

# Modelling Alternative Macroprudential Policies with Financial Frictions

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## ABSTRACT

*This paper studies the effectiveness of macroprudential policy in a New Keynesian DSGE model with financial frictions. The financial sector is modelled vis-à-vis Gertler and Karadi (2011) with endogenous bank leverage ratio. Macroprudential policies operate independently of standard monetary policy targeting price stability, and the simulation results show that they can mitigate shocks and stabilise credit. First, a countercyclical feedback rule to regulate the loan-to-value (LTV) ratio of the borrowing household is imposed. On the other hand, a proportional tax policy is implemented to restrict the leverage ratio of financial intermediaries during economic booms. The LTV ratio regulation significantly dampens economic fluctuations but shifts credit towards the business sector. Comparatively, the tax policy stabilises the aggregate credit market more effectively by directly controlling the balance sheet of financial intermediaries. Nonetheless, policymakers may face high administering and monitoring costs when implementing the tax policy, as well as a notable trade-off between economic growth and financial stability. The qualitative results remain robust when a “leaning-against-the-wind” monetary policy is introduced. The paper concludes with an extended discussion on the potential trade-off between the pursuit of price and finance stability.*

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## 1. INTRODUCTION

The 2008 financial crisis and the subsequent global recession have generated discussions among researchers and policymakers regarding the role of traditional monetary policy and the need for alternative policy to restore economic stability. Blanchard *et al* (2010) discuss the failure of financial regulation to prevent or limit systematic risk in financial markets. In addition, traditional monetary policy has been insufficient to achieve a quick and effective recovery. The crucial role of the financial system in this crisis has

prompted a search for macroprudential tools to restore financial and economic stability. These tools target broad financial markets instead of individual institutions, and the key objective of this type of supervision and regulation is to mitigate the transmission of shocks to the general economy. However, arguments have been raised regarding the design of macroprudential instruments and their interaction with traditional monetary policy. In addition, the costs of implementation and associated challenges still remain unclear to policymakers. Galati and Moessner (2013) provide a comprehensive overview on the literature concerning the effectiveness of macroprudential policy tools embedded in theoretical models as well as some recent empirical analyses.

Pioneered by Bernanke and Gertler (1989), the role of financial factors has been highlighted and gradually incorporated into general equilibrium models. First, financial intermediation is critical for our understanding of business cycle dynamics. Financial frictions amplify the macroeconomic impact of the exogenous changes (Quadrini 2011). When negative nonfinancial shocks impact the economy, a fall in investment would be exacerbated by the fall of the market value of assets used as collateral. Further, financial disruption must be explicitly modelled to examine the transmission mechanism to nonfinancial sectors. Without incorporating financial frictions, the model would not be able to produce the pro-cyclicality of credit, and be unable to track the effect of credit liberalisation occurring before the recession. Second, the incorporation of financial frictions is crucial in the study of macroprudential policies. In a globally integrated financial world, financial institutions are highly interconnected. Microprudential measures, such as capital adequacy rules, have been adopted widely by financial regulators targeting risks of individual financial institutions. Nonetheless, these policies may be insufficient and ineffective to address financial stability concerns. Macroprudential policy aims to reduce systemic risk by enhancing the resilience of the overall financial system including banks, firms and households. The policy targets the procyclicality of credit flows and reduces the cyclical components of systemic risks. Incorporating financial friction in the general equilibrium framework allows us explicitly to identify the source of the market failure and to conduct policy experiments to study the trade-off between the costs of systemic risk and economic prosperity.

The contribution of this paper is threefold. First, it adds to the theoretical literature by examining the implication of macroprudential policies on credit stabilisation, with a focus on the trade-off between economic growth and financial stability. To model the recent recession, a housing sector is incorporated to study the interaction between asset prices and business cycle fluctuations, and model financial frictions in the traditional New Keynesian DSGE framework. More explicitly, both commercial and residential housing consumption are modelled, to study the distribution of risk among different market agents. Second, this paper examines two types of leaning-against-the-wind (LAW) macroprudential instruments: a countercyclical loan-to-value (LTV) ratio rule

that targets households' borrowing constraints, and a fiscal policy measure in the form of a Pigouvian tax/subsidy that affects directly the balance sheet of financial intermediaries. This was motivated by IMF (2018), which surveys the implementation of macroprudential tools across the world. The most common tools adopted are capital conservation (39 per cent) and a limit on leverage ratio (18 per cent).

Third, to the best of our knowledge, this paper is the first to study comparatively the effectiveness of LAW monetary policy and macroprudential instruments. Our results show that adopting an augmented Taylor Rule that incorporates credit flow improves financial stability but destabilises output and inflation. This may present a conflict for policymakers who target both financial and price stability. The conflict, however, can be mitigated with the adoption of macroprudential instruments. The interaction of a LAW monetary policy and macroprudential tools is carefully examined and simulation results show that the joint implementation of both policies limits the extent of destabilisation. These results provide some insights into future research on policy coordination, by highlighting the trade-off between price and financial stability.

The economy consists of two types of household. Patient households own financial intermediaries and operate monopolistically competitive firms. They deposit savings into banks for each period, and serve as lenders in the economy. In contrast, impatient households make labour and consumption decisions while facing borrowing constraints attached to the market value of their housing stock. The maximum allowable fraction of housing stock used as collateral is defined as the LTV ratio, which is controlled by regulatory authorities. The financial intermediaries are modelled similar to Gertler and Karadi (2011), with moral hazard and costly enforcement that creates a wedge between saving and lending rates. Banks channel funds from savers to borrowers and bankers can choose to divert available funds in each period. The depositors can then force diverted managers to resign but the transferred assets are non-recoverable under costly enforcement. Bankers' liabilities are constrained by their equity capital, whilst changes to their balance sheets would affect the rest of the economy and amplify business cycles.

The model mechanism works as follows. Suppose there is a positive housing demand shock. Consumption and housing prices increase in response, expanding the borrowing constraint of households. Higher consumer prices reduce the net value of debt and cause the lender's balance sheet to deteriorate. Facing higher demand for loans, profit-maximising banks optimally expand lending in the economy and raise their leverage ratio. This leads to a greater liquidity risk in the financial market and increases the systematic risk. Nonetheless, macroprudential policy can be used to mitigate the impact from this positive demand shock. Specifically, the regulatory authority lowers the target LTV ratio of households, causing the collateral value to drop. This generates a contractionary effect on the borrowing constraint, which relieves the tension on financial intermediaries. Credit expansion, which may reduce

liquidity risk in the financial market, is thus limited. The opposite applies for negative shocks. The target LTV ratio is raised to stimulate lending in the economy, which promotes a fast and effective recovery. Nonetheless, when the household credit market is regulated, profit-maximising banks seek to expand lending in the business sector. This creates a credit shift from the restricted sector to the unregulated sector. As a result, business lending and aggregate credit market may become more volatile in response to shocks.

In contrast, a procyclical tax policy allows regulatory authorities to control directly the endogenous leverage ratio of banks. During economic booms, the government initiates a positive proportional tax on bank lending and use the proceeds to subsidise equity capital. This calms the active credit market and subsequently reduces liquidity risk. This policy demonstrates little evidence of credit shift towards the business sector as the policy targets the aggregate credit market. However, implementation may be difficult and costly. Lastly, a LAW monetary policy, modelled using an augmented Taylor Rule, promotes financial stability but destabilises output and inflation. Simulation results show that when the monetary authorities simultaneously target price and financial stability, a trade-off effect may emerge and lead to price destabilisation in the pursuit of stable credit cycles.

The rest of the paper is organised as follows. Section 2 reviews the existing literature on housing markets, financial frictions and macroprudential policies. Section 3 presents the model. Section 4 reports the calibration of key parameters. Section 5 analyses the model implications, and Section 6 extends the model to incorporate a LAW monetary policy. Section 7 concludes.

## 2. LITERATURE REVIEW

The present paper is related to four strands of literature. The first studies the relationship between credit and housing. From a theoretical perspective, Kiyotaki and Moore (1997) consider collateral constraints tied to the real estate value of entrepreneurs. Iacoviello (2005) and Iacoviello and Neri (2010) discuss the importance of housing in business cycle fluctuations.<sup>2</sup> Liu *et al* (2013) also report the crucial role of land prices in driving macroeconomic variables, arguing that land price is the dominant factor that affects housing price. Davis and Heathcote (2007) find similar results using empirical analysis. Recently, Liu *et al* (2016) find that land price is capable of generating large volatility in unemployment. Research by the IMF finds that credit and housing cycles are closely linked to business cycles (IMF 2009). Fitzpatrick and McQuinn (2007) also find that the housing boom and credit liberalisation are mutually reinforcing in the long-run, using data from Ireland. Similar results are reported for Norway by Anundsen and Jansen (2013). Favara and Imbs (2010) suggest that bank deregulation in the United States has a significant impact on housing price.

