

# Monetary policy before and after the crisis

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## Abstract

This paper develops a dynamic stochastic general equilibrium model (DSGE) in which firms and intermediaries are both subject to borrowing constraints. The proposed model is used to study the welfare implications of the prevail monetary policy focusing on short-term nominal interest rate, the pre-crisis macro-prudential policy setting counter-cyclically regulatory loan-to-value (LTV) ratio, and post-crisis credit market intervention. Our analysis suggests that both the pre-crisis and post-crisis policies are Pareto improving. The social welfare and entrepreneur's welfare are enhanced most when we allow for aggressive post-crisis credit intervention, which brings higher levels of consumption, house holding and GDP. In contrast, households prefer the pre-crisis policy, especially the interest rate rule responding to output gap and inflation, which better reduces volatility of variables of interest.

Keywords: Macro-prudential policy; monetary policy; credit policy; welfare analysis

JEL classification:

# 1 Introduction

This paper investigates the welfare implications of the pre-crisis and the post-crisis policies in a general equilibrium model with financial frictions. The pre-crisis policy aims at preventing the occurrence of crisis while the post-crisis policy focuses on dampening the impact of crisis. The pre-crisis policy tools considered in this paper include Taylor-type interest rate rules that respond to financial indicators such as credit growth and housing prices, and macro-prudential measures, for which we consider a counter-cyclical loan-to-value (LTV) ratio policy. As for policies conducted during the onset and post-crisis period, we focus on the credit policy allowing for direct credit market interventions.

In the early days, the major responsibility of central banks was to provide liquidity for the financial system during panics to maintain financial stability. Bagehot (1873) promoted the role of a lender of last resort and suggested that central banks should inject credit to those solvent financial institutions without limit at a penalty rate in times of crisis. However, in the aftermath of high inflation era of the 1970s and early 1980s, the focus of central banks shifted to maintain price stability and the main monetary policy turned to set the policy rate presumably according to a rule-based approach to stabilize inflation. Moreover, financial regulations and supervision were more inclined to focus on the soundness of individual financial institutions.

The onset of recent financial crisis and the subsequent recession in 2007-2009 forced policymakers to reconsider a broader set of policy framework. On one hand, central banks had engaged in unprecedented scale of liquidity injection into financial intermediaries and markets upon the eruption of the crisis. That is, central banks started to use their powers as a lender of last resort to facilitate credit flows and conducted credit market intervention that set up facilities to inject credit directly into the private sector. On the other hand, a new set of macro-prudential policies that are aimed at promoting financial stability and containing systemic risk were introduced to the pre-crisis policy framework. Among these policy tools, the restriction on LTV ratio was the most frequently used instrument according to the survey on macro-prudential policies

conducted by IMF (2011). The LTV ratio policy is designed to be counter-cyclical in order to address the problem of credit pro-cyclicality. That is, the authority adjusts the regulatory LTV ratio in response to indicators of financial vulnerability.

A growing number of research seeks to examine the effectiveness of the liquidity injection policy. Cúrdia and Woodford (2011) suggest that direct lending can be beneficial at times of unusual financial distress. Nevertheless, they also stress that the appropriateness of active credit policy depends on conditions that are specific to the markets for particular financial instruments. Gertler and Karadi (2011) develop a model in which private intermediaries face endogenous balance sheets constraints, and the central bank can elastically obtain funds at an efficiency costs per units to supply to the private sector. They find that benefits from credit policy is substantial in crisis situation. Gertler and Kiyotaki (2010) investigate different types of credit policies by extending Gertler and Karadi (2011), and show that direct lending is beneficial during a crises. Miao and Wang (2015) find that credit policy can mitigate the downturn immediately after the collapse of the banking bubble in a model where a banking bubble can emerge.

Another strand of literature focuses on comparison between conventional monetary policy and macro-prudential policies, particularly the LTV ratio policy. Lambertini et al. (2013) investigate the gains of monetary and LTV ratio policy that lean against house-price and credit cycles. They find that having monetary policy responding to credit growth and introducing a countercyclical LTV ratio policy responding to credit growth both lead to a Pareto improvement. Quint and Rabanal (2014) study the mix of monetary and macro-prudential policies in an estimated dynamic stochastic general equilibrium model of the euro area, and find that the introduction of a macro-prudential rule reduces macroeconomic volatility and improves welfare. Rubio and Carrasco-Gallego (2014) further analyze the interaction between a macro-prudential rule for the LTV ratio, which responds to credit growth, and a traditional Taylor rule. They show that both policies acting together unambiguously improves the stability of the system. In a recent study, Brzoza-Brzezina et al. (2015) consider both conventional interest rate policy and

macro-prudential policy (LTV ratio policy) in the Euro area. They examine whether the LTV ratio policy can contribute to provide stability in the peripheral member of the Euro area, and find that appropriate adjustments in the LTV ratio can lower the volatility of credit and output.

In this paper, we attempt to evaluate the effects of three types of policies over the business cycle: (1) the Taylor-type interest rate rules responding to financial dicators, (2) the counter-cyclical LTV ratio policy, and (3) the direct credit market interventions. The first two policy instruments belong to the pre-crisis framework, and the last one is regarded as one of the onset and post-crisis policy tools. To attain the goal, we develop a DSGE model with credit market imperfections for policy analysis. The assumption of imperfection reflects the fact that there are financial frictions appear in both non-financial firms and financial intermediaries. To incorporate these two frictions into the model, we combine the analytical framework in Iacoviello (2005) with the one in Gertler and Karadi (2011). The former introduces collateral constraints tied to real estate values into non-financial sectors, and the latter is featured by introducing endogenous balance sheet constraints on financial intermediaries.

This paper contributes to the literature in two folds. First, we introduce financial frictions on both borrowers' and lenders' sides into the model. Although introducing financial frictions into business cycle models is not new (see e.g., Bernanke and Gertler, 1989; Bernanke et al., 1999; Carlstrom and Fuerst, 1997; Kiyotaki and Moore, 1997), previous studies assume that financial frictions exist only in non-financial sectors and leave financial intermediaries face perfect credit markets. They fail to take into account the feature of the recent financial crisis, which is a breakdown of financial intermediation. A few recent studies, such as Gertler and Karadi (2011), focus on frictions in the financial sector, but they impose no constraint on non-financial firms's ability to obtain funding from intermediaries.

Our paper differs from these studies in one important aspect that we consider the presence of frictions faced both by borrowers and intermediaries. The closest study in spirit to the current analysis is Iacoviello (2015), which also develops a model with two-sided frictions. In Ia-

coviello (2015), firms face a common collateral constraint and banks are subject to a regulatory capital-asset constraint, which restricts the capacity of banks' lending. While the implication of regulatory capital-asset constraint is important, this paper focuses on a market-determined lending constraint that associates depositors' willingness to supply fund with intermediaries leverage ratio. In order to motivate an endogenous lending constraint for banks to obtain funds, we follow Gertler and Karadi (2011) by introducing an agency problem between banks and their depositors.

The second contribution of the current paper is to evaluate welfare implications of pre-crisis macro-prudential policy versus post-crisis credit intervention policy using the proposed two-sided friction model. In this model, asset prices, bank credit, and economic activity are inter-dependently intertwined in a unified framework to evaluate the welfare implication of pre-crisis policies and post-crisis credit market interventions. Different from previous literatures focusing on at most two instruments, we compare multidimensional tools and analyze implications for business cycles, welfare and macroeconomic stability.

Our main result indicates that both pre-crisis policies and post-crisis credit interventions are Pareto improving. We first assess whether interest rate rules responding to output gap, credit growth and house prices can improve welfare. The analysis shows that an optimal interest rate should respond to output gap and inflation but not to other financial indicators, which implies that monetary policy does not need to respond to credit market and house prices.

We then investigate the effectiveness of a counter-cyclical LTV ratio policy as the prevailing macro-prudential policy tool. We find that LTV ratio responding to either one of output gap, credit growth and house price fluctuations are able to reach social optimum. To maximize their welfare the households prefer the rule considering credit growth because it leads to lower consumption and house holding volatility. For firms, they prefer the rule incorporating output gap since such a rule brings higher levels of consumption.

Last, we consider a credit policy that focuses on lessening the impact of financial crisis. We

show that an aggressive credit policy improves welfare during a crisis. However, a conservative intervention fails to help both individual and social welfare. A moderate intervention improves the household's welfare but decreases the firm's and social welfare.

The remainder of the paper is organized as follows. Section 2 presents the baseline model. Section 3 describes the data and estimation results. Section 4 discusses the impulse responses of different shocks. Section 5 conducts the welfare analysis and section 6 concludes.

