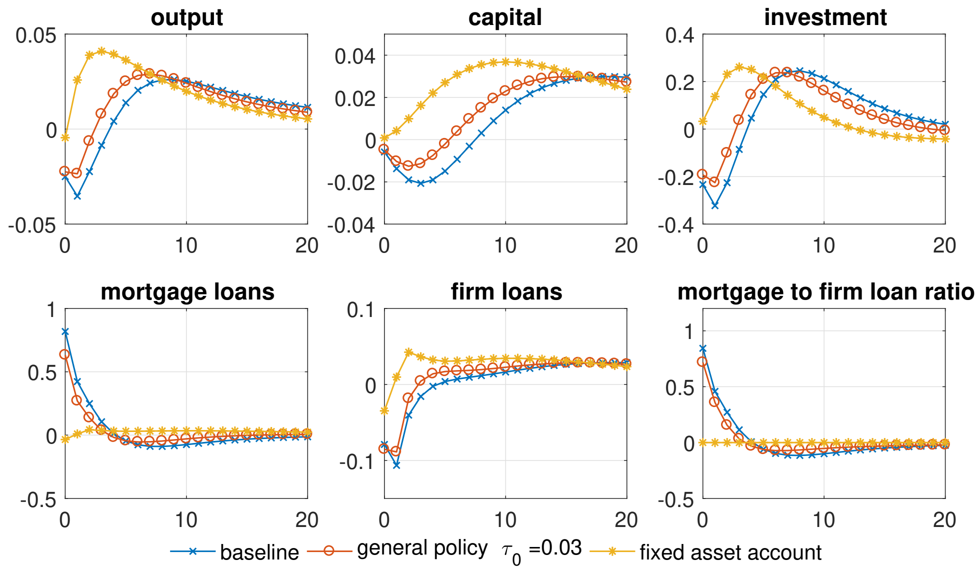

Figure 5: Counterfactual analysis: IRFs to a 0.165% increase in m_t (LTV ratio liberalization)

5.2 Welfare and Consumption Equivalent

We use consumption equivalent to compare welfare. When we take the second-order approximation to the utility function around the steady state, the volatilities of consumption, housing and labor are included. If we write the welfare of patient households (42) in a recursive form,

$$\mathcal{W}_{s,t} = U\left(C_{s,t}, H_{s,t}, L_{s,t}\right) + \beta_s \mathbb{E}_t \mathcal{W}_{s,t+1}.$$

In the steady state, we have

$$\bar{\mathcal{W}_s} = \frac{U(\bar{C}_s, \bar{H}_s, \bar{L}_s) + \beta_s \mathcal{M}_s}{1 - \beta_s},$$

where $\mathcal{M}_s$ is the second moments of C_s, H_s and L_s.

Denote Γ as the percentage increase of consumption needed for the baseline model to reach the same level of welfare under bank asset-side policies. Denote $\bar{\mathcal{W}}_s^p$ as the welfare of patient households under the policy and Γ_s^p as the consumption equivalent, and we have

$$\bar{\mathcal{W}}_s^p = \frac{U\left((1+\Gamma_s^p)\bar{C}_s, \bar{H}_s, \bar{L}_s\right) + \beta_s \mathcal{M}_s}{1 - \beta_s}.$$

Analogously, when we consider social welfare, consumption equivalent is defined as the average percentage increase of consumption needed for both patient and impatient households in the baseline model to reach the same level of social welfare under bank asset-side policies.