Second, the present research is also closely related to the growing literature that incorporates financial frictions into DSGE models. Carlstrom and Fuerst (1997), Kiyotaki and Moore (1997) and Bernanke *et al* (1999) are among the

pioneering studies on this topic. The important role of financial frictions has been stressed and carefully studied in a variety of contexts in the last decade.<sup>3</sup> Recent studies also focus on the important role of financial intermediation in driving business cycles. Christiano *et al* (2010) highlight the nominal friction (as lending contracts are denominated in nominal terms) that accounts for a significant portion of business cycle fluctuations. Gertler and Kiyotaki (2010) investigate how interruptions in the financial market could lead to a crisis and the effectiveness of several types of market intervention in mitigating the crisis. Gertler and Karadi (2011) further explore an effective but unconventional monetary policy in a simulated financial crisis.<sup>4</sup>

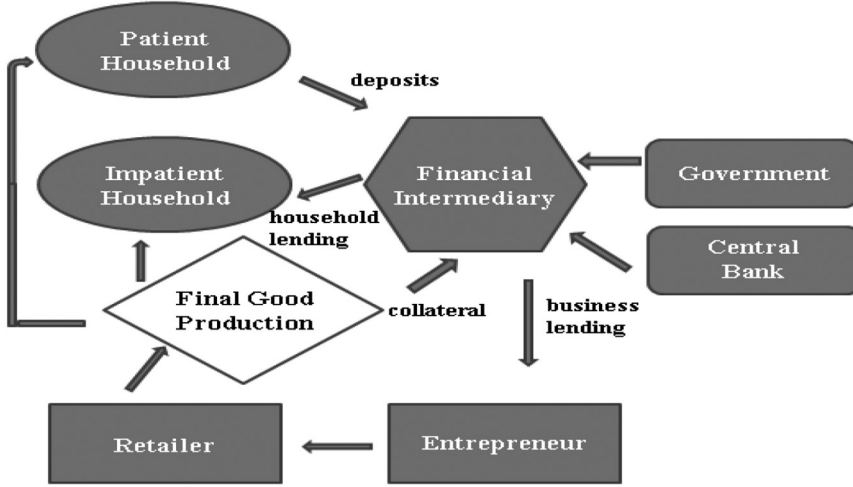
Macroprudential policy, the third area that the present study engages with, refers to the financial regulation that targets financial stability and systematic risk directly. It is often mentioned as either an alternative or complementary approach to traditional monetary policy. Common macroprudential tools target banks' capital buffers and leverage ratios, as well as households' debt-to-income and LTV ratios. Galati and Moessner (2018) provide an excellent survey of macroprudential policy research and comment on the current policy debate. Suh (2012) studies the interaction between monetary and macroprudential policy in a DSGE model with the financial accelerator. The findings suggest that macroprudential policy is effective in stabilising the economy, but it creates regulatory arbitrage that reallocates credit to a less regulated sector. Gelain *et al* (2013) incorporate housing into a standard DSGE model and find that a permanent tightening of households' collateral constraint is most effective in reducing excessive volatility. Gertler *et al* (2012) examines a Pigouvian tax-subsidy transfer on banks' balance sheets and find the policy to be successful in reducing aggregate volatility. Nonetheless, common ground concerning the most effective and appropriate macroprudential policy has not been reached in the literature. Some policies are sector-specific while others can be difficult to implement. The present paper contributes to the debate by examining both leverage and fiscal macroprudential regulation, and studies the effect on credit stabilisation at the cost of economic growth.

Lastly, this paper dives into the research on leaning-against-the-wind policies. Smets (2014 p 280) provides an excellent overview on this line of work and concludes that 'the empirical literature tentatively supports the effectiveness of macroprudential tools in dampening procyclicality', and 'to what extent such measures are effective enough to significantly reduce systemic risk is, however, as yet unclear'. Beau *et al* (2014), IMF (2015) and Svensson (2017) stress the concerns over the implementation of macroprudential policies, and analyse a more approachable LAW monetary policy that targets both price and credit stability. Nonetheless, their results show that although LAW monetary policy could dampen credit cyclicality, it may also reduce economic growth and inflation. Further, the coordination with macroprudential tools is highly contingent on the nature of shocks and state of the economy. The present paper offers a novel approach to study coordination between LAW monetary

policy and macroprudential tools. Model results show that LAW monetary policy can be conflicting between the pursuit of price and financial stability, but the effect may be mitigated with the implementation of macroprudential policies.

### 3. MODEL

Figure 1: General framework of the baseline model



#### 3.1 Households

Figure 1 provides the general overview of the model's mechanism. There exist two types of household, differed by their discount factors. The impatient households (indexed  $j=b$ ) are subject to a lower discount factor than the patient households (indexed  $j=s$ ), and borrow funds to consume each period ( $\beta_b < \beta_s$ ). Patient households optimally choose the amount of savings each period, earning the risk-free rate  $R_t$ . The representative household makes consumption,  $C_{t,s}$ , housing,  $H_{t,s}$  and labour,  $L_{t,s}$  choices each period by maximising the lifetime expected utility, which is given by:

$$\max_{C_s, H_s, L_s, D_s} E_0 \left\{ \sum_{t=0}^{\infty} \beta_s^t \left[ v_c \log C_{t,s} + v_h \varepsilon_t^H \log(\kappa H_{t,s}) - v_l \frac{L_{t,s}^{1+\varphi_L}}{1+\varphi_L} \right] \right\} \quad (1)$$

$$\text{subject to } C_{t,s} + P_t^H (H_{t,s} - H_{t-1,s}) + D_t \leq R_t D_{t-1} + W_{t,s} L_{t,s} + r_t^h (1-\kappa) P_t^H H_{t-1,s} + \Pi_t \quad (2)$$

$\varepsilon^H$  is a preference shock on housing goods (a positive value indicates an increase in housing demand). The parameter  $v_c$  controls the utility from consumption,  $v_h$  governs the utility from housing goods and  $v_l$  dictates the disutility of labour supply.  $P_t^H$  denotes the housing price in units of consumption. Patient households make real bank deposit  $D_t$ , earning real return  $R_{t+1}$  in the following

period. In addition,  $W_s$  is the real wage and  $\Pi_t$  denotes the net profits received from owning financial and non-financial firms. All variables are in real terms and the optimal choices are characterised by the following first-order conditions:

$$v_l L_{t,s}^{\phi_L} = \frac{v_c}{C_{t,s}} W_{t,s} \quad (3)$$

$$\frac{1}{C_{t,s}} = \beta_s E_t \frac{1}{C_{t+1}} R_{t+1} \quad (4)$$

$$\frac{v_c}{C_{t,s}} P_t^H = \frac{v_h \varepsilon_t^H}{H_{t,s}} + \beta_s E_t \frac{v_c}{C_{t+1,s}} P_{t+1}^H [1 + r_{t+1}^h (1 - \kappa)] \quad (5)$$

Equation (3) is the labour supply decision and (4) is the standard Euler equation. (5) characterises the housing demand for patient households, which shows that the shadow price of housing goods in period t is the sum of the period-t marginal utility from housing goods and the discounted value of the shadow price in t+1.

### 3.2 Impatient Households

Impatient households make consumption, labour and housing decisions every period. The representative household, denoted by b, is subject to a discount factor  $\beta_b$  and maximises the expected utility given by:

$$\max_{C_b, H_b, L_b, D_b} E_0 \left\{ \sum_{t=0}^{\infty} \beta_b^t [v_c \log C_{t,b} + v_h \varepsilon_t^H \log H_{t,b} - v_l \frac{L_{t,b}^{1+\phi_L}}{1+\phi_L}] \right\} \quad (6)$$

$$\text{subject to } C_{t,b} + P_t^H (H_{t,b} - H_{t-1,b}) + R_t^L B_{t-1,b} \leq W_{t,b} L_{t,b} + B_{t,b} \quad (7)$$

$$B_{t,b} \leq m_t E_t \left[ \frac{P_{t+1}^H}{R_{t+1}^L} H_{t,b} \right] \quad (8)$$

In equation (8),  $m_t$  represents the maximum allowable LTV ratio and  $E_t P_{t+1}^H H_{t,b}$  is the expected future value of the borrower's real estate. Households borrow  $B_{t,b}$  in period t and repay  $R_{t+1}^L B_{t,b}$  in period t+1. It also implies that during period t, the impatient households may only borrow up to a fraction  $m_t$  of the expected value of their housing stock in period t+1, less the interest payment. In equilibrium, this constraint binds under the assumption that borrowers are less patient than savers. Let  $\lambda_t$  be the Lagrange multiplier associated with the borrowing constraint, then the first-order conditions that characterise the optimal choices are:

$$v_l L_{t,b}^{\phi_L} = \frac{v_c}{C_{t,b}} W_{t,b} \quad (9)$$

$$\frac{v_c}{C_{t,b}} = \lambda_t E_t R_{t+1}^L + \beta_b E_t \frac{v_c}{C_{t+1,b}} R_{t+1}^L \quad (10)$$

$$\frac{v_c}{C_{t,b}} P_t^H = \frac{v_h \varepsilon_t^H}{H_{t,b}} + \beta_b E_t \frac{v_c}{C_{t+1,b}} P_{t+1}^H + \lambda_t m_t E_t P_{t+1}^H \quad (11)$$

The critical role of the collateral constraint emerges when comparing the first-order conditions of the patient and impatient households. A strictly positive Lagrange multiplier  $\lambda_t$  in equation (10) implies that the traditional intertemporal optimal condition fails to hold with equality. In addition, the marginal utility of investment in housing increases with the magnitude of  $\lambda_t$ . Moreover, equation (11) shows that the borrower's marginal return on housing goods depends on the LTV ratio. In a financially frictionless economy, the borrowing rate would be equivalent to the saving rate,  $R_t^L = R_t$ .