## **2 The model**

The core framework is the DSGE model with financial intermediaries developed by Gertler and Karadi (2011). Based on this model, we add a housing market and incorporate a collateral constraint faced by non-financial firms following Iacoviello (2005). The economy features households, financial intermediaries, entrepreneurs, monopolistically competitive retailers, and a central bank. Households work, consume consumption goods and housing, and save. Financial intermediaries obtain funds from households and lend to non-financial firms. Entrepreneurs hire labor, invest, produce goods and use real estate as collateral to obtain loans. Monopolistically competitive retailers serve to introduce nominal rigidities on prices. Finally, the policy authority conducts Taylor-type interest rate rule, pre-crisis macro-prudential LTV ratio following feedback rule, or post-crisis credit market intervention.

### **2.1 Households**

The economy consists of a continuum of identical households, within which there are a fraction  $1 - f$  of workers and a fraction  $f$  of bankers. Each worker earn wages for supplying labor and returns earnings to the household. Each banker manages a bank, and accumulates profit that is transferred back to the household. A particular household thus effectively owns the banks that its bankers manage. The household consumes and saves by lending funds to competitive financial intermediaries, and possibly also by lending funds to the government. Notice that the

deposits it holds are in banks that it does not own. Over time, an individual is able to switch between the two occupations with an independent random process: with probability  $\theta$  a banker this period remains a banker next period. However, the relative proportion of each type is fixed at any moment in time.

At time  $t$ , households choose consumption  $C_t$  and deposit  $D_t$ , house holding  $H_t$  and labor supply  $L_t$  to maximize expected discount utility given by

$$E_t \sum_{i=0}^{\infty} \beta^i \left( \ln(C_{t+i} - \gamma_{ch} C_{t+i-1}) + A_{ht} j_h \ln(H_{t+i} - \gamma_h H_{t+i-1}) - A_{nt} j_n \frac{L_{t+i}^\chi}{\chi} \right),$$

where  $\beta \in (0, 1)$  is the discount factor, and  $\gamma_{ch}$  and  $\gamma_h$  are habit persistence parameters.  $j_h$  and  $j_n$  represent the weight of housing and labor in the utility function, respectively. The term  $A_{ht}$  represents a shock to the household's preference for housing services, i.e., a housing demand shock, and the term  $A_{nt}$  denotes a labor supply shock. The two AR(1) shocks follow the stationary process given by

$$\ln A_{ht} = \rho_h \ln A_{ht-1} + \epsilon_{ht}, \quad \epsilon_{ht} \sim N(0, \sigma_h),$$

$$\ln A_{nt} = \rho_n \ln A_{nt-1} + \epsilon_{nt}, \quad \epsilon_{nt} \sim N(0, \sigma_n),$$

where  $\rho_h \in (-1, 1)$  and  $\rho_n \in (-1, 1)$  measure the persistence of the shock, and  $\epsilon_{ht}$  and  $\epsilon_{nt}$  are independent and identically distributed standard normal process.

Households are subject to the following budget constraint,

$$C_t + q_t h_t + \frac{\Omega_h (H_t - H_{t-1})^2}{2H} + T_t + D_t = w_t L_t + q_t h_{t-1} + \Pi_t + R_{t-1}^d D_{t-1},$$

with  $q_t$  being the house price,  $w_t$  the real wage rate and  $R_t^d$  the gross real return from  $t$  to  $t + 1$ . The parameter  $\Omega_h$  represents the adjustment cost and  $H$  is the steady state value of  $H_t$ . Finally,  $\Pi_t$  is the profit paid to household from the ownership of non-financial firms and financial intermediaries, and  $T_t$  is the lump sum tax.

Let  $q_t$  and  $q_{ht}$  denote the marginal utility of consumption and housing, respectively. Then

the standard first-order conditions for consumption, housing demand, and labor supply are

$$1 = E_t \left[ \beta \Lambda_{t,t+1} R_t^d \right], \quad (1)$$

$$w_t \varrho_t = A_{nt} j_n L_t^{\chi-1}, \quad (2)$$

$$q_t = A_{ht} j_h \frac{\varrho_{ht}}{\varrho_t} - \Omega_h \frac{(H_t - H_{t-1})}{H} + E_t \left[ \beta \Lambda_{t,t+1} \left( q_{t+1} + \frac{\Omega_h (H_{t+1} - H_t)}{H} \right) \right], \quad (3)$$

where

$$\varrho_t = \frac{1}{C_t - \gamma_{ch} C_{t-1}} - \frac{\beta \gamma_{ch}}{C_{t+1} - \gamma_{ch} C_t}, \quad (4)$$

$$\varrho_{ht} = \frac{A_{ht}}{H_t - \gamma_h H_{t-1}} - \frac{\beta \gamma_h A_{ht+1}}{H_{t+1} - \gamma_h H_t}, \quad (5)$$

$$\Lambda_{t,t+1} = \frac{\varrho_{t+1}}{\varrho_t}. \quad (6)$$

## 2.2 Financial Intermediaries

Following Gertler and Karadi (2011), we introduce financial intermediaries into the model economy. The flow of funds constraint of the bank can be expressed as

$$B_t = \underbrace{R_{t-1} B_{t-1} - R_{t-1}^d D_{t-1}}_{N_t} + D_t,$$

where  $B_t$  is the fund supplied to entrepreneurs, which is also the asset of the bank, and  $N_t$  denotes the banker's net worth.

Note that for the banker to be willing to fund assets, it must be that a discounted return from lending is greater than a discounted cost of borrowing. Therefore, by denoting  $\beta^i \Lambda_{t,t+i}$  as the stochastic discount the banker at  $t$  applies to earnings at  $t+i$ , we have the following participation constraint,

$$E_t \left[ \beta^{i+1} \Lambda_{t,t+i+1} (R_{t+i+1} - R_{t+i+1}^d) \right] \geq 0, \quad \forall i \geq 0.$$

Once the participation constraint is satisfied, the banker keeps accumulating profits and maximizes its expected lifetime terminal wealth before they exit the industry. The maximized ex-



pected terminal wealth is given by

$$V_t \equiv \max E_t \sum_{i=0}^{\infty} (1 - \theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} N_{t+1+i}.$$

At the beginning of the period, however, banker may choose to divert the funds, and transfer them back to the household of which he or she is a member. To avoid such a moral hazard problem, the following incentive constraint is imposed on the banker's ability to obtain funds:

$$V_t \geq \lambda B_t,$$

where  $\lambda B_t$  is the fraction of available funds can be diverted by the bank. It is further assumed that the bank is forced to go bankrupt when the bank chooses to divert. Hence, the incentive constraint means that households are willing to supply funds to the banker only when the franchise value of the bank,  $V_t$ , is higher than the divertible amount.

Note that  $V_t$  can be shown as

$$V_t = v_t B_t + \eta_t N_t \tag{7}$$

with

$$v_t = E_t \left[ (1 - \theta) \beta \Lambda_{t,t+1} (R_t - R_t^d) + \theta \beta \Lambda_{t,t+1} x_{t,t+1} v_{t+1} \right], \tag{8}$$

$$\eta_t = E_t \left[ (1 - \theta) + \theta \beta \Lambda_{t,t+1} z_{t,t+1} \eta_{t+1} \right], \tag{9}$$

where  $x_{t,t+1} \equiv B_{t+1}/B_t$  and  $z_{t,t+1} \equiv N_{t+1}/N_t$  denote the gross growth rate of assets and net worth, respectively. Then the incentive constraint turns out to be

$$v_t B_t + \eta_t N_t \geq \lambda B_t.$$

If this constraint binds, we have

$$B_t = \underbrace{\frac{\eta_t}{\lambda - v_t}}_{\phi_t} N_t, \tag{10}$$

where  $\phi_t$  is the leverage ratio of the intermediary. Combining the binding incentive constraint and the flow of funds constraint, we get the evolution of the banker's net worth

$$N_t = \left[ (R_{t-1} - R_{t-1}^d) \phi_{t-1} + R_{t-1}^d \right] N_{t-1},$$

and

$$z_{t,t+1} = \frac{N_{t+1}}{N_t} = (R_t - R_t^d)\phi_t + R_t^d, \quad (11)$$

$$x_{t,t+1} = \frac{B_{t+1}}{B_t} = \frac{\phi_{t+1} N_{t+1}}{\phi_t N_t}. \quad (12)$$

As in Gertler and Karadi (2011), an existing banker at time  $t$  remains to run business next period with probability  $\theta$ , and a newly entering banker receive start up fund equal to the fraction  $\omega/(1 - \theta)$  of the total final period assets of exiting bankers at time  $t$ . Under this assumption, the equation of motion for  $N_t$  is given by

$$N_t = \theta \underbrace{\left[ (R_{t-1} - R_{t-1}^d)\phi_{t-1} + R_{t-1}^d \right]}_{N_{et}} N_{t-1} + \underbrace{\omega B_{t-1}}_{N_{nt}}, \quad (13)$$

where  $\omega B_{t-1} = \frac{\omega}{1-\theta}(1 - \theta)B_{t-1}$ .

