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HOUSING MARKET VOLATILITY, SHADOW BANKS AND MACROPRUDENTIAL REGULATION: A DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL ANALYSIS*

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Given the risks of shadow banks and their risk contagion with the housing market, this study investigates the necessity, policy transmission mechanism and impact of incorporating shadow banks into a macroprudential regulation framework. It constructs a dynamic stochastic general equilibrium (DSGE) model incorporating housing market volatility and heterogeneous financial intermediation, where housing market volatility transmits to the financial intermediation sector through the collateral channel. Meanwhile, regulatory asymmetry expands the shadow banking scale and leverage indicators driven by the housing market, increasing the shadow banking risk. Moreover, considering shadow banking credit size, the macroprudential regulation framework can mitigate the volatility of economic variables and maintain macro-financial and economic stability under the conditions of tightening monetary policy and strengthening regulation. However, policy effects are limited in curbing shadow banking risks from housing market fluctuations. Thus, it is necessary to crop the source of shadow banking risks from the transmission mechanism, formulate more targeted and specialized regulatory policies to complement housing market control measures, maximize cross-market effects among different policies, and incorporate shadow banking into the regulatory system.

Keywords: Housing market volatility; shadow banks; macroprudential regulation; countercyclical capital regulation; dynamic stochastic general equilibrium.

JEL Classifications: E32, E44, G23, R21

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1. Introduction[1]

Fluctuations in the housing market have long been a social concern and inescapable in exploring macro-financial stability. Global housing prices have been increasing at record speed since 2005, clear evidence of an upward trend. In China, the average price of commercial housing has more than tripled since 2003, with residential prices in first-tier cities increasing by more than six times (CEIC database). Moreover, the growth rate of housing prices is expected to reach 5% by 2021.[2] With the inevitable expansion of global housing markets, the emergence of shadow banks has compounded systemic financial stability issues. According to the Financial Stability Board, the shadow banking system is "a credit intermediation involving entities and activities outside the regular banking system." Given their large size and lack of regulation, shadow banks significantly impact macroeconomic stability.

While the housing market and shadow banks are at risk, substantial evidence shows that a significant portion of shadow banking funds flows into the housing market. Thus, shadow banks are closely related to housing market volatility. Real estate is a crucial collateral asset for firms. Relative to mechanical devices, credit intermediaries are more receptive to real estate assets (Zeng, 2012), and the increase in collateral value, given the increase in housing prices, allows for applying for more loans from commercial banks (Zhu *et al.*, 2017). Thus, the housing market volatility transmits to the credit intermediation sector via the collateral channel. However, given the series of credit tightening measures introduced by the government and regulators, enterprises face credit constraints when borrowing from commercial banks. They are forced to raise funds by trusted and entrusted loans or channels with shadow banking characteristics, leading to the expansion of shadow banking credit size and the accumulation of shadow banking risks (Qiu and Zhou, 2014). Hence, once the housing market fluctuates, business risks of real estate enterprises are transformed into financial risks of shadow banks, affecting macroeconomic stability (Wei, 2016). Thus, it is necessary to dig deeper into the impact of housing market volatility on shadow banks and macroeconomic stability to better eliminate the impact of shadow banks on systemic financial stability.

Based on the importance of housing markets and credit intermediaries for systemic financial stability, substantive debates on financial regulation occurred after the 2008 financial crisis. Currently, there is a broad consensus among scholars and policymakers that regulatory frameworks should consider the macro stability of financial markets and regulate single financial institutions (Allen and Gale, 2000; Borio, 2003; Kroszner, 2010). This macroprudential approach to financial regulation should consider systemic developments in the financial markets, such as volatility in total credit and financial markets, and

[1] While the risk issue of