### 3.3 Financial Intermediaries

The financial sector is modelled in a way similar to Gertler and Karadi (2011), by introducing a wedge between deposit and lending rates. Assuming frictionless transfer of funds between financial intermediaries and borrowers, the credit friction is embedded in the funds available to banks. There exists a continuum of mass-one banks owned by the households with the timeline summarised as follows. At the beginning of period  $t$ , bank  $j$  raises deposit  $D_t^j$  from the patient household at deposit rate  $R_{t+1}$ , payable in period  $t+1$ . Bank  $j$  issues one-period loans to the impatient households with real estate collateral, and one-period loans to non-financial firms backed by equity capital. All loans are subject to interest rate  $R_{t+1}^L$ , payable in period  $t+1$ . Here,  $K_{t+1}$  is the capital holding of firms with unit price  $Q_t$ , which can be interpreted as the value of financial claims that banks hold against non-financial firms. Intermediary  $j$ 's balance sheet consists of assets given by:

$$B_t^j = B_{t,b}^j + B_{t,e}^j = m_t E_t \left[ \frac{P_{t+1}^H}{R_{t+1}^L} H_{t,b}^j \right] + Q_t K_{t+1}^j \quad (12)$$

$B_{t,b}$  and  $B_{t,e}$  denote, respectively, bank loans issued to impatient households and non-financial firms. With liabilities  $D_t^j$  and residual net worth  $N_t^j$ , the following condition holds for every period:

$$B_t^j = D_t^j + N_t^j \quad (13)$$

Subsequently, the law of motion of intermediary  $j$ 's net worth can be written as:

$$N_{t+1}^j = R_{t+1}^L B_t^j - R_{t+1} D_t^j \quad (14)$$

The banker only funds projects with an expected return of no less than the discounted cost of borrowing, thus requiring the following inequality to hold:

$$E_t \Lambda_{t,t+1+i} (R_{t+1+i}^L - R_{t+1+i}) \geq 0, i \geq 0 \quad (15)$$

$\Lambda_{t,t+1+i}$  is the stochastic discount factor applied in period  $t$  to earnings in  $t+1+i$ . The survival rate of the financial intermediary is  $\theta$ , a probability that is independent of job history. This implies that the average lifetime of a banker in any period is  $1/(1-\theta)$ . Similar to the birth-and-death assumption of banks in

Bernanke *et al* (1999), a positive exit probability prevents bankers from accumulating sufficient net worth to finance equity investments internally. In each period,  $(1-\theta)$  of bankers exit and become workers, while a similar number of workers take up jobs as financial intermediaries. Bankers who exit from the financial sector transfer their earnings back to their corresponding households, and the households provide some startup funds for new bankers. Financial intermediary  $j$  maximises the expected discounted terminal net worth,  $V_t^j$  by choosing the amount of assets to purchase:

$$V_t^j = \max E_t \sum_{i=0}^{\infty} (1-\theta)^i \beta_s^{i+1} \Lambda_{t,t+i} [(R_{t+i}^L - R_{t+i}) B_t^j + R_{t+i} N_{t+i}^j] \quad (16)$$

$V_t^j$  can then be rewritten as:

$$V_t^j = v_t B_t^j + \eta_t N_t^j \quad (17)$$

$$\text{with } v_t = E_t [(1-\theta) \beta_s \Lambda_{t,t+1} (R_{t+1}^L - R_{t+1}) + \beta_s \Lambda_{t,t+1} \theta \frac{B_{t+1}^j}{B_t^j} v_{t+1}] \quad (18)$$

$$\eta_t = E_t [(1-\theta) + \beta_s \Lambda_{t,t+1} \theta \frac{N_{t+1}^j}{N_t^j} \eta_{t+1}] \quad (19)$$

$v_t$  is the expected discounted marginal benefit to banker  $j$  for a unit increase in asset holdings  $B_t^j$ , keeping  $N_t^j$  constant. Analogously,  $\eta_t$  is the expected discounted marginal gain for a unit increase in net worth, holding total assets constant. A moral hazard with costly enforcement problem is introduced to limit the liability of financial intermediaries. This aims to prevent intermediaries from borrowing indefinitely from households given a positive expected risk premium, as shown in (15). At the beginning of any period, the banker can choose to divert a fraction  $\lambda$  of all available funds from the projects and transfer them back to the corresponding household. Upon this action, depositors can force the intermediary into bankruptcy and recapture the remaining fraction  $1-\lambda$  of total assets. Costly enforcement implies that it is too expensive for depositors to recover the diverted fraction  $\lambda$  of total assets. To ensure that depositors are willing to supply funds to bankers in each period, the following incentive constraint must be satisfied:

$$V_t^j = v_t B_t^j + \eta_t N_t^j \geq \lambda B_t^j \quad (20)$$

The left-hand side of (20) is the cost of diverting funds for banker  $j$ , which is equivalent to the value of operating the intermediary. The right-hand side is the gain from diverting a fraction  $\lambda$  of available assets. The financial intermediary chooses not to divert only when the value of operating the intermediary is greater than or equal to the benefit from diverted assets. Free of agency problems, the financial intermediary would continue to expand borrowing until  $R_{t+1}^L$  is adjusted to ensure  $v_t=0$ . With the incentive compatibility constraint in place, the intermediary's asset holdings are restricted by the equity capital. When the constraint binds, (20) can be rewritten as:

$$B_t^j = \frac{\eta_t}{\lambda - v_t} N_t^j = \phi_t N_t^j \quad (21)$$

where  $\phi_t$  is the endogenous leverage ratio of the banks that depositors would tolerate. Following the proof set forth in Gertler and Karadi (2011), the incentive compatibility constraint binds if and only if  $0 < v_t < \lambda$ . Intuitively, if  $v_t \leq 0$ , the left-hand side of (20) is always greater than the right-hand side, making the constraint non-binding. This implies that the value of operating a bank is always greater than the benefit from diverting funds. Now, suppose  $v_t \leq 0$ , then the marginal gain of increasing investment in financial assets is less than or equal to zero, implying that the financial intermediary will not take deposits from households to acquire assets  $B_t^j$ , which results in a slack constraint. It is important to emphasise that the credit condition tightens when  $\lambda$  increases. When the constraint binds, the law of motion of intermediary  $j$ 's net worth becomes:

$$N_{t+1}^j = [(R_{t+1}^L - R_{t+1})\phi_t + R_{t+1}]N_t^j \quad (22)$$

The leverage ratio does not depend on any bank-specific characteristics; therefore, aggregate variables can be obtained simply by summing across all intermediaries. Let  $N_t$  be the aggregate net worth of all banks, it can be written as the sum of the net worth of existing bankers,  $N_{et}$  and the net worth of new bankers:

$$N_{nt}: B_t = \phi_t N_t = \phi_t (N_{et} + N_{nt}) \quad (23)$$

Given that only a fraction  $\theta$  of bankers at  $t-1$  survive through period  $t$ , along with equation (22),  $N_{et}$  can be expressed as:

$$N_{et} = \theta N_t = \theta [(R_t^L - R_t)\phi_{t-1} + R_t]N_{t-1} \quad (24)$$

New bankers receive startup funds from their respective households. It is assumed that these funds equal a fraction of the value of assets that exiting bankers intermediated in their final operating period, which is given by  $(1-\theta)B_t$ . Households are assumed to transfer  $\varpi/(1-\theta)$  of the total final-period assets of exiting bankers to newly-entering financial intermediaries.  $N_{nt}$  can then be written as:

$$N_{nt} = \varpi B_t \quad (25)$$

with the law of motion for  $N_t$  rewritten as:

$$N_t = \theta [(R_t^L - R_t)\phi_{t-1} + R_t]N_{t-1} + \varpi B_t \quad (26)$$

Entrepreneurs lease part of the housing stock to produce intermediate goods, and capital producers are modelled in a way similar to Bernanke *et al* (1999). Retail firms are included to introduce sticky prices, following Calvo (1983). All details are presented in the Appendix.

### 3.4 Central Bank and Monetary Policy

The central bank in this economy administers a log-linearised Taylor Rule of the following form:

$$\hat{i}_t = \rho_r(\hat{i}_{t-1}) + (1 - \rho_r)[\gamma_\pi \hat{\pi}_t + \gamma_Y \hat{Y}_t] + \varepsilon_t^R \quad (27)$$

where  $i_t$  is the nominal interest rate. The central bank adjusts interest rates according to the log deviation of inflation and output from their steady-state levels.  $\gamma_\pi > 0$  and  $\gamma_Y > 0$  are the parameters chosen by the central bank to conduct monetary policy. When  $\rho_r > 0$ , this rule also includes a first-order autoregressive component that captures the interest rate inertia similar to Woodford (2000). The relationship between real and nominal interest rates is characterised by the Fisher equation  $1 + i_t = R_{t+1} \frac{E_t P_{t+1}}{P_t} = R_{t+1} E_t(1 + \pi_{t+1})$ . Here,  $\varepsilon_t^R$  is a random monetary shock with zero mean and variance  $\sigma^2_R$ .

### 3.5 Macprudential Policy

#### 3.5.1 Dynamic Loan-to-Value Ratio

Impatient households can only borrow up to a fraction of the expected value of their housing stock, which is characterised by Equation (8). The regulatory authority controls for the LTV ratio in order to moderate credit growth in the economy. Under the assumption that the impatient households are subject to a lower discount factor than the patient households, the borrowing constraint would always bind. Therefore, a high LTV ratio releases the tension of the collateral constraint and induces borrowing. A lower LTV ratio implies a tighter constraint that restricts the amount of lending in the real economy. The first experiment is to allow a fixed LTV ratio for the impatient households. More specifically, we set  $m_t = m$  in the baseline model, where  $m$  is the steady-state value of  $m_t$ . With the constraint binding, changes in the maximum LTV ratio directly signal credit liberalisation or tightening policies. This assists the study of the impact of credit conditions on the real economy.

The 2008 financial crisis grew out of strong economic conditions associated with a period of housing price boom and credit liberalisation. A fixed LTV ratio, however, is unable to capture the dynamic and corrective measures policymakers may want to implement. A countercyclical LTV ratio is thus desired, to limit lending during booms and stimulate the economy during downturns. In an alternative experiment, the model adopts a dynamic, LAW simple feedback rule of the form:

$$\hat{m}_t = \rho_m \hat{m}_{t+1} - \varphi_Y \hat{Y}_t - \varphi_P \hat{P}_t^H \quad (28)$$

The regulatory authority chooses parameters<sup>5</sup>  $\varphi_Y > 0$  and  $\varphi_P > 0$ . In this setup, policymakers adjust the LTV ratio corresponding to the log deviations of output and housing price from their steady-state values. In the literature, Gerlach and Peng (2005) also document the regulation of household credit as a stabilising tool for housing prices in Hong Kong and South Korea during the 1997 East Asian crisis.

### 3.5.2 Tax-Subsidy Policy

Financial intermediaries face an endogenous capital-to-loan ratio of  $N_t/B_t=1/\phi_t$ , which is the reciprocal of their leverage ratio. Similar to the discussion above, the regulatory authority wants to raise banks' capital and restrict credit growth during economic upturns. Here, a tax-subsidy scheme adapted from Gertler *et al* (2012) is introduced. In this setup, the government collects tax on banks' loans and uses the proceeds to subsidise banks' net worth. This policy directly affects the leverage ratio and allows policymakers to stabilise the credit market via the balance sheet mechanism of financial intermediaries.