## 2.3 Entrepreneurs

As the setup in Iacoviello (2005), entrepreneurs produce intermediate goods  $Y_t$  and maximize a life time utility function given by

$$E_t \sum_{i=0}^{\infty} \beta_e^i \ln(C_{et+i} - \gamma_{ce} C_{et+i-1}),$$

where  $\gamma_{ce}$  measures the entrepreneur's degree of habit persistence and  $\beta_e$  denotes the discount factor with  $\beta_e < \beta$ . That is, entrepreneurs discount the future more heavily than the households do, which ensures that they are borrowers. Entrepreneurs are allowed to borrow from bankers only, but not from the households directly. They maximize the objective function subject to technology constraint, the flow of funds constraint, capital law of motion and the collateral

constraint as follows,

$$Y_t = A_{zt} (K_{t-1}^\alpha) (H_{et-1}^\xi) (L_t^{1-\alpha-\xi}), \quad (14)$$

$$P_t^w Y_t + B_t + q_t H_{et-1} = C_{et} + I_t + q_t H_{et} + \frac{\Omega_h (H_{et} - H_{et-1})^2}{2 H_e} + w_t L_t + R_{t-1} B_{t-1}, \quad (15)$$

$$K_t = (1 - \delta) K_{t-1} + \left[ 1 - \frac{\Omega_k}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t, \quad (16)$$

$$B_t \leq m E_t \left( \frac{q_{t+1} H_{et}}{R_t} \right). \quad (17)$$

The term  $A_{zt}$  is a technology shock with the following AR(1) process

$$\ln A_{zt} = \rho_z \ln A_{zt-1} + \epsilon_{zt}, \quad \epsilon_z \sim N(0, \sigma_z),$$

where  $\rho_z \in (-1, 1)$  is the persistence parameter, and  $\epsilon_z$  is i.i.d. standard normal process.

Inputs used to produce intermediate good  $Y_t$  include the capital  $K_t$ , the real estate  $H_{et}$  and the labor  $L_t$ . The parameter  $\alpha$  and  $\xi$  measure the output elasticities of capital and real estate, respectively. Entrepreneurs sell intermediate good to retailers at the wholesale price  $P_t^w$ , and pay the gross interest rate  $R_t$  for bank loans. The parameter  $\Omega_h$  and  $\Omega_k$  are the adjustment cost of changing the stock of real estate and capital,  $H_e$  is the steady state value of  $H_{et}$ ,  $\delta$  is the depreciation rate of capital, and  $m$  can be interpreted as a loan-to-value (LTV) ratio.

Let  $\mu_{bt}$  denote the multiplier associated with the borrowing constraint,  $\mu_{kt}$  the multiplier for the capital accumulation equation, and then the first-order-conditions for the entrepreneur's optimization problem are given by

$$1 = E_t \left[ \beta_e \Lambda_{et,t+1} R_t \right] + \frac{\mu_{bt} R_t}{Q_{et}}, \quad (18)$$

$$q_t = E_t \left[ \beta_e \Lambda_{et+1,t} \left( P_{t+1}^w \xi \frac{Y_{t+1}}{H_{et}} + q_{t+1} + \frac{\Omega_h (H_{et+1} - H_{et})}{H_e} \right) + \frac{\mu_{bt} m q_{t+1}}{Q_{et}} \right] - \frac{\Omega_h (H_{et} - H_{et-1})}{H_e}, \quad (19)$$

$$q_t^k = E_t \left[ \beta_e \Lambda_{et+1,t} \left( P_{t+1}^w \alpha \frac{Y_{t+1}}{K_t} + q_{t+1}^k (1 - \delta) \right) \right], \quad (20)$$

$$1 = q_t^k \left[ 1 - \frac{\Omega_k}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 - \Omega_k \left( \frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + E_t \left[ \beta_e \Lambda_{et+1,t} q_{t+1}^k \Omega_k \left( \frac{I_{t+1}}{I_t} - 1 \right) \left( \frac{I_{t+1}}{I_t} \right)^2 \right], \quad (21)$$

$$w_t = P_t^w (1 - \alpha - \xi) \frac{Y_t}{L_t}, \quad (22)$$

where the shadow price of capital in consumption units is given by  $q_t^k = \frac{\mu_{kt}}{\varrho_{et}}$  and

$$\varrho_{et} = \frac{1}{C_{et} - \gamma_{ce}C_{et-1}} - \frac{\beta_e \gamma_{ce}}{C_{et+1} - \gamma_{ce}C_{et}}, \quad (23)$$

$$\Lambda_{et,t+1} = \frac{\varrho_{et+1}}{\varrho_{et}}. \quad (24)$$

## 2.4 Retailers

There are a continuum of mass unity of retailers indexed by  $s$ . Retailer  $s$  buys intermediate goods  $Y_t$  from entrepreneurs at  $P_t^w$  in a competitive market and then differentiates the goods at no cost into  $Y_t(s)$ . The final output  $Y_t^f$  is a CES composite given by

$$Y_t^f = \left[ \int_0^1 Y_t(s)^{\frac{\varepsilon-1}{\varepsilon}} ds \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

The individual demand curve is obtained from cost minimization by users of final output, which can be shown as

$$Y_t(s) = \left( \frac{P_t(s)}{P_t} \right)^{-\varepsilon} Y_t^f.$$

Let  $P_t(s)$  be the price of  $Y_t(s)$ , the composite price index is given by

$$P_t = \left[ \int_0^1 P_t(s)^{\varepsilon-1} ds \right]^{\frac{1}{\varepsilon-1}}.$$

Retailers use one unit of intermediate good to produce one unit of retail output, and each of them chooses a sale price  $P_t(s)$ , taking  $P_t^w$  and the demand curve as given. In particular, a retailer can freely adjust its price with probability  $1 - \zeta$  in every period. Therefore, the retailer chooses the optimal reset price  $P_t^*(s)$  to solve

$$\max_{P_t^*(s)} E_t \sum_{i=0}^{\infty} \zeta^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^*(s)}{P_{t+i}} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_p} - P_{t+i}^w \right] Y_{t+i}(s),$$

where  $\pi_t$  is the rate of inflation from  $t - 1$  to  $t$  and  $\gamma_p$  is the price indexing parameters. The optimality condition is

$$E_t \sum_{i=0}^{\infty} \zeta^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^*(s)}{P_{t+i}} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_p} - \frac{\varepsilon}{\varepsilon - 1} P_{t+i}^w \right] Y_{t+i}(s). \quad (25)$$

With the constant probability  $\zeta$ , the evolution of the aggregate price level is

$$P_t = \left[ (1 - \zeta)(P_t^*)^{1-\varepsilon} + \zeta(\pi_{t-1}^{\gamma_p} P_{t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \quad (26)$$

## 2.5 Government policies

### 2.5.1 Monetary policy

We assume that monetary policy is set according to a conventional Taylor rule with interest rate smoothing given by

$$i_t = r_i i_{t-1} + (1 - r_i) \left[ i + r_\pi \pi_t + r_y (\log Y_t - \log Y_t^*) \right] + e_t, \quad (27)$$

where  $i$  is the steady state nominal rate,  $Y_t^*$  is the equilibrium level of output under flexible prices,  $e_t$  is an exogenous shock to monetary policy and  $i_t$  is the net nominal interest rate which is linked with the real rate via the Fisher equation

$$1 + i_t = R_{t+1}^d E_t \frac{P_{t+1}}{P_t}. \quad (28)$$

Alternatively, we also consider the monetary policy that reacts to credit and asset prices.

$$i_t = r_i i_{t-1} + (1 - r_i) \left[ i + r_\pi \pi_t + r_y (\log Y_t - \log Y_t^*) + r_x (\log X_t - \log X_{t-1}) \right] + e_t, \quad (29)$$

where  $X \in [B, q]$ . The four policy parameters  $r_i$ ,  $r_\pi$ ,  $r_y$  and  $r_x$  corresponds to nominal interest rate, inflation rate, output gap and targeted variables, respectively.

### 2.5.2 Loan-to-value ratio policy

Besides the benchmark Taylor rule (27), we assume that the policy maker also considers a countercyclical LTV ratio policy. The policy authority allows the LTV ratio  $m_t$  to vary around its steady state value  $m$  according to the following rule

$$m_t = \kappa_m m_{t-1} + (1 - \kappa_m) \left[ m + \kappa_x (\log X_t - \log X_{t-1}) \right], \quad (30)$$

where  $X_t$  can be macroeconomic variables or asset prices. The term  $\kappa_m$  is an autoregressive parameter and  $\kappa_x$  measure the response of LTV ratio to the corresponding alternative macroeconomic indicators.