5.3 Empirical Evidence

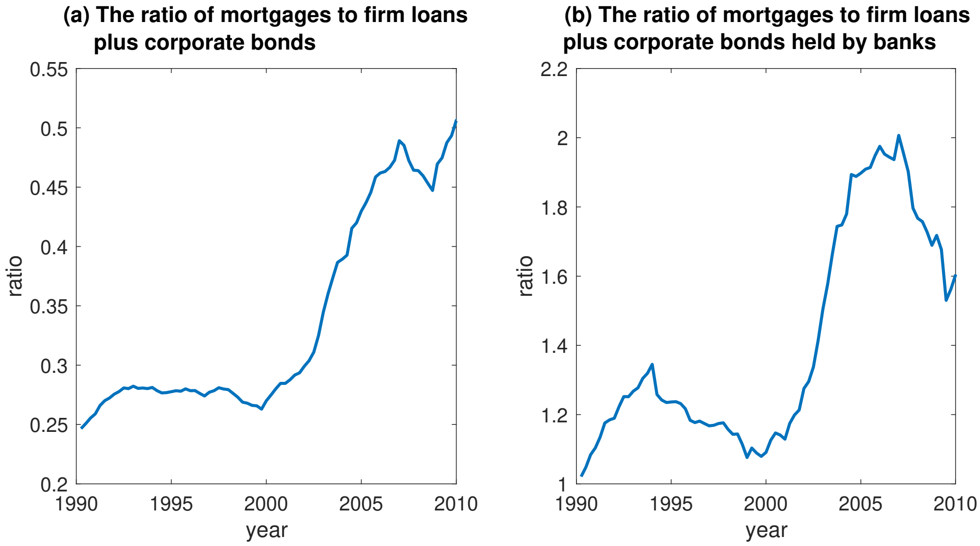

Figure 6: The ratio of mortgage loans to firm loans plus corporate bonds (panel (a)) and the ratio of mortgage loans to firm loans plus corporate bonds held by banks (panel (b)) in US from 1990-2010

Figure 6 shows the ratio of mortgage loans to firm loans when we consider a broader definition of firm borrowing. We consider commercial and industrial loans plus corporate bonds in Panel (a) and commercial and industrial loans plus corporate bonds held by banks in Panel (b). The pattern shown in Panel (d) in Figure 1 persists.

5.4 Extended Model with Housing Investment

This section provides a simple extension of our baseline model. We introduce housing investment so that the supply of housing varies when the house price changes.

We add "housing producing firms" as a new sector. Following Clerc et al. (2015) and Mendicino et al. (2018), we model housing producing firms and capital producing firms symmetrically. That is, housing producing firms produce new units of housing from the consumption good and sell them to both types of households. They transfer their profits back to patient households because patient households have ownership. In every period, they choose housing investment I_t^h given the house price Q_t^h subject to flow-variable adjustment costs:

$$\max \mathbb{E}_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau^h I_\tau^h - I_\tau^h \left[1 + \Psi_h (\frac{I_\tau^h}{I_{\tau-1}^h}) \right] \right\}. \tag{45}$$

The adjustment cost function $\Psi_h(\cdot)$ is convex and satisfies the following condition: $\Psi_h(1) = 0, \Psi_h'(1) = 0, \Psi_h''(1) > 0$. The optimality condition of housing investment is given by

$$Q_t^h = 1 + \Psi_h(\frac{I_t^h}{I_{t-1}^h}) + \frac{I_t^h}{I_{t-1}^h} \Psi_h'(\frac{I_t^h}{I_{t-1}^h}) - \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\frac{I_{t+1}^h}{I_t^h} \right)^2 \Psi_h'(\frac{I_{t+1}^h}{I_t^h}) \right]. \tag{46}$$

A constant housing depreciation rate δ_h is introduced to ensure that the housing stock does not grow infinitely. Thus, the budget constraints of patient and impatient households are modified:

$$C_{s,t} + Q_t^h[H_{s,t} - (1-\delta_h)H_{s,t-1}] + D_t = W_{s,t}L_{s,t} + R_t D_{t-1} + T_{s,t}, \tag{47}$$

$$C_{b,t} + Q_t^h(H_{b,t} - (1-\delta_h)H_{b,t-1}) + R_{b,t}B_{t-1} = W_{b,t}L_{b,t} + B_t. \tag{48}$$

Both types of households take into account the fact that housing will depreciate at a constant rate δ_h after they enjoy housing consumption in each period, and their housing demand functions are modified accordingly:

$$\frac{Q_t^h}{C_{s,t}} = \frac{\chi_s}{H_{s,t}} + (1-\delta_h)\beta_s \mathbb{E}_t\left(\frac{Q_{t+1}^h}{C_{s,t+1}}\right), \tag{49}$$

$$\frac{\chi_b}{H_{b,t}} - (Q_t^h - m_t\frac{\mathbb{E}_t Q_{t+1}^h}{R_{b,t+1}})\frac{1}{C_{b,t}} + \beta_b(1-\delta_h - m_t)\mathbb{E}_t\left(\frac{Q_{t+1}^h}{C_{b,t+1}}\right) = 0. \tag{50}$$

The aggregate housing stock in the economy evolves as

$$H_t = (1-\delta_H)H_{t-1} + I_t^h, \tag{51}$$

and the resource constraint is now modified to

$$Y_t = C_{s,t} + C_{b,t} + \left[1 + \Psi(\frac{I_t}{I_{t-1}})\right] I_t + \left[1 + \Psi_h(\frac{I_t^h}{I_{t-1}^h})\right] I_t^h. \tag{52}$$

For comparison, we keep the other sectors unchanged from the baseline model. Before reporting the numerical results of the extended model, the newly added parameter values are set as follows. We set the housing depreciation rate δ_h to be 0.012 to match the ratio of housing investment to GDP from the data. The elasticity of housing investment to housing prices is set to be 1, which equals the elasticity of capital investment to capital prices in our baseline model. We keep the other parameter values unchanged from the baseline model.