Let  $\tau_t^s$  be the subsidy rate on net worth and  $\tau_t$  be the tax rate on loans, the balance sheet of the bank (Equation 13) can be rewritten as  $(1-\tau_t)B_t = D_t + (1+\tau_t^s)N_t$ . An additional balanced budget condition is introduced as  $\tau_t B_t = \tau_t^s N_t$ . In addition, there exists a cost of administering this tax scheme, which is quadratic in the tax rate,  $\psi \tau_t^2 B_t$ . The tax rate is administered through a feedback rule that corresponds to changes in output. The log-linearised rule is given by:

$$\hat{\tau}_t = \rho_\tau \hat{\tau}_{t+1} + \theta_Y \hat{Y}_t, \quad \theta_Y > 0 \quad (29)$$

When output increases above its steady-state level, the positive tax rate imposed on bank lending asserts a negative pressure on the leverage ratio. Subsequent subsidies of banks' net worth lead to a further decrease in leverage, which increases the capital-to-loan ratio. During economic recessions, the tax and subsidy reverse their positions, and a tax will be imposed on banks' capital holdings to stimulate borrowing. As a result, the leverage ratio falls, and aggregate lending is expanded to enhance economic recovery. Unlike in Lima *et al* (2012), the steady-state tax rate in the present model is zero instead of some small positive value. This implies that the economy bears no cost from raising taxes in the equilibrium and only faces such a burden in response to a random shock. This allows for a better comparison across models because the steady-state values remain unchanged.

The central bank, regulatory authority, and government play different roles in shaping the economy. First, the central bank determines the nominal interest rate through monetary policy, which affects the real interest rate via the Fisher equation. This influences the funding cost of financial intermediaries and their lending rates. Second, regulations on the LTV ratio have a direct impact on household borrowing, which is then passed on to banks' balance sheets. However, the borrowing condition of entrepreneurs is influenced only indirectly, through lending rates. The tax-subsidy scheme targets the leverage ratio of financial intermediaries directly, which has an impact on both business and household borrowing conditions. With the understanding that each policy affects different agents via different channels, the interaction between monetary policy and macroprudential tools is further examined in Section 6.

## 4. CALIBRATION

Table 1: Parameter calibration

$\beta_s$	0.985	Saver's discount factor	$\phi_I$	4	Capital adjustment cost parameter
$\beta_b$	0.95	Borrower's discount factor	$\gamma$	0.779	Probability of keeping price fixed
$v_c$	0.9	Weight of consumption in utility	$\omega$	7.2	Elasticity of marginal depreciation with respect to utilisation rate
$v_h$	0.1	Weight of housing in utility	$\gamma_P$	0.241	Measure of inflation indexation
$v_l$	2	Weight of labour in utility	$\gamma_\Pi$	1.5	Degree of intervention for inflation
$\varphi_L$	0.276	Inverse Frisch elasticity of labour supply	$\gamma_Y$	0.125	Degree of intervention for output
$\varpi$	0.002	Proportional wealth transfer to entering banks	$\rho_r$	0.8	Degree of inertia for nominal interest rate
$\theta$	0.948	Survival rate of bankers	$\rho_A$	0.85	Autocorrelation of technology shock
$\lambda$	0.17	Fraction of divertible asset	$\rho_H$	0.95	Autocorrelation of housing shock
$\kappa$	0.33	Fraction of leased housing stock	$\rho_R$	0.8	Autocorrelation of monetary shock
$\alpha$	0.64	Patient household's labour share	$\rho_c$	0.33	Autocorrelation of capital shock
$U$	1	Steady state capital utilisation rate	$\eta$	0	Share of capital in production function
$\delta(U)$	0.025	Steady state rate of depreciation	$\nu$	0.03	Share of housing in production function
			$\gamma_Y$	0.5	Degree of intervention for credit

Table 1 provides a summary of the parameters and their calibrated values. The time period in the model is one quarter. Parameter values are taken mostly from Iacoviello (2005), Gertler and Karadi (2011) and Justiniano *et al* (2015). The discount factors for saving and borrowing households are chosen to be 0.985 and 0.95, respectively. This implies that the annual net equity return for the patient households is 6.1 per cent. The weights of consumption goods and housing goods in the utility function ( $v_c, v_h$ ) are calibrated as 0.9 and 0.1, respectively. The weight of labour in the utility function ( $v_l$ ) is set to 2. The inverse of the Frisch elasticity of labour supply ( $\varphi_L$ ) is 0.276. According to the Bureau of Economic Analysis, investments in commercial real estate as a percentage of GDP are, on average, twice that of investments in residential property. The model assumes that the patient households lease a fraction  $1-\kappa = 0.67$  of housing stock to firms. This is also consistent with the estimation results from Yepez (2018), where the posterior mean of  $1-\kappa$  from the Bayesian estimation is around 0.6.

The financial sector consists of three suggestive parameters  $(\theta, \lambda, \varpi)$ , which are the survival rate of bankers, the fraction of wealth a banker could divert and the proportional wealth transfer to the entering banks, respectively. The parameters are chosen to meet two goals. First, the steady-state interest rate spread is 1 per cent. Moreover, the steady state leverage ratio of banks is four. In Gertler and Karadi (2011), the fraction of assets a banker can divert ( $\lambda$ ) is extraordinarily high, more than 30 per cent. This is set to achieve a life expectancy of ten years for bankers. The model sets the survival rate of bankers ( $\theta$ ) to be 0.948, which implies an average career horizon of five years. This lowers the fraction of assets a banker can divert to 17 per cent. Entering bankers get a wealth transfer  $\varpi/(1-\theta)$  with  $\varpi=0.002$ . In the production sector, the share of capital ( $\eta$ ) and housing stock ( $v$ ) in the Cobb-Douglas production function are set to be 0.33 and 0.03, respectively. The patient households' labour share ( $\alpha$ ) is set to 0.64. The steady-state utilisation rate is normalised to 1 with rate of depreciation  $\delta(U)=0.025$ . This implies that capital takes an average of ten years to fully depreciate. The capital adjustment cost parameter  $\phi_i$  is 4 and the elasticity of marginal depreciation with respect to the utilisation rate ( $w$ ) is 7.2. Retail firms' elasticity of substitution is 4.167, implying a steady-state real markup of 1.316. The probability of keeping prices fixed ( $\gamma$ ) is 0.779 and the measure of inflation indexation ( $\gamma_p$ ) is 0.241.

The baseline calibration for the degree of intervention in monetary policy is set following Gertler and Karadi (2011), where  $\gamma_\pi=1.5$  and  $\gamma_Y=0.125$ . The degree of inertia ( $\rho_\pi$ ) is 0.8. The autoregressive coefficients in the exogenous processes are  $\rho_A=0.85$ ,  $\rho_H=0.95$ ,  $\rho_R=0.8$  and  $\rho_c=0$ . The steady-state consumption ratio between impatient and patient households ( $C_b/C_s$ ) is 0.89 and the ratio of labour supply ( $L_b/L_s$ ) is 1.55. The annualised household debt-to-GDP ratio ( $B_b/Y$ ) is 0.26 and the business-to-household credit ratio ( $B_e/B_b$ ) is 3.9. The aggregate consumption-to-GDP ratio ( $C/Y$ ) is 0.84, the investment-to-GDP ratio ( $I/Y$ ) is 0.16 and the capital-to-GDP ratio ( $K/Y$ ) is 5.02. The steady-state LTV ratio ( $m$ ) and leverage ratio ( $\phi$ ) are 0.7 and 4, respectively. The tax and subsidy rates are zero in equilibrium. The real interest rate ( $R$ ) is 1.015 and the lending rate ( $R_L$ ) is 1.025.

## 5. MODEL ANALYSIS

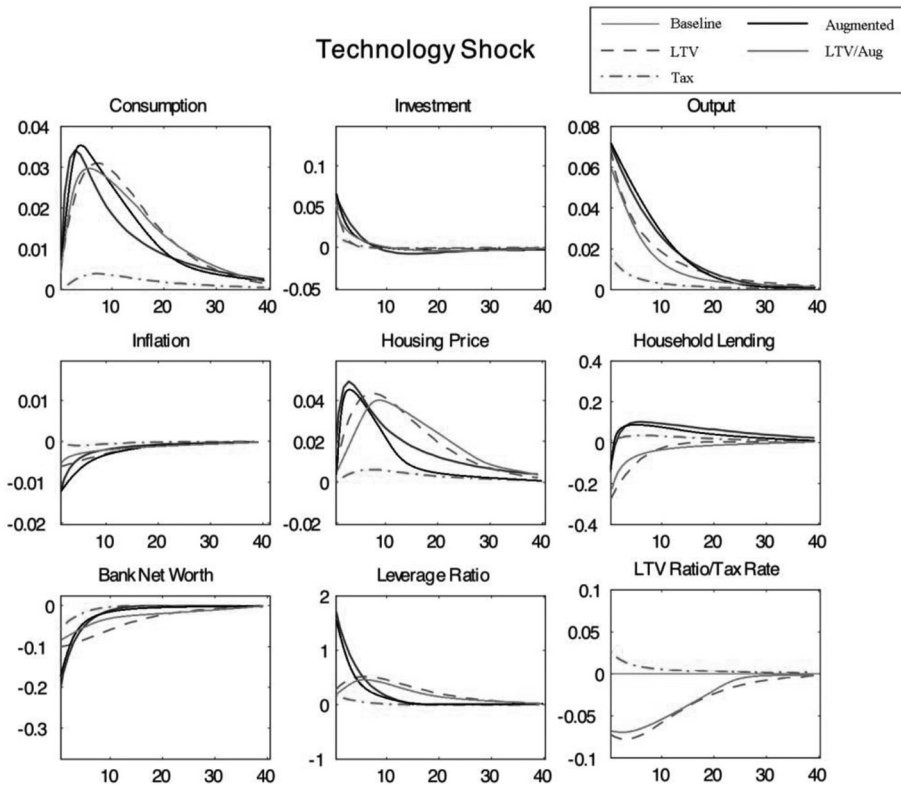
This section reports the simulation results from three alternative specifications with four shocks.<sup>6</sup> First, the baseline model ("BLM"), summarised in Sections 3.1 to 3.4, considers a fixed LTV ratio with  $m=0.7$ , which is the steady-state value for  $m_t$ . This implies that the impatient households can only borrow up to 70 per cent of the expected value of their housing stock. In fact, this number is compatible with the average LTV ratio for US residential mortgages (76 per cent) before the recession in 2008 (IMF 2011). The central bank conducts monetary policy according to equation (27) with no other active regulatory policy. The second model adopts a dynamic LTV ratio rule ("LTVM"), which is characterised by (28). The regulatory authority lowers the LTV ratio during

economic booms to limit credit expansion and increases the ratio during recessions. In the last specification, the baseline model is augmented with the tax-subsidy scheme (“PTM”), which is characterised by Equation (29). The government sets positive tax and subsidy rates during economic booms to increase the capital-to-loan ratio of financial intermediaries. The monetary policy is effective in all three models with no change in the parameter values.