### 2.5.3 Credit policy

Together with the benchmark Taylor rule (27), we suppose that the central bank also conducts direct credit market intervention. The setup of credit intervention follows Gertler and Karadi (2011). The credit policy allows the central bank to facilitate lending by issuing government debt,  $D_{gt}$ , to households at risk-free rate  $R_t^d$  and then lending to entrepreneurs at the market lending rate  $R_t$ . Under this case, household saving  $D_t$  now includes deposit in banks  $D_{pt}$ , and government bonds  $D_{gt}$ . Unlike private financial institutions, the government always honors its debt and thus there is neither moral hazard problem nor incentive constraint. That is, the central bank is able to lend funds more elastically than a private financial intermediary can be. However, the government intermediation yields a deadweight loss  $\tau$  per unit supplied.

To reflect the central bank's role of assisting channeling funds, in this section we redefine  $B_t$  as the total value of intermediated assets.  $B_{pt}$  and  $B_{gt}$  is denoted as the total value of assets intermediated by private sectors and government, respectively. We further assume that the central bank is willing to fund the fraction  $\psi_t$  of intermediated assets, i.e.,

$$B_t = B_{pt} + B_{gt} = \phi_t N_t + \psi_t B_t = \phi_{ct} N_t,$$

where  $\phi_{ct} = \frac{\phi_t}{1-\psi_t}$  is the leverage ratio for total intermediated funds. Now we write down the government budget constraint

$$G_t + \tau\psi_t B_t = T_t + (R_t - R_t^d)D_{gt},$$

where  $G_t$  denotes the government consumption and  $D_{gt}$  represents the government bonds. We further assume that government consumptions are kept constant at the level  $G$ .

Next, we assume that the policy authority conducts credit policy according to the following rule as in Gertler and Karadi (2011)

$$\psi_t = \psi + \rho_c E_t[(\log R_{t+1} - \log R_{t+1}^d) - (\log R - \log R^d)] \quad (31)$$

where  $\psi$  is the steady state fraction of publicly intermediated assets,  $\log R - \log R^d$  is the steady state premium, and  $\rho_c > 0$  is the feedback parameter. That is, the central bank expands credit as

the credit spread increases and tightens liquidity when the spread decreases relative to its steady state.

## 2.6 Equilibrium

To analyze the model, we compute the stationary equilibrium under the assumption that banks hit the incentive constraint and reach the maximum leverage ratio, and entrepreneurs face binding borrowing constraint and borrow up to the limit. The equilibrium is an allocation  $\{C_t, C_{et}, H_t, H_{et}, L_t, K_t, I_t, N_t, B_t\}_{t=0}^{\infty}$ , the sequence of values  $\{w_t, q_t, q_t^k, \mu_{bt}, R_t^d, R_t, i_t, P_t, P_t^w, P(s)_t^*\}_{t=0}^{\infty}$ , the bank-related values  $\{V_t, v_t, \eta_t, \phi_t, z_{t,t+1}, x_{t,t+1}\}_{t=0}^{\infty}$ , and the sequence of measurements of utility  $\{\varrho_t, \varrho_{et}, \varrho_{ht}, \Lambda_{t,t+1}, \Lambda_{et,t+1}\}_{t=0}^{\infty}$  satisfying equations (1) to (26), (28), the definition of leverage ratio of the intermediary, and the following market clearing conditions

$$Y_t = C_t + C_{et} + I_t + G_t + \tau\psi_t B_t, \quad (32)$$

$$1 = H_t + H_{et}. \quad (33)$$

The labor market clearing condition has been imposed at the beginning.

## 3 Estimation

In this paper, a subset of model parameters are calibrated and not included in the Bayesian estimation process. These parameters are chosen either according to the conventional values in the literature, or following the estimation result in related researches. This is commonly done in the DSGE literature because allowing fixed parameters in the estimation process can be viewed as imposing strict priors for these parameters.

Table 1 lists the calibrated parameters. For standard parameters, we choose typical values that are within the range considered in the related literatures. The discount factor  $\beta$  equals 0.99, implying a steady state 4% annual real interest rate. Then, we set  $\beta' = 0.98$  to ensure that the entrepreneur is the net borrower. The weight on housing  $j_h$  is set at 0.075, implying a steady

state ratio of housing wealth to annual output of 1.45. The labor disutility parameter  $j_n = 2$  control the steady state market hours at about 1/4 and labor supply elasticity  $\chi$  is fixed at 1.01. As for the technology parameters, the output elasticities of real estate  $\xi$  and the capital share in production  $\alpha$  are set at 0.04 and 0.3, respectively. The capital depreciation rate  $\delta$  is fixed at 0.025, which is the typical value in the literature. We set the maximum loan-to-ratio value  $m = 0.9$ . For the retail firm related parameters and Taylor rule parameters, we follow Gertler and Karadi (2011) to set the elasticity substitution  $\epsilon$ , the price rigidity parameter  $\gamma$ , the price indexing parameter  $\gamma_p$ , the smoothing parameter  $r_i$ , the inflation coefficient  $r_\pi$ , and the output gap coefficient  $r_y$ . The rest three financial sector parameters are also chosen following Gertler and Karadi (2011): the fraction of capital can be diverted  $\lambda = 0.3806$ ; the proportional transfer to entering bankers  $\omega = 0.0023$ ; and the survival probability  $\theta = 0.9714$ . These parameters ensure a steady state interest rate spread of one hundred basis point, a steady state leverage ratio of four, and an average survival time for a banker of a decade.

We use Bayesian methods to estimate the model. We fit the model to the following six U.S. time series: real gross domestic product, real personal consumption expenditures, loans to business, real house prices, per capita hours worked, and real nonresidential fixed investment. Quarterly data from 1975:Q1 to 2014:Q1 are used. The logarithm of variables are detrended using Hodrick-Prescott filter program in Matlab. The six time series are plotted in Figure 1.

Table 2 summarizes the prior distributions and reports the means and 10% and 90% of the posterior distribution for the estimated structural parameters. According to the last three column of Table 2, the household's degree of habit persistence in housing, it is relatively modest comparing to that in consumption (0.43 vs. 0.21). The estimated real estate adjustment cost is much more bigger than the capital adjustment cost (0.51 vs. 0.06). Finally, the housing demand shock process is estimated to be less persistent and have larger standard deviation relative to other shocks.



Table 1: Calibrated parameters

Description	Parameters	Value
Household discount rate	$\beta$	0.9900
Entrepreneur discount rate	$\beta'$	0.9800
Labor supply aversion	$\chi$	1.0100
Weighting on housing services	$j_h$	0.0750
Weighting on labor supply	$j_n$	2.0000
Housing share	$\xi$	0.0400
Capital share	$\alpha$	0.3000
Capital depreciation rate	$\delta$	0.0250
LTV ratio	$m$	0.9000
Elasticity of substitution between goods	$\epsilon$	4.1670
Probability of keeping the price constant	$\zeta$	0.7500
Price indexation parameter	$\gamma_P$	0.2410
Interest rate smoothing parameter	$r_i$	0.8000
Inflation coefficient in the Taylor rule	$r_\pi$	1.5000
Markup coefficient in the Taylor rule	$r_y$	0.1250
Steady state proportion of government expenditures	$\frac{G}{Y}$	0.2000
Fraction of capital that can be diverted	$\lambda$	0.3806
Proportional transfer to the entering bankers	$\omega$	0.0023
Survival rate of the bankers	$\theta$	0.9714