We show the responses of variables to a positive bank liberalization shock in Figure 7. It shows that introducing housing investment alleviates boom-bust cycles of output and investment. Indeed, the boom-bust patterns of output and physical capital investment are both weakened as funds are used for physical capital investment and housing investment. However, it remains true that as borrowers begin to obtain more funds from banks via the collateral value channel, firms obtain less funds regardless of whether they invest in physical capital or houses. When bank liberalization decreases mortgage interest rate and increases house prices, the borrowing constraint is relaxed, and impatient households obtain more funds from banks. Thus, the collateral value channel remains when housing investment is introduced.

The above analysis implies that our result does not necessarily rely on a low elasticity of housing investment. From the above, when we choose elasticity of investment to asset prices to be the same for both houses and physical capital, the boom-bust pattern persists. If we set the elasticity of housing investment to be 0.4 as in Mendicino et al. (2018), the boom-bust patterns of output and physical capital investment will be amplified because less funds are used for housing investment. In general, our result does not rely on the assumption that

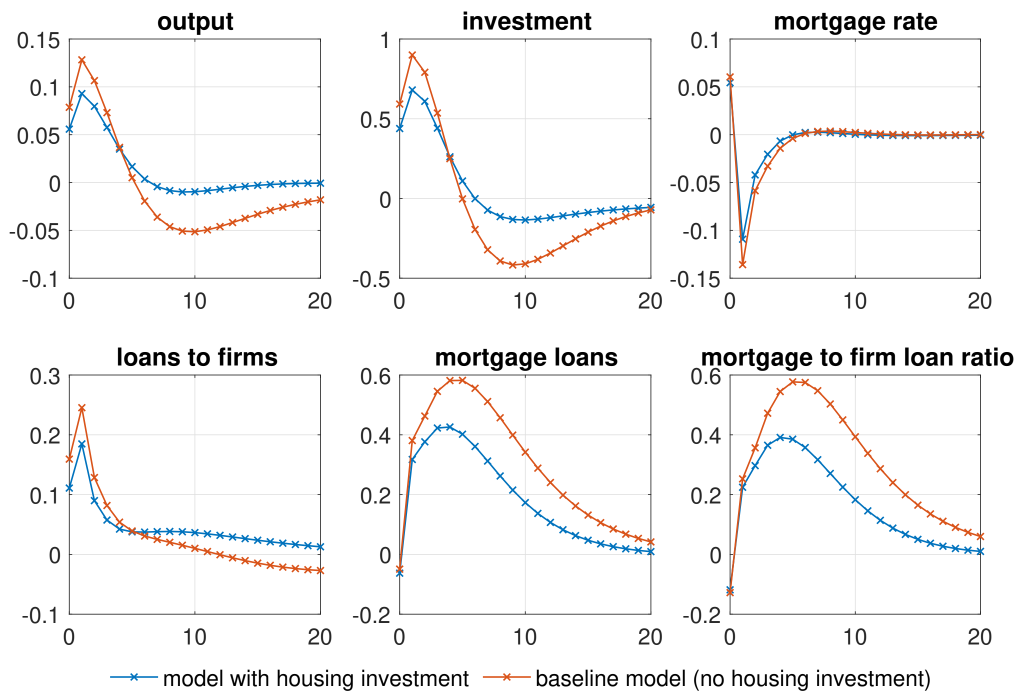

Figure 7: IRFs of bank liberalization: baseline model v.s. extended model with housing investment

housing investment is less elastic than physical capital investment, although this is indeed the case in reality.

When housing investment is introduced into the model, the welfare implications of bank asset-side regulation are consistent with the baseline model. Figure 8 shows the welfare of both types of households and social welfare under different policy parameters τ_0 when the policy rule (40) is considered. The results show that (1) social welfare is improved when the policymaker designs the tax on mortgage loans to respond more aggressively to the change in the bank asset account structure; (2) as the responsiveness policy parameter τ_0 varies, we still observe a nonmonotonic change in the welfare of patient households; and (3) there is welfare conflict between patient and impatient households when τ_0 is large.

5.5 Robustness Check

The result of this paper is robust to the choice of parameters at reasonable intervals. To be specific, the results hold when $\varphi_s(\varphi_b)$ ranges from 0.2 to 1.2, γ from 0.4 to 0.65, $\bar{m}$ from 0.8 to 0.9, Θ from 0.25 to 0.35, and β_b from 0.95 to 0.98. Details are shown in Table 4. The welfare values are consumption equivalent, and the second and fifth columns with asterisks indicate the cases in which the welfare of patient households is maximized.