The impulse response functions from positive productivity, housing demand, capital quality shocks and expansionary monetary policy are displayed in Figures 2 and 3. The standard deviation for each shock is  $\sigma_A=\sigma_\xi=0.01$ ,  $\sigma_R=0.01$  (annualised) and  $\sigma_H=0.0021$ . The magnitude of the housing demand shock is taken from Suh (2012), who matches the historical volatility of US housing prices. Moreover, 1 per cent productivity and capital quality shocks are taken from Gertler and Karadi (2011). The macroprudential policies, if effective, should stabilise the economy relative to the baseline model. Furthermore, fluctuations of household lending and housing prices should be dampened significantly.

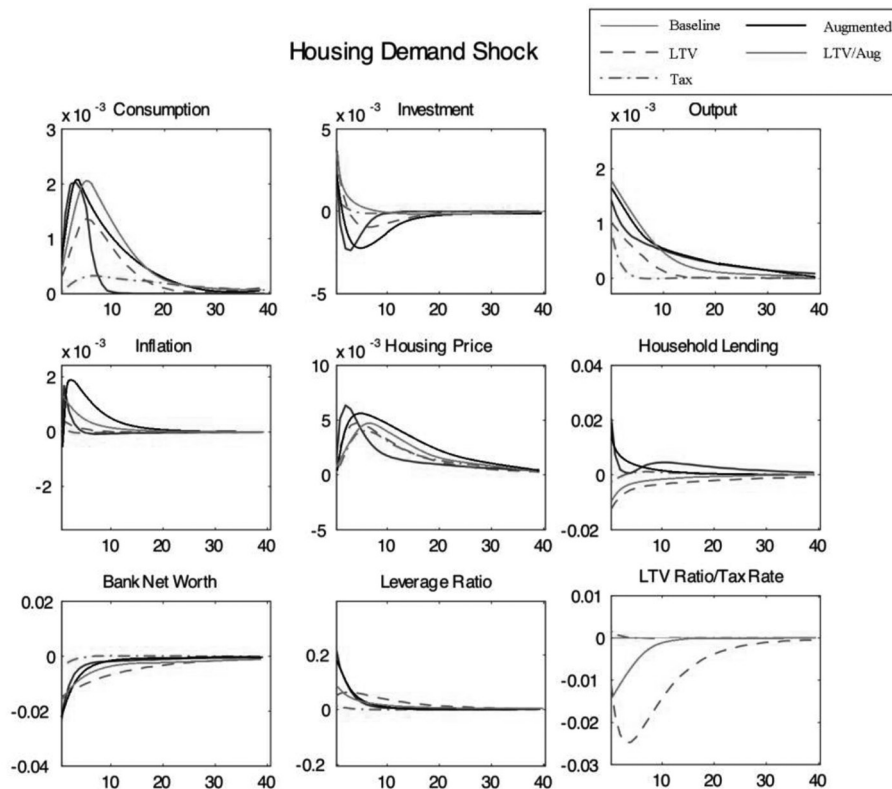
### 5.1 Technology Shock

Figure 2: Impulse response functions after a technology shock



In the baseline model, output, consumption, and investment increase, while inflation decreases, in response to a 1 per cent technology shock (Figure 2 solid lines). An increase in consumption drives up housing demand, causing housing prices to rise under a fixed housing supply. Consequently, household lending expands, resulting in a higher leverage ratio for financial intermediaries. It should be emphasised that the leverage ratio has increased more than 150 per cent in comparison to the steady-state level, creating excessive liquidity risk in the credit market. Consistent with findings in Gertler and Karadi (2011), the credit spread falls in response to a positive productivity shock that causes the banks' net worth to decrease. With a dynamic LTV ratio rule, the impulse response functions are moderately dampened for consumption, investment, output, inflation and housing price (Figure 2 dashed lines). The LTV ratio decreases by around 6 per cent in response to higher output and housing price. The contractionary LTV ratio further leads to a decrease in household lending, since impatient households now face a lower collateral value. However,

Figure 3: Impulse response functions after a housing demand shock



decreasing net worth and an increasing leverage ratio cause aggregate lending to increase in response to the shock (as is evident from Equation 21). This suggests that financial intermediaries seek to expand business lending when the household credit market is regulated. This creates a credit shift from the impatient households to entrepreneurs, which is consistent with the findings of Suh (2012). The regulatory authorities should consider this possibility when choosing the appropriate macroprudential policy.

The tax policy, PTM, is comparably more effective (Figure 2 dash-dotted lines). The leverage ratio remains stable as the government imposes a 1 per cent tax on aggregate lending and simultaneously subsidises the banks' net worth. Furthermore, the percentage change in all other variables is significantly smaller than that of the BLM and LTVM. Household lending and housing prices increase slightly in response to the technology shock, but revert back quickly to their steady state levels. Small changes in the leverage ratio and banks' net worth provide minimal evidence of credit shift. Both macroprudential policies are effective in financial stabilisation, but the tax policy may be more desirable in this particular setup.

### *5.2 Housing Demand Shock*

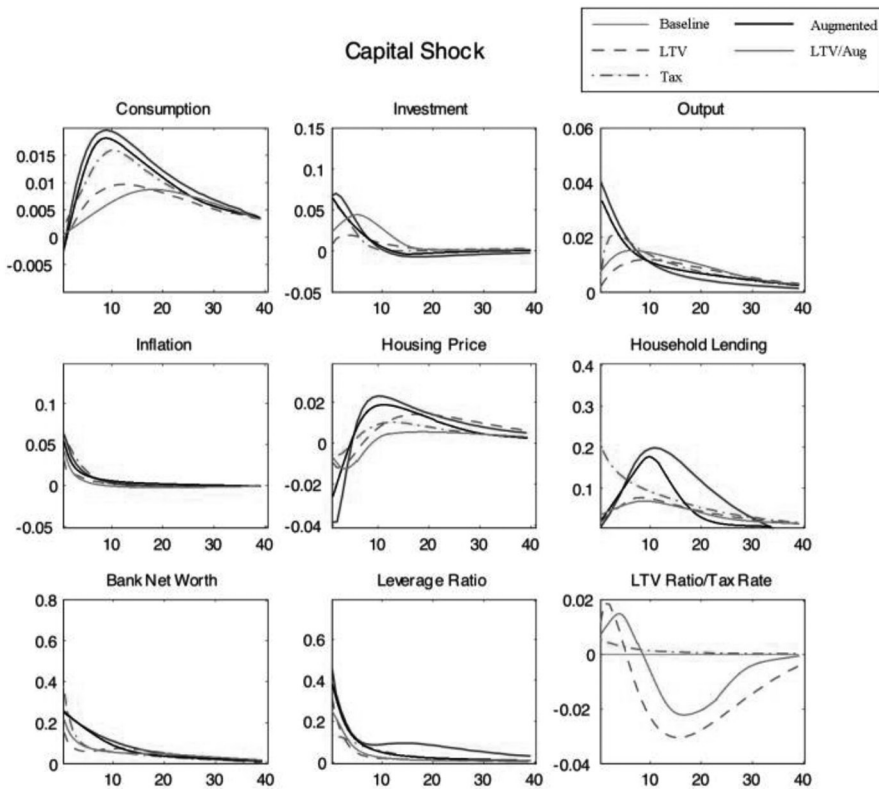
Figure 3 displays the impulse response functions from a housing demand shock of 21 bps, calibrated following Suh (2012). A positive shock implies that both patient and impatient households now obtain more utility from housing stock. Given an exogenous and fixed housing supply, the price is completely driven by demand. In the BLM, consumption, output and inflation increase while investment falls. As more people demand housing goods, prices increase and lending expands. Financial intermediaries also become more leveraged. In the LTVM, impatient households face a 1 per cent drop in the target LTV ratio, which limits the maximum loan size. This reduces household lending and dampens the growth of housing prices. In addition, the increase in the leverage ratio is reduced by more than 50 per cent in comparison to the BLM. This limits significantly the liquidity risk of financial intermediaries. Similar to the technology shock, a small decrease in banks' net worth and a relatively large increase in the leverage ratio imply a rise in aggregate lending. Growing business lending is the result of banks' profit-maximising behaviour. In this model, the entrepreneurs face no credit constraint and the amount of lending depends solely on the price and quantity of capital. This setup allows the banks to seek alternative markets to expand asset holdings. It should be emphasised that the steady-state business-to-household lending ratio is 3.9, which implies that a more volatile credit market in the business sector increases the volatility of the overall financial market, despite the dampened effect in household lending. In contrast, the PTM is also effective in response to a housing demand shock. All variables other than housing price are associated with small fluctuations, and the tax rate is positive at around 30 bps. Housing price increases slightly less than the LTVM, but reverts quickly to the steady-state level.

### 5.3 Capital Quality Shock

In Figure 4, a 1 per cent capital quality shock is imposed to examine the effects on the housing market. With an autoregressive coefficient of zero, the disturbance is considered temporary. The overall effect has two stages. First, a positive shock to quality increases the effective quantity of capital, which enhances the balance sheet of financial intermediaries. Consequently, increasing demand for capital drives up the price,  $Q_t$  and banks' leverage ratios. The effects of the shock are amplified by the presence of financial frictions. Demand for housing drops initially as resources are directed toward the production sector, causing the housing price to fall. In the second stage, positive income growth naturally induces greater housing demand and puts additional pressure on the credit market. In the BLM, the housing price first decreases by 4 per cent, and then quickly rises to 2 per cent above the steady-state level.