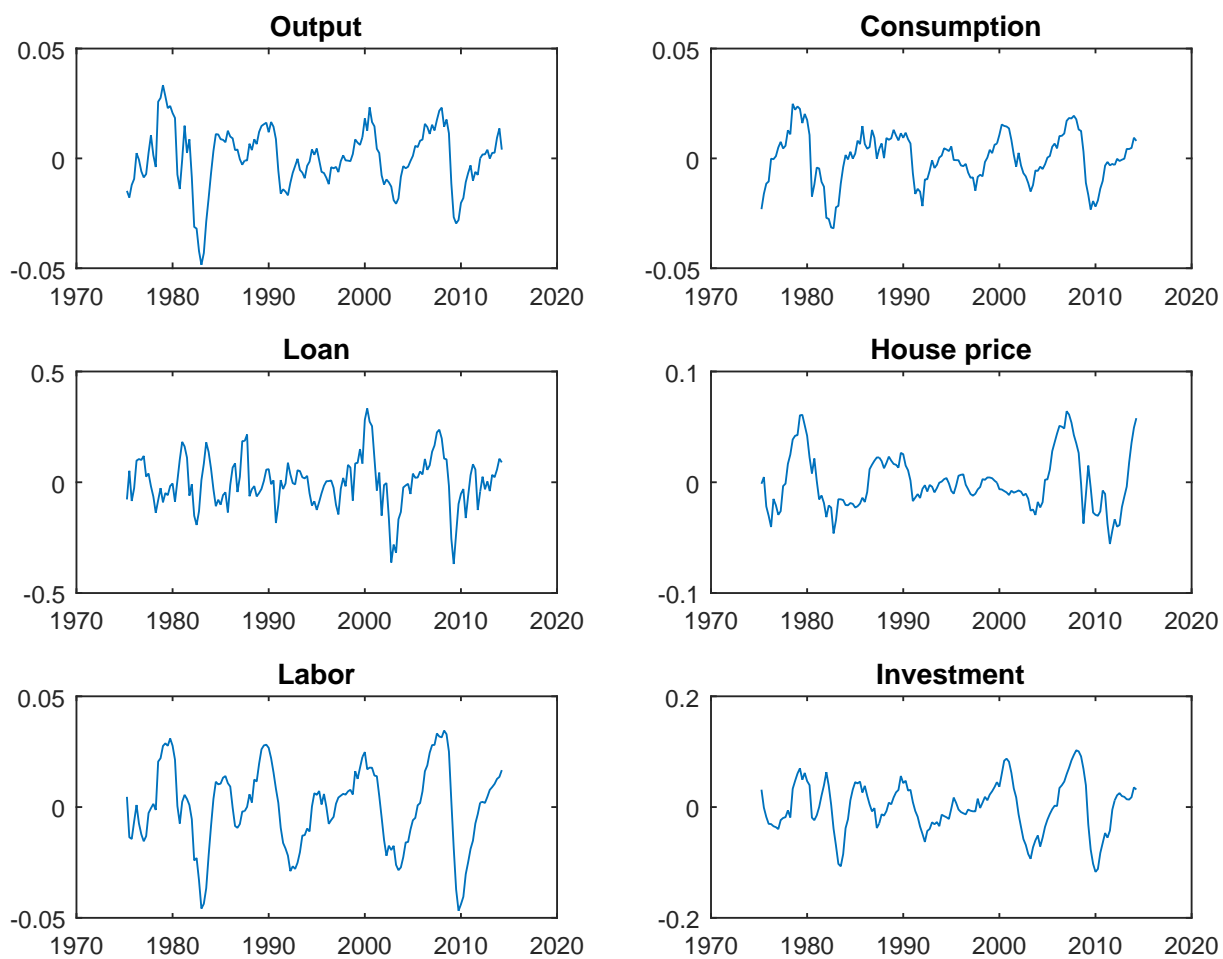


Figure 1: Data

Table 2: Prior and posterior distribution of structural and shock parameters

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev	10%	Mean	90%
Habit in consumption, household	$\gamma_{ch}$	beta	0.8	0.15	0.1633	0.2093	0.2529
Habit in consumption, entrepreneur	$\gamma_{ce}$	beta	0.8	0.15	0.7637	0.8308	0.8920
Habit in real estate	$\gamma_h$	beta	0.8	0.15	0.2840	0.4333	0.5717
Adjustment cost, capital	$\Omega_k$	gamm	0.5	0.15	0.0462	0.0627	0.0795
Adjustment cost, real estate	$\Omega_h$	gamm	0.5	0.15	0.4124	0.5055	0.6003
Autocorr., technology shock	$\rho_z$	beta	0.8	0.1	0.9419	0.9622	0.9799
Autocorr., housing demand shock	$\rho_h$	beta	0.8	0.1	0.6765	0.7318	0.7860
Autocorr., labor supply shock	$\rho_n$	beta	0.8	0.1	0.9953	0.9970	0.9985
Autocorr., government expenditure shock	$\rho_g$	beta	0.8	0.1	0.9946	0.9967	0.9985
St.dev., technology shock	$\sigma_z$	invg	0.005	0.025	0.0074	0.0079	0.0086
St.dev., housing demand shock	$\sigma_h$	invg	0.05	0.05	0.2762	0.3419	0.4125
St.dev., labor supply shock	$\sigma_n$	invg	0.005	0.025	0.0179	0.0205	0.0232
St.dev., government expenditure shock	$\sigma_g$	invg	0.0025	0.025	0.0957	0.1038	0.1123

## 4 Properties of the model

This section illustrates how the model behaves in response to the shocks given estimated parameter values. To further highlight the effect of different policies, in each figure we compare three models: (1) the model with the conventional Taylor rule (27) monetary policy, which we call the baseline model (solid line); (2) the baseline model added with the countercyclical LTV ratio policy responding to output (dashed and dotted line), and (3) the baseline model added with the credit policy (dashed line).

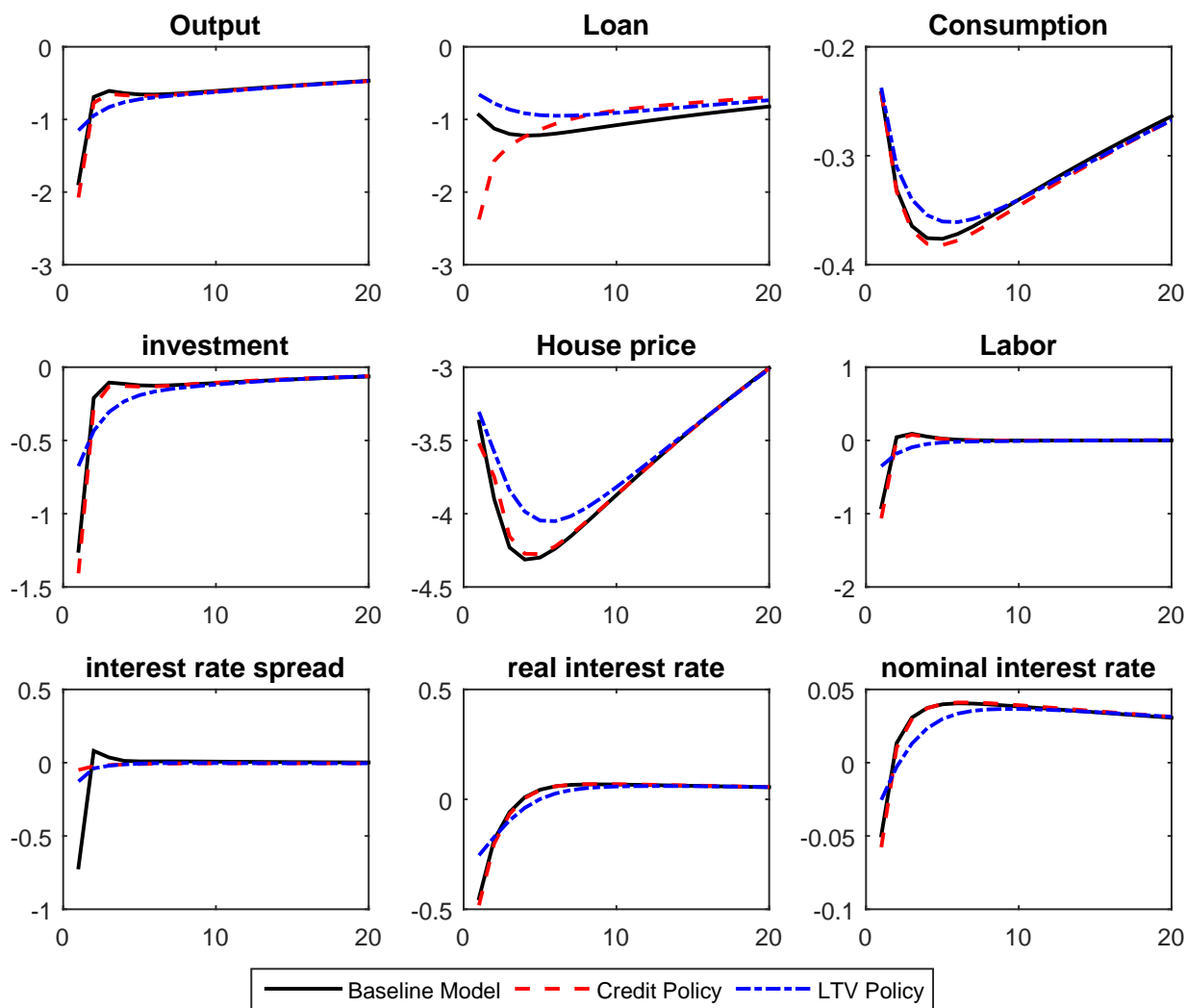


Figure 2: Impulse responses to technology shock.