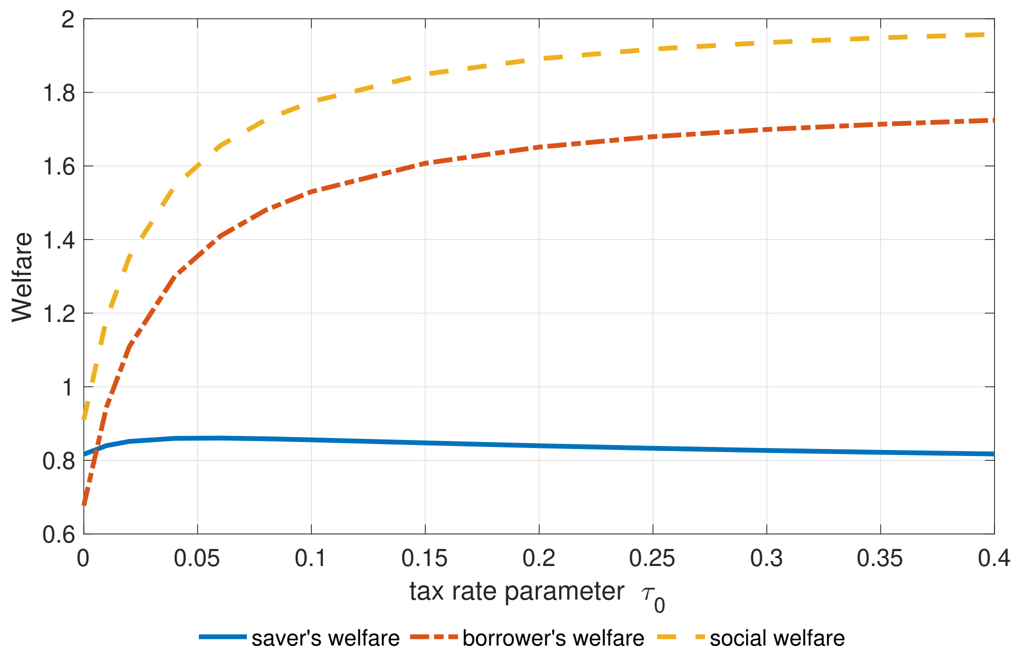

Figure 8: Welfare values under bank asset-side policy rule (40) with housing investment

Table 4: Robustness Testing

inverse Frisch labor elasticity	$\varphi_s(\varphi_b) = 0.2$			$\varphi_s(\varphi_b) = 1.2$		
$\varphi_s(\varphi_b)$	baseline	$\tau_0 = 0.04^*$	$\tau_0 = 1$	baseline	$\tau_0 = 0.03^*$	$\tau_0 = 1$
social welfare	0	0.559	0.940	0	0.490	0.940
patient hh's welfare	0	0.022	−0.003	0	0.023	−0.003
impatient hh's welfare	0	0.758	1.346	0	0.660	1.346
wage income share	$\gamma = 0.4$			$\gamma = 0.65$		
γ	baseline	$\tau_0 = 0.05^*$	$\tau_0 = 1$	baseline	$\tau_0 = 0.01^*$	$\tau_0 = 1$
social welfare	0	0.517	0.791	0	0.299	1.153
patient hh's welfare	0	0.054	0.029	0	0.003	−0.022
impatient hh's welfare	0	0.683	1.098	0	0.399	1.698
steady-state LTV ratio	$\bar{m} = 0.8$			$\bar{m} = 0.9$		
$\bar{m}$	baseline	$\tau_0 = 0.03^*$	$\tau_0 = 1$	baseline	$\tau_0 = 0.05^*$	$\tau_0 = 1$
social welfare	0	0.414	0.809	0	0.906	1.346
patient hh's welfare	0	0.017	−0.010	0	0.055	0.036
impatient hh's welfare	0	0.553	1.149	0	1.257	1.962
bank financial friction	$\Theta = 0.25$			$\Theta = 0.35$		
Θ	baseline	$\tau_0 = 0.03^*$	$\tau_0 = 1$	baseline	$\tau_0 = 0.03^*$	$\tau_0 = 1$
social welfare	0	0.376	0.695	0	0.603	1.198
patient hh's welfare	0	0.020	0.001	0	0.026	−0.006
impatient hh's welfare	0	0.499	0.971	0	0.821	1.757
borrower discount factor	$\beta_b = 0.95$			$\beta_b = 0.98$		
β_b	baseline	$\tau_0 = 0.03^*$	$\tau_0 = 1$	baseline	$\tau_0 = 0.04^*$	$\tau_0 = 1$
social welfare	0	0.467	0.919	0	0.528	0.852
patient hh's welfare	0	0.014	−0.011	0	0.039	0.012
impatient hh's welfare	0	0.579	1.191	0	0.853	1.505