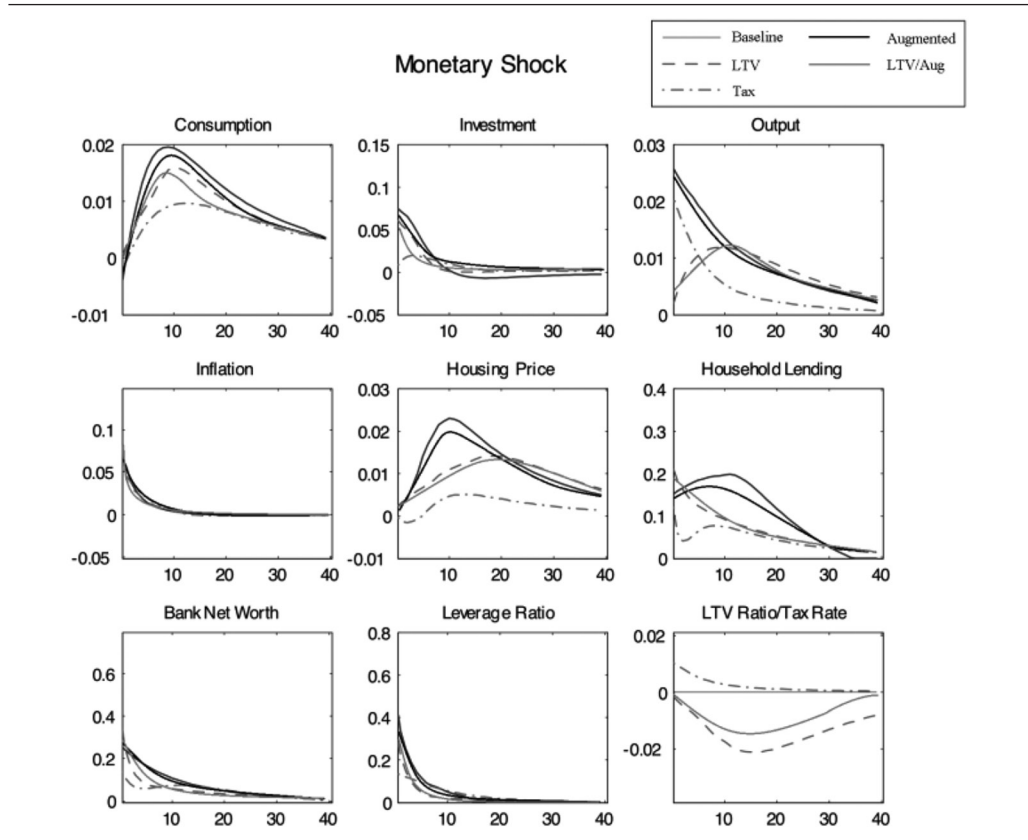
Consumption and the leverage ratio are hump-shaped, given the two-stage adjustment process and banks' net worth growth of 30 per cent. The introduction

Figure 4: Impulse response functions after a capital shock



of the dynamic LTV ratio effectively dampens the effects from the shock and restricts credit expansion. Because the housing price falls immediately after the shock, the target LTV ratio first increases above its steady-state level, then drops significantly. The borrowing limit for impatient households increases first, which leads to greater household lending. As output and housing prices both increase, the LTV ratio falls below the long-run level, which leads to a gradual decrease in household loans. This macroprudential policy actively adjusts the borrowing constraints to reduce fluctuations in the credit market. As a result, disturbances in the economy are effectively mitigated. In contrast with technology and housing demand shocks, business lending expands naturally in response to the higher price and quantity of capital, with little evidence of credit reallocation. The tax policy is more effective in stabilising the credit market than in the aggregate economy. A positive tax on total lending reduces the growth of household borrowing and alleviates the increase in housing price. Changes in the net worth of financial intermediaries have two

Figure 5: Impulse response functions after a monetary shock



parts. The first part comes from increases in the quantity and price of capital, as shown in the BLM. However, the positive subsidy further enhances banks' net worth. As a result, the net present value of financial intermediaries increases by nearly 40 per cent in response to the capital quality shock. Consequently, the credit market is more restricted, with a smaller increase in the leverage ratio. Since households own the financial intermediaries, consumption and output growth are higher in comparison to the LTVM, but are still noticeably smaller than those from the BLM.

#### *5.4 Monetary Shock*

Figure 5 displays the impulse response functions from an unexpected 1 per cent (annualised) decline in the nominal interest rate. Consumption, investment, output and inflation rise in response to the shock. This expansionary shock lowers the borrowing expense of banks and induces more lending. The leverage ratio, housing price and household lending increase significantly in the BLM. The greater risk premium also increases banks' net worth. With monetary policy solely in effect, the economy experiences large fluctuations and faces higher financial risk. In contrast, the countercyclical loan-to-value ratio policy is effective in stabilising the economy. In the LTVM, the percentage deviations are clearly smaller. The LTV ratio decreases by around 2 per cent before gradually returning to the steady-state level. The housing price and household lending increase by about half as much as in the baseline case. However, business lending expands significantly, creating the aforementioned credit shift issue. As the cost of borrowing decreases, financial intermediaries have a larger incentive to expand lending in all sectors. Regulatory control in the housing sector promotes active lending in the business sector. The tax scheme is effective in mitigating the economic response to disturbances, as demonstrated in previous sections. The tax rate increases by 1 per cent in response to a 2 per cent rise in output. Although the initial deviation of output is greater than in the LTVM, the recovery is also more rapid. The tax policy effectively reduces the changes to banks' balance sheets, resulting in small fluctuations of the housing price and household lending. In this case, business lending also expands more than household lending because of the lower borrowing cost for banks, suggesting some evidence for a credit shift. However, the magnitude is smaller in comparison to the LTVM.

#### *5.5 Volatility of Economic Variables*

Macroprudential policy aims to stabilise the economy and dampen fluctuations caused by unexpected shocks. The impulse response functions presented above provide direct measures of the percentage change of major variables in response to shocks. However, evaluation of the relative volatility is essential for a complete assessment. More specifically, a successful macroprudential policy should not only reduce the relative change of an economic variable, but also lessen the overall variation. Table 2 summarises the unconditional standard

deviation of consumption, output, investments, inflation, housing price, banks' net worth, household lending and business lending. The percentage differences between the baseline model and other models are listed in brackets. Both the dynamic LTV ratio rule and tax policy significantly reduce the volatility of the housing price. In addition, household lending is around 10 per cent less volatile in models with macroprudential policy. However, the results are not uniform among the other variables. In the LTVM, the standard deviations of investment and business lending are higher than the baseline model. This suggests that banks reallocate towards the less regulated production sector when a restriction is applied to the housing market. Financial intermediaries expand business lending to maximise profit, which leads to a more volatile credit market. Since the ratio of business-to-household lending is 3.9 in the steady state, aggregate lending in the economy fluctuates even more than in the case with a fixed LTV ratio.

The tax policy is more effective in stabilising the economy, but at the cost of relatively low economic growth following positive shocks. All variables are less volatile in comparison to the BLM and LTVM. Furthermore, the standard deviation of business lending and investments are significantly lessened. In summary, the regulatory authority needs to consider the possible trade-off between the business and household sectors when choosing the appropriate policy, as well as the cost of administering such a policy.

Table 2: Unconditional standard deviation of major economic variables

	C	Y	I	$\pi$	P <sup>H</sup>	N	B <sub>b</sub>	B <sub>e</sub>
BLM	0.01356	0.01621	0.01296	0.0079	0.0197	0.0780	0.1036	0.0908
LTVM	0.01302	0.01603	0.01383	0.0075	0.0164	0.0659	0.0939	0.1216
	(-3.9%)	(-1.1%)	(6.7%)	(-5.1%)	(-16.8%)	(-15.5%)	(-9.4%)	(33.9%)
PTM	0.01229	0.01581	0.01250	0.0073	0.0141	0.0783	0.0930	0.0735
	(-9.4%)	(-2.5%)	(-3.5%)	(-7.6%)	(-28.4%)	(0.4%)	(-10.2%)	(-19.1%)

## 6. EXTENSION

This section explores alternative monetary policy and its interaction with the proposed macroprudential tools. The question for debate is whether macroprudential policies could complement, conflict with, or act independently of monetary policies that pursue price stability. With monetary policy characterised by the classic Taylor Rule that targets output and inflation, a positive productivity shock to the economy could drive up housing demand and subsequently lead to an asset price boom, along with faster credit growth than inflation. A plain macroprudential policy that targets lending in the economy may mute output growth and fail to meet the inflation target set by the central bank. To investigate this issue further, Beau *et al* (2014) propose a LAW Taylor Rule that incorporates credit growth as part of the Fed's target. This policy regime allows the central bank simultaneously to target price and financial

stability, limiting the deviation of aggregate credit from its steady-state value. This monetary policy would operate independently of macroprudential tools introduced earlier. Equation (27) can be rewritten as:

$$\hat{i}_t = \rho_r(\hat{i}_{t-1}) + (1 - \rho_r)[\gamma_\pi \hat{\pi}_t + \gamma_Y \hat{Y}_t + \gamma_B B_t] + \varepsilon_t^R \quad (30)$$

where  $B_t$  is the total amount of debt in the economy. Constraining the deviation of lending from the steady-state level allows the central bank to limit the amount of overall credit with greater implementation practicality, as argued by Dudley (2015). This allows the regulators to raise banks' lending costs with rising asset prices, and as a result increase their capital. To calibrate this augmented rule, coefficients are obtained from Beau *et al* (2014) with  $\gamma_B$  equal to 0.5. Impulse response functions are reported in Figures 2 to 5 (black line). Gourio *et al* (2017) consider similar monetary policy and identify an optimal coefficient of 1.0. Nonetheless, model simulation results show minimal differences across the two coefficients.