## 4.1 Technology shock

We begin with the response of the model economy to a negative technology shock. Figure 2 displays the impulse responses of some key variables to an estimated one standard deviation technology shock. Accordingly, the shock leads to a decline in output. Entrepreneurs lower the demand of labor and reduce the investment in both capital and real estate. The market price of real estate falls as a result. Individuals consume less, save more with a lower deposit rate. Bankers gains from obtain more savings and pay a relative low deposit rate, and are able to increase the supply of loan with a higher leverage ratio. However, because entrepreneurs cut their need for loan, the lending rate drops and interest rate spread eventually falls.

We can observe that the baseline model, the solid line, and the model with credit policy, the dash line, roughly overlap except for the responses of loan and interest rate premium. In the baseline model and the model with credit policy, the decrease in consumption and house price are both nearly 0.38 percent and 4.3 percent after four quarters, respectively. That is, the dynamics in the model with credit intervention is almost of similar magnitude to the case where only the conventional monetary policy is involved. By contrast, the dash and dotted line, which portrays the model with LTV ratio policy, produces smaller negative effect on key variables. By conducting the LTV ratio policy, the decrease in consumption is about 0.34 percent and the fall in house price is around 3.7 percent after four quarters. Differences in the dynamics of outputs, investments and labor hours are even more obvious. The decline in these three variables are less than half of the other two cases. In other words, the LTV ratio policy significantly moderates the contraction of economic activity.

The prime reason for the ineffectiveness of credit policy is that the interest rate spread decreases when technology shock hits. According to equation (31), the tightness of liquidity hurts entrepreneur's ability to invest and produce. On the contrary, the LTV ratio policy (30), which adjusts the LTV ratio in response to outputs, effectively dampens the decline in loan demand and therefore mitigates the deterioration in economic activity.

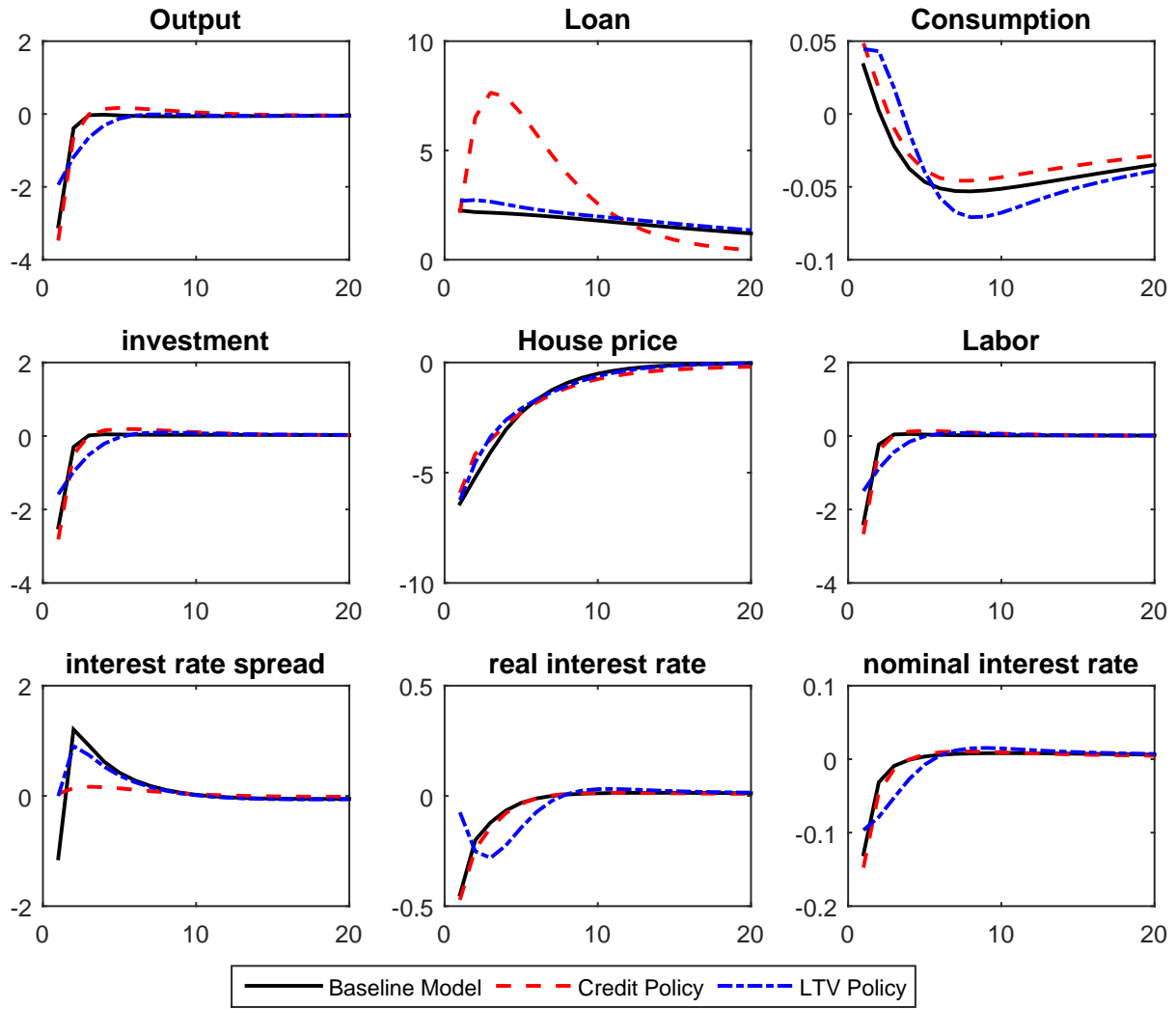


Figure 3: Impulse responses to housing demand shock.

## 4.2 Housing demand shock

Next we turn to the impulse responses to an estimated one standard deviation housing demand shock. In this case, the household decreases the demand in house and thus works less and increases the demand in goods and savings . The reduction in the household demand of housing leads to a lower house price. Furthermore, the drop in house price decreases the entrepreneur’s real estate wealth and limits the entrepreneur’s budget to hire labor and to invest in capital goods. Entrepreneurs require more loans to bridge the gap but their borrowing power are constrained by the value of mortgage and the regulation on loan-to-value ratio. At last, the output drops

sharply and the household consumption falls hereafter.

As Figure 3 shows, a one standard deviation shock leads to a 0.05 percent decline in consumption after four quarters in the baseline model. The decrease in consumption in the model with credit intervention is slightly less than in the baseline case, around 0.04 percent. As for dynamics in the model where countercyclical LTV ratio policy is conducted, the decline reaches 0.08 percent by the second year. However, the negative effects on other economic variables such as output, labor and investment are smallest when the LTV ratio policy is considered. For example, the fall in output is about 3 percent in the benchmark model and the credit policy case, thrice as large as the case with the LTV ratio intervention. This implies that the countercyclical LTV ratio policy works better to mitigate the effect from a negative housing demand shock.

The major advantage of conducting an LTV ratio policy in response to house price shock is that it deals with crisis by allowing a higher LTV ratio, which, to some extent, boosts the value of houses. In other words, the LTV ratio policy directly resolves the basic problem, the deteriorating housing prices, by creating additional value for real estates and enhancing entrepreneur's borrowing capacity. As for the credit intervention that reacts to the increasing interest rate spread, it raises the supply of loan, which lowers the lending rate, and makes the entrepreneurs easier to obtain loans. However, entrepreneurs would increase the demand in real estate rather than hire labor or invest in capital because that the negative house preference shock does not interrupt the market liquidity. Financial intermediaries alone are able to offer enough loans to meet the increase in interest rate premium. Therefore, when the central bank use their powers as a lender of last resort to facilitate credit flows, the excess liquidity will flow to the housing market.