Compared to the standard Taylor Rule, the LAW monetary policy is effective in limiting household lending growth. The impulse response functions show milder effect on housing price, household lending, leverage ratio and bank net worth. However, the response of inflation warrants further investigation. Simulation results show that the augmented Taylor Rule amplifies slightly the effects on output and inflation following a housing demand and technology shock. The increase in the real rate following these shocks destabilises output and inflation, which violates the primary objective of maintaining price stability by the monetary authorities. The adoption of the augmented Taylor Rule may create a potential conflict when the monetary authority simultaneously targets price and financial stability.

The conflict could be mitigated when macroprudential policy is introduced. These policies operate independently of monetary authorities with the sole objective of maintaining financial stability. This paper explores the interaction of the augmented Taylor Rule with the macroprudential tools introduced above, to study whether they complement, conflict with, or act neutrally of each other. Simulation shows that simultaneous implementation of the augmented Taylor Rule and tax policy generates indistinguishable impulse response functions compared to the standard Taylor Rule with tax policy. This can be explained by the nature of the tax policy that targets bank balance sheet directly, consistent with previous results when jointly administering both macroprudential tools.

The regime with independent but joint implementation of the augmented Taylor Rule and the LTV macroprudential policy is more interesting. The brown lines in Figures 2 to 5 depict the impulse response functions after the four external shocks previously described. The simulation results track closely to those from the LTVM (dotted-line). Overall credit and housing price growth are limited by the introduction of the macroprudential rule, supporting the robustness of the model. Furthermore, this newly proposed regime produces a milder response on inflation after productivity, monetary and capital shocks. An

interesting result emerges after the housing demand shock, where inflation and output responses are noticeably stronger. This could be a result of the greater reduction of household lending given the higher real interest rate, leading to higher housing prices and commercial lending. The credit shift from residential to business is consistently identified in this regime, and is also amplified by the leaning-against-the-wind monetary authorities. This also points to the possible conflict as the augmented Taylor Rule may be price-destabilising. However, the extent of the destabilisation is reduced by the implementation of the macroprudential policy when comparing the black and brown lines.

These results demonstrate how macroprudential policies could interfere with the conduct of LAW monetary policies characterised by the augmented Taylor Rule. Under the influence of various external shocks, there exists a trade-off between price and financial stability. The introduction of macroprudential tools in this paper may dampen the conflict while reinforcing financial stability.

## 7. CONCLUSIONS

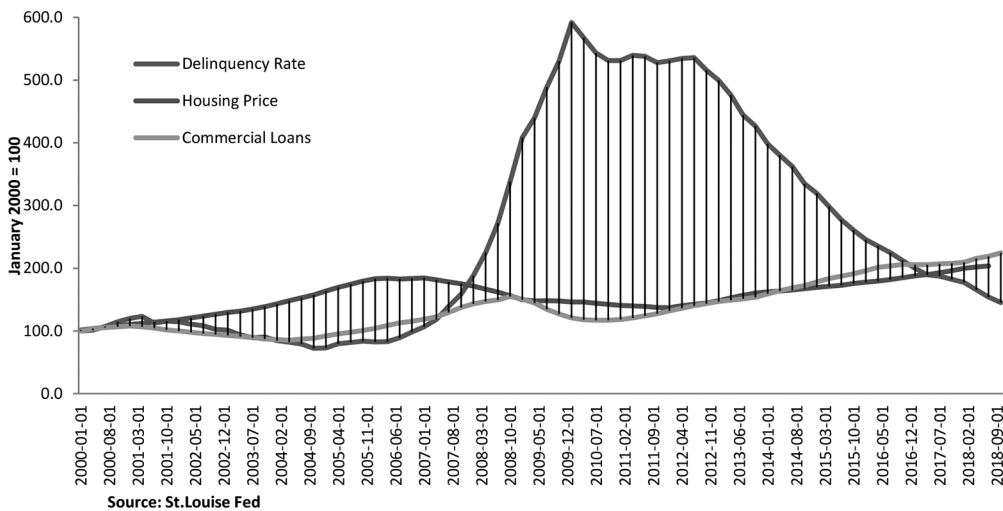
This paper models a New Keynesian DSGE economy with the housing sector and financial frictions to examine the implication of macroprudential policies. Findings suggest that a countercyclical loan-to-value ratio rule, responding to output and housing price changes, is effective in stabilising the economy but causes a credit shift to the business sector. Profit-maximising banks expand lending in the business sector when restrictions are applied in the housing market. The policy that subsidises the net worth of banks financed by a tax on lending appears to be more effective, but at a potentially high cost. These results show that financial stabilisation can be attained at a reduced rate of growth for output and inflation, and requires policymakers to evaluate carefully the extent of the systematic risk and overall financial vulnerability.

The main contribution of this paper is the examination of an economy that is closely related to the recent financial crisis, which began with a housing price boom, coupled with the failure of financial regulation. This model addresses explicitly the financial sector and housing market. Macroprudential instruments target the financial market directly, and can help to reduce systematic risk. The results suggest that if these policies had been preventively adopted before the housing boom in 2007, housing price and credit growth may have been significantly limited to prevent the later crash. However, the implementation of macroprudential policies may pose a challenge to policymakers because of the considerable administration and monitoring costs. LAW monetary policy as an alternative approach could lead to price destabilisation, but is more practical to implement. Nonetheless, this paper offers preliminary insights into the implication of macroprudential tools in a New Keynesian DSGE model with housing and financial frictions. An alternative consideration of financial frictions, such as financial accelerators (Suh 2012), can also be utilised to address the issues studied here. Moreover, investment

in housing is not incorporated in this paper and can be extended further to study the real economy more extensively. In addition, explicit credit constraints on non-financial firms are not modelled. The credit shift phenomenon can be further examined when the firms are regulated jointly with the housing sector.

The US Federal Reserve has raised interest rate four times in 2018, with 9 total adjustments made since 2015. Currently, the Fed’s target rate of 2.5 per cent still falls short of the pre-crisis level of 5.25 per cent. With inflation momentum abating and the economy affected by trade wars, the Federal Open Market Committee statement in January 2019 expressed uncertainty over whether the Fed would raise interest rates again in 2019. There has been some concern over whether another recession is possible. However, the current economy does not resemble the pre-recession state, evidently from Figure 6 that depicts the trajectory of housing price, commercial loans and delinquency rate since 2000 (expressed as an index with January 2000 = 100). Lending and housing price growth rates follow each other closely, compared to the substantial gap in the periods leading up to the recession. The delinquency rate has also improved noticeably since 2013, despite recent increases. These signs offer little support for an “overheated” market and the Fed should maintain price targeting as their main objective for the conduct of monetary policy.

Figure 6: S&P Case-Shiller National Housing Price Index and Delinquency Rate Index



Further research is needed to study the issues related to the implementation and design of macroprudential policy. Appropriate and effective financial regulation poses a challenge to many countries with active financial markets. More importantly, mechanism to identify and evaluate potential financial

vulnerability is needed. With regard to the implementation of macroprudential policy, some EU countries have adopted capital buffer and minimum leverage ratio requirements (e.g. 3.25 per cent for the UK) since 2016 (ESRB 2018). Empirical studies on the effectiveness of these measures are essential to offer better understanding of the cost and benefit structure. The literature has not yet reached a consensus on the design and implementation of regulatory instruments, and future research is still needed on the best instruments and policy mix to promote long-term economic and financial stability.

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#### ENDNOTES

1. Sherry Yu: Division of Social Sciences, New College of Florida, 5800 Bay Shore Road, Sarasota, FL, 34243, USA. Email: syu@ncf.edu. The author is grateful for the guidance and comments of Prof. Jianjun Miao, as well as the useful suggestions of the two anonymous referees and the associate editor that greatly improved this manuscript.
2. See, among others Justiniano *et al* (2012), Punzi (2013), Ferrero (2015) and Favilukis *et al* (2017).
3. See, for example, Smets and Wouters (2007), Gertler *et al* (2007), Gilchrist *et al* (2009) and Christiano *et al* (2011).
4. This strand of the literature is rich and expanding. See, *inter alia*: Forlati and Lambertini (2011), Angelini *et al* (2012), Lambertini *et al* (2013), Quint and Rabanal (2014), Brzoza-Brzezina *et al* (2015) and Clerc *et al* (2015).
5. Other researchers, including but not limited to Gelain *et al* (2013), Lambertini *et al* (2013), Brzoza-Brzezina *et al* (2014), Mendicino and Punzi (2014) and Quint and Rabanal (2014), have adopted similar approaches.
6. The results from a model with both macroprudential policies are not reported here because the impulse response functions with both policies are indistinguishable from those of the tax policy alone. Since the tax policy targets the aggregate credit market and controls directly the balance sheet of financial intermediaries, the LTV ratio rule becomes ineffective as it targets only the housing market.

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## APPENDIX

The detailed layout of the dynamic stochastic general equilibrium model presented in this paper is documented in this section.

### A.1 Entrepreneurs

There is a continuum of infinitely lived entrepreneurs of measure one, who produces a homogeneous goods utilising household labour, capital and housing stock. Entrepreneurs use a standard Cobb-Douglas production function with constant return-to-scale. Note that there is imperfect substitution between

impatient and patient household labour, which may be explained by assuming the patient households to be managers of firms and impatient households to be workers. The imperfect substitution is motivated by the imperfect risk-sharing between different households. As shown in Iacoviello (2005) and Curdia and Woodford (2015), this setup amplifies price stickiness and enables the model to match closely the procyclicality of credit. The representative entrepreneur produces intermediate goods  $Y_t$ , using capital goods  $K_t$ , housing stock leased from patient households,  $(1-\kappa)H_{t,s}$ , and the labour input of the patient and impatient households according to the production function:

$$Y_t = A_t (U_t \xi_t K_t)^\eta [(1-\kappa)H_{t,s}]^\nu L_{t,s}^{\alpha(1-\eta-\nu)} L_{t,b}^{(1-\alpha)(1-\eta-\nu)} \quad (\text{A.1})$$

$A_t$  is the technology shock,  $\xi_t$  is an exogenous shock to the quality of capital and  $U_t$  is the utilisation rate of capital.  $\xi_t K_t$  is the effective quantity of capital at time  $t$ . Firms raise funds from financial intermediaries by issuing claims against working capital  $K_{t+1}$  at price  $Q_t$ . Specifically:

$$B_{t,e} = Q_t K_{t+1} \quad (\text{A.2})$$

Allowing entrepreneurs to lease part of the housing stock enables us to capture the dynamic demand for commercial housing including office space, warehouse, production facility, etc. The endogenous borrowing constraints are only applicable to banks since non-financial firms face no credit friction. Banks have perfect information about firms and there is perfect enforcement. The financial constraints discussed in Section 3.3, however, directly affect the supply of funds to the firms.

Intermediate-goods producers choose a capital utilisation rate  $U_t$ , capital  $K_t$ , housing goods  $H_{t,s}$  and labour rate ( $L_{t,s}$ ,  $L_{t,b}$ ) to produce  $Y_t$ , and sells this product at price  $P_{mt}$ . let  $\delta(\cdot)$  denote the depreciation rate on capital, the firm solves:

$$\max_{U_t, L_{t,s}, L_{t,b}, K_t} P_{mt} Y_t + Q_t \xi_t K_t - \delta(U_t) \xi_t K_t - W_{t,s} L_{t,s} - W_{t,b} L_{t,b} - R_t^L Q_{t-1} K_t - r_t^h (1-\kappa) P_t^H H_{t-1,s} \quad (\text{A.3})$$

The first order conditions are given by:

$$L_{t,s} : W_{t,s} = P_{mt} (1-\eta-\nu) \alpha \frac{Y_t}{L_{t,s}} \quad (\text{A.4})$$

$$L_{t,b} : W_{t,b} = P_{mt} (1-\eta-\nu) (1-\alpha) \frac{Y_t}{L_{t,b}} \quad (\text{A.5})$$

$$U_t : \delta'(U_t) \xi_t K_t = P_{mt} \eta \frac{Y_t}{U_t} \quad (\text{A.6})$$

The representative firm pays out the ex-post return to capital to the banks and earns zero profit. The ex-post return to capital is given by:

$$R_{t+1}^L = \frac{[P_{m+1} \eta \frac{Y_{t+1}}{\xi_{t+1} K_{t+1}} + Q_{t+1} - \delta(U_{t+1})] \xi_{t+1}}{Q_t} \quad (\text{A.7})$$

The intuition is that the ex-post gross rate of return on capital equals the sum of the marginal productivity of capital goods and the capital gain from changes in price. Note that the valuation shock  $\xi_{t+1}$  provides additional variation to the return on capital. The value of capital stock at the end of period  $t+1$  is  $\xi_{t+1}U_{t+1}[Q_{t+1} - \delta(U_{t+1})]$ . Similarly, the non-financial firm pays the ex-post return to housing stock as rents to the patient households. Taking the derivative with respect to  $H_{t,s}$ , the ex-post rent is given by:

$$r_{t+1}^h = \nu \frac{P_{m,t+1} Y_{t+1}}{(1-\kappa) P_{t+1}^H H_{t,s}} \quad (\text{A.8})$$

## A.2 Capital Producers

Capital producers are essential to introduce capital adjustment costs in a tractable way. Following Bernanke *et al* (1999), capital adjustment costs induce additional variations in the price of capital in response to changes in capital stock. At the end of period  $t$ , competitive capital-producing firms purchase used capital from intermediate-goods producers and refurbish the old and produce new capital. They sell both repaired and new capital. Assuming the cost of replacing depreciated capital is one, the price of a unit of new or repaired capital is denoted by  $Q_t$ . Let  $I_t$  be the gross capital created,  $I_{nt}$  the net capital created and  $I$  the steady state value of  $I_t$ , then the capital-goods producer solves:

$$\max_{I_{nt}} E_0 \sum_{t=0}^{\infty} \beta_s^t \Lambda_{0,t} [(Q-1)I_{nt} - \Phi(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}})(I_{nt} + \bar{I})] \quad (\text{A.9})$$

$$\text{subject to } I_{nt} = I_t - \delta(U_t) \xi_t K_t \quad (\text{A.10})$$

$\Phi(\cdot)$  is the capital adjustment cost function, with  $\Phi(1)=\Phi'(1)=0$  and  $\Phi''(1)=\Phi'''(1)=0$ . The first-order condition that characterises the net investment  $Q$  relation is given by:

$$Q_t = 1 + \Phi(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}) + \Phi'(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}})(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}) - E_t \beta_s \Lambda_{t,t+1} \Phi'(\frac{I_{nt+1} + \bar{I}}{I_{nt} + \bar{I}})(\frac{I_{nt+1} + \bar{I}}{I_{nt} + \bar{I}})^2 \quad (\text{A.11})$$

Note that given no idiosyncratic shock among capital-goods producers, all firms choose the same net investment rate. In this setup, the price of capital increases when total net investment expenditure expands. The depreciation rate and adjustment cost function are assumed to take the following functional forms:

$$\delta(U_t) = \bar{\delta} - \frac{\bar{\delta}}{1+\omega} + \frac{\bar{\delta}}{1+\omega} U_t^{1+\omega} \quad (\text{A.12})$$

$$\Phi(\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}}) = \frac{\phi_t}{2} (\frac{I_{nt} + \bar{I}}{I_{nt-1} + \bar{I}} - 1)^2 \quad (\text{A.13})$$

where  $\bar{\delta}$  is determined by the steady state, and  $\omega$  and  $\phi_t$  are parameters.

### A.3 Retail Firms

Retail firms are present in the model to introduce sticky prices. There is a continuum of monopolistic competitive retailers who purchase intermediate output from intermediate-good producers and produce the final output,  $Y_t$ . The CES composite of final goods is given by:

$$Y_t = \left[ \int_0^1 Y_{st}^{\frac{\varepsilon-1}{\varepsilon}} ds \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (\text{A.14})$$

is the output by retailer  $s$ ,  $Y_{st} = \left( \frac{P_{st}}{P_t} \right)^{-\varepsilon} Y_t$  (A.15)

$$P_t = \left[ \int_0^1 P_{st}^{1-\varepsilon} ds \right]^{\frac{1}{1-\varepsilon}} \quad (\text{A.16})$$

One unit of intermediate goods can be used to produce one unit of final goods. The marginal cost is simply the price of intermediate output,  $P_{mt}$ . To introduce nominal rigidities, only a fraction  $1-\gamma$  of retailers can reset the price freely in any period (Calvo 1983). Retailers that do not re-optimize prices will index their prices with respect to inflation and parameter  $\gamma_p$ . Specifically, the retailer chooses the optimal reset price  $P_t^*$  to solve:

$$\max_{P_t^*} E_t \sum_{i=0}^{\infty} \gamma^i \beta_s^i \Lambda_{t,t+i} \left[ \frac{P_t^*}{P_{t+i}} \prod_{k=1}^i (1 + \pi^{t+k-1})^{\gamma_p} - P_{mt+i} \right] Y_{st+i} \quad (\text{A.17})$$

$\pi_t$  is the rate of inflation from  $t-1$  to  $t$ . The first-order condition is:

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta_s^i \Lambda_{t,t+i} \left[ \frac{P_t^*}{P_{t+i}} \left[ \prod_{k=1}^i (1 + \pi^{t+k-1})^{\gamma_p} \right]^{1-\varepsilon} - \frac{1}{1-1/\varepsilon} P_{mt+i} \right] Y_{st+i} = 0 \quad (\text{A.18})$$

Using the law of large numbers, the law of motion for the price level can be derived:

$$P_t^{1-\varepsilon} = (1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma((1 + \pi_{t-1})^{\gamma_p} P_{t-1})^{1-\varepsilon} \quad (\text{A.19})$$

Let  $\bar{P}_t^* = P_t^* / P_t$ , then the law of motion for the relative price level is given by:

$$1 = (1-\gamma)(\bar{P}_t^*)^{1-\varepsilon} + \gamma \left[ \frac{(1 + \pi_{t-1})^{\gamma_p}}{1 + \pi^t} \right]^{1-\varepsilon} \quad (\text{A.20})$$

### A.4. Competitive Equilibrium

The shocks to productivity, housing preference, monetary policy and the quality of capital ( $\hat{a}_t, \hat{\varepsilon}_t^H, \hat{\varepsilon}_t^R, \hat{\xi}_t$ ) follow standard AR(1) processes in a log-linearised form. A competitive equilibrium is a sequence of allocations:

$\{H_{t,s}, H_{t,b}, L_{t,s}, L_{t,b}, C_{t,s}, C_{t,b}, D_t, B_{t,b}, B_{t,e}, B_t, K_{t+1}, Y_t, N_t, I_t, I_{mt}, v_t, \eta_t, \phi_t, \tau_t, \tau_t^s, m_t\}_{t=0}^{\infty}$  together with a sequence of prices  $\{W_{t,s}, W_{t,b}, \Lambda_{t,t+1}, U_t, P_t^H, P_{mt}, P_t^*, Q_t, \lambda_t, R_{t+1}, R_{t+1}^L, i_t, r_{t+1}^h, \pi_t\}_{t=0}^{\infty}$  and exogenous processes  $\{A_t, e_t^R, e_t^H, \xi_t\}_{t=0}^{\infty}$  such that i) the allocations solve each household's, bank's, entrepreneur's, capital-good producer's, and retailer's maximisation

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problems at equilibrium prices, given pre-determined variables and assuming that all markets clear. The aggregate clearing conditions are given by

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

$$L_{t,s} + L_{t,b} = 1$$

$$Y_t = C_{t,s} + C_{t,b} + I_t + \Phi\left(\frac{I_t + \bar{I}}{I_{t-1} + \bar{I}}\right)(I_t + \bar{I}) + \psi\tau_t^2 B_t \quad (\text{A.21})$$

$$\tau_t B_t = \tau_t^s N_t$$