### **4.3 Bank net worth shock**

Figure 4 illustrates the case where a redistribution shock hits the banker's wealth. Following Gertler and Karadi (2011), we assume that intermediary net worth declines by one percent and

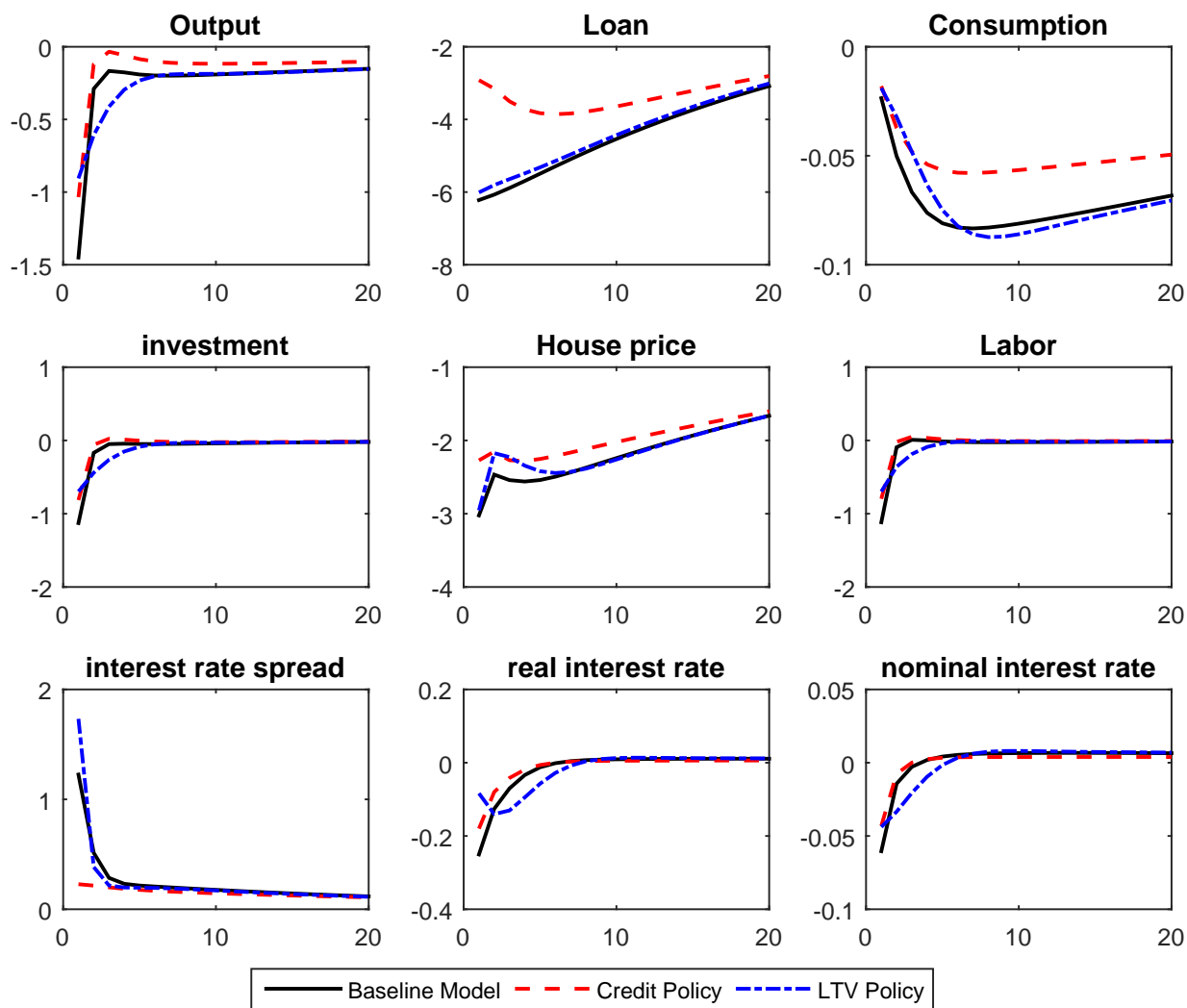


Figure 4: Impulse responses to bank net worth shock.



is transferred to households. The net worth shock tightens the banker's ability to lend and results in a drop in funds available to the entrepreneur and leads to a rise in the premium. Therefore, the entrepreneur reduces the demand of labor, real estate, and investment and eventually produces less. After that, the house price falls and the consumption decreases.

Different from the previous two cases that the LTV ratio policy dominates the the other two policy, the answer of which policy most effectively moderate the contraction arising from a net worth shock is ambiguous. In the model that LTV ratio policy is conducted, the falls in consumption and house price fails to outperform the baseline model, but the declines in output, labor and investment are dampened significantly. As for the credit intervention, although the collapse in output, labor and investment are slightly worse than what occurs in the LTV ratio policy case, the credit policy significantly dampens the reduction in consumptions and house prices. Moreover, the credit intervention effectively dampens the decline in all key variables comparing to the baseline model.

The net worth shock damages banker's ability to transfer funds from households to entrepreneurs, and leads to a rise in the premium. Hence, there is a space for the involvement of credit intervention which increases the loanable fund supply and bridges the funding gap directly in response to a higher interest rate spread. The LTV ratio policy loosens the requirement on LTV ratio which increases the demand in funds, and thus is not as effective as credit policy.

## **5 Optimal policy and welfare evaluation**

In this section, we study the welfare implications of monetary policies, pre-crisis macro-prudential policies and post-crisis credit market intervention in the presence of two financial frictions. The discussion of optimized policy is based on social welfare criteria. We do not rely on an ad hoc loss function which aims at minimizing the volatility of variables such as output and inflation that policy makers are concerned. That is, the policy authority maximizes social welfare subject to the competitive equilibrium conditions and a specific policy rule. We first present the agents'

welfare function given by the following conditional expectation of lifetime utilities:

$$V_t = \max E_t \sum_{i=0}^{\infty} \beta^i U(C_{t+i}, H_{t+i}, L_{t+i})$$

$$V_{et} = \max E_t \sum_{i=0}^{\infty} \beta_e^i U_e(C_{et+i})$$

where  $V_t$  and  $V_{et}$  denote the welfare of the household and the entrepreneur, respectively.

Next, we follow Rubio (2011) and Lambertini et al. (2013) to define a social welfare function

$$V_t^s = (1 - \beta)V_t + (1 - \beta_e)V_{et},$$

which is a weighted average of the welfare of households and entrepreneurs. The weights  $1 - \beta$  and  $1 - \beta_e$  ensure that social planner equalizes utility across different agent types given a constant utility level.

The computation of welfare follows the standard approach commonly adopted in the DSGE literature.<sup>1</sup> Thus, the welfare performance is evaluated conditional on the initial state,  $t = 0$ , being the deterministic steady state. Following Lambertini et al. (2013), we explore the maximum social welfare over varying parameters of each particular policy rule under consideration. To put it simply, we compute the optimized policy rules that are characterized by the combination of parameters that generates the highest social welfare. We consider three groups of policy rules and find the optimal policy in each case respectively. First, different kinds of interest-rate rules are considered given a constant LTV ratio; second, different countercyclical LTV ratio rules are considered given the baseline Taylor-type rule; finally, different levels of credit interventions are considered given a constant LTV ratio and the baseline Taylor-type rule. Table 3 summarizes the results and reports the social and individual welfare levels. Table 4 and Table 5 display the standard deviation and theoretical stochastic mean of selected variables under alternative policy rules, respectively.

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<sup>1</sup>See Schmitt-Grohé and Uribe (2004, 2006, 2007a,b), Kim et al. (2005) and Faia and Monacelli (2007).

Table 3: Optimized parameter and conditional welfare

Rules	Policy parameters	Welfare values		
		Household	Entrepreneur	Social
A. Baseline policy	$r_i = 0.8, r_\pi = 1.5, r_y = 0.125$	-259.0269	-183.6047	-6.2624
B. Optimized interest-rate rules				
GDP	$r_i = 0, r_\pi = 1.15, r_y = 0.52$	-255.0140	-182.4384	-6.1989
Loan	$r_i = 0, r_\pi = 1.15, r_y = 0.52, r_b = 0$	-255.0140	-182.4384	-6.1989
Housing price	$r_i = 0, r_\pi = 1.15, r_y = 0.52, r_q = 0$	-255.0140	-182.4384	-6.1989
C. Optimized LTV ratio rules				
GDP	$r_m = 0.80, \kappa_y = -1.15$	-258.6668	-182.5112	-6.2369
Loan	$r_m = 0.76, \kappa_b = -1.15$	-258.6230	-183.5152	-6.2565
Housing price	$r_m = 0.72, \kappa_q = -1.65$	-258.6851	-183.1220	-6.2493
D. Credit policy				
Conservative	$\rho_c = 10$	-259.0951	-184.6855	-6.2847
Moderate	$\rho_c = 50$	-258.9480	-183.8403	-6.2663
Aggressive	$\rho_c = 100$	-258.3366	-179.5626	-6.1746

## 5.1 Interest rate rule

We first evaluate the baseline policy which is characterized by the baseline Taylor rule with interest rate smoothing as in (27),

$$i_t = r_i i_{t-1} + (1 - r_i) \left[ i + r_\pi \pi_t + r_y (\log Y_t - \log Y_t^*) \right] + e_t.$$

The result is reported in Table 3 (panel A). Next, we consider the augmented interest rate rule (29) that responds to an indicator, either credit growth or changes in house prices. We obtain the optimized interest rate rule by grid search over multidimension of parameter values. The search range is set to be  $[0, 1]$  for  $r_i$ ,  $[1, 2]$  for  $r_\pi$ ,  $[0, 3]$  for  $r_y$  and  $[0, 3]$  for  $r_X$ . The grid step for each range is 0.01.

Table 4: Stabilization effect

Rules	$C$	$C_e$	$H$	$q$	GDP	$i$
A. Baseline policy	0.1273	0.0462	0.1086	1.5739	0.4478	0.0059
B. Optimized interest-rate rule	0.1271	0.0451	0.1083	1.5561	0.4313	0.0251
C. Optimized LTV ratio rules						
GDP	0.1273	0.0463	0.1087	1.5696	0.4443	0.0064
Loan	0.1272	0.0463	0.1074	1.5717	0.4476	0.0061
Housing price	0.1272	0.0463	0.1091	1.5692	0.4458	0.0059
D. Credit policy						
Conservative	0.1275	0.0463	0.1101	1.5735	0.4495	0.0060
Moderate	0.1276	0.0463	0.1119	1.5731	0.4502	0.0060
Aggressive	0.1276	0.0463	0.1129	1.5732	0.4505	0.0060

Note: Stabilization effect represents standard deviation of the second-order approximation.

Table 3 (panel B) displays the interest rate rules that maximize the social welfare function. The main characteristic of the optimized policy in this economy is that it calls for a muted response to either credit growth or changes in housing price. That is, targeting financial variables does not improve the social welfare comparing to the baseline policy. The optimized interest rate rule features a moderate response to inflation and a nonactive response to output gap. Also, we can observe that the best policy rule requires no interest rate smoothing. The lack of inertia effect does no harm to the social welfare because the monetary authority is perfect foresight in our model. Policy makers are able to choose the parameters directly to maximize the social welfare function. Hence, there is no need to adopt policy rules with inertia which aims at stabilizing the volatility of nominal interest rates.

Another important observation from Table 3 (panel B) is that the best Taylor-type rule is

Table 5: Level effect

Rules	$C$	$Ce$	$H$	$He$	$q$	GDP	$i$
A. Baseline policy	0.5052	0.1421	0.5734	0.4266	7.3076	1.3230	1.0111
B. Optimized interest-rate rule	0.5082	0.1434	0.5610	0.4390	7.4574	1.3213	1.0091
C. Optimized LTV ratio rules							
GDP	0.5059	0.1434	0.5652	0.4348	7.3858	1.3227	1.0092
Loan	0.5054	0.1426	0.5725	0.4275	7.3136	1.3235	1.0092
Housing price	0.5055	0.1430	0.5668	0.4332	7.3684	1.3225	1.0092
D. Credit policy							
Conservative	0.5053	0.1411	0.5724	0.4276	7.2790	1.3228	1.0092
Moderate	0.5072	0.1417	0.5480	0.4520	7.4783	1.3268	1.0092
Aggressive	0.5142	0.1445	0.4616	0.5384	8.3029	1.3400	1.0092

Note: Level effect represents theoretical stochastic mean of the second-order approximation.

Pareto optimal. It not only maximizes social welfare, but also improves both households' and entrepreneurs' welfare. From Table 4 (panel B), we can find that the optimized rule targeting inflation and output gap implies a lower volatility for all variables except nominal interest rate. Obviously, the sharp increase in nominal interest rate volatility is consistent with the zero smoothing factor.

## 5.2 Countercyclical LTV ratio policy

Now we turn to assess LTV ratio policies that react to macroeconomic conditions and financial variables in a countercyclical manner. We suppose that the regulation on LTV ratio is conducted according to the feedback rule given by (30), with  $X_t \in [GDP_t, B_t, q_t]$  and  $m$  being the steady state LTV ratio. We search over the interval  $[0,1]$  for the autoregressive parameter  $\kappa_m$ , and

the interval  $[-20,0]$  for the parameter  $\kappa_x$  which is the response coefficient of target variables. According to this rule, the limit on LTV ratio will be tightened when there is a boom and will be relaxed when there is a bust. Notice that we keep interest rate rule fixed and assume the monetary authority follows a Taylor-type rule which is the same as the baseline model.

The LTV ratio rules that maximize the social welfare function is reported in Table 3 (panel C). Clearly, the rules that target different variables all feature a high smoothing parameter and a moderate response to the target variable. The result indicates that allowing for a counter-cyclical LTV ratio policy yields non-negligible welfare gains compared to the baseline model with a constant LTV ratio. Moreover, we can find that not only the social welfare but also each individual welfare rises. That is, the three LTV ratio rules that respond to movements in the targeting variables are all Pareto improving.

Among all these optimized LTV ratio rules, the rule reacting to output gap increases the welfare of entrepreneurs most significantly. This improvement is mainly contributed by a higher level of firm's consumption as shown in Table 5 (panel C). However, according to Table 4 (panel C), the rule that responds to credit growth can better reduce the volatility of households' consumption and house holding, and improves the household's welfare more effectively.

### 5.3 Credit policy

Lastly, we evaluate the credit policies according to the policy rule given by (31). This rule requires the central bank tightens liquidity when the interest rate spread decreases, and expands credit as the credit spread increases relative to its steady state. Notice that the baseline interest rate rule is considered and there is no LTV ratio policy when we discuss the credit intervention.

Table 3 (panel D) shows the welfare when different levels of intervention are conducted. Obviously, due to the drop in the social welfare and the welfare of entrepreneurs, we can see that the conservative intervention ( $\rho_c = 10$ ) fails to outperform the baseline policy. As for the moderate intervention ( $\rho_c = 50$ ), although each individual welfare keeps improving, the

social welfare still falls behind the baseline model. An aggressive credit intervention ( $\rho_c = 100$ ) attains a higher welfare level, no matter in terms of household's welfare, entrepreneur's welfare, or social welfare as a whole, leading to a Pareto improvement from the benchmark policy. Therefore, allowing for credit policy in response to changes in credit spreads is Pareto improving only when an aggressive intervention is adopted.

According to Table 4 (panel D), the credit policies are not able to reduce the standard deviation of consumption and GDP effectively comparing to the baseline model. However, the volatility of house prices is dampened regardless of which level of credit intervention is involved. Despite credit intervention leads to a slight rise in volatility, Table 5 (panel D) shows that a less conservative intervention tends to result in a higher level of individual consumptions, house prices, and GDP. And it is the level effect allows the aggressive credit policy to beat the baseline model.

## 5.4 Overall evaluation

Among all these policy rules aiming at maximizing social welfare, we can observe that: (1) households receive the largest welfare gains from an interest rate response to inflation and output gap; in contrast, (2) both the welfare of entrepreneurs and the social welfare improve most from the aggressive credit policy. When we compare the rule favored by households to the policy preferred by entrepreneurs, the results in Table 4 and Table 5 show that: (3) the policy preferred by entrepreneurs brings higher levels of consumption, house holding and GDP; however, (4) the policy preferred by households reduces volatility of variables such as consumption, house holding, house prices and GDP.

## 6 Conclusion

This paper combines the structure in Iacoviello (2005) with Gertler and Karadi (2011) to develop a DSGE model which incorporates two financial frictions. Based on this model, we

investigate the effects of a variety of policy instruments. Three types of policies are considered: (1) the conventional and augmented Taylor rules with interest rate smoothing; (2) the LTV ratio policy leaning against the wind; and (3) the credit policy allowing monetary authorities to engage in direct lending activities. The first two policy instruments are part of the pre-crisis policy framework, and the credit intervention is regarded as one of the post-crisis policy tools. We investigate the design of optimal policy rules by taking into account all possible sources of macroeconomic fluctuations. and evaluated alternative policies by using the welfare of the agents as a relevant criterion.

Our analysis first suggests that an interest rate rule responding to output gap and inflation, countercyclical LTV rules and an aggressive credit intervention lead to a Pareto improvement. That is, both the pre-crisis and post-crisis policies are able to attain the social optimal level. Second, we find that the post-crisis policy allowing for aggressive credit intervention enhances social welfare and entrepreneur's welfare the most compared to other alternative policies. However, the post-crisis policy faces a trade-off between volatility and level of variables of interest. For example, the credit intervention produces higher levels of consumption, house holding and GDP, but it also results in a higher volatility. Lastly, the interest rate rule responding to output gap and inflation, performs better to improve household's well-being by reducing volatility of variables such as consumption, house holding, house prices and GDP.

The model in this paper leaves out a number of features that may serve as the avenue for future research. Instead of assuming that financial crises are triggered by exogenous shocks, we may further consider endogenous shocks such as the belief shock in Miao and Wang (2015). Moreover, the typical solution techniques used for the DSGE models, which is based on log linearization, do not allow for the non-linear dynamics that typically characterize boom-bust episodes. We may follow recent studies such as Guerrieri and Iacoviello (2015b) and Guerrieri and Iacoviello (2015a) to incorporate non-linear technique into our DSGE model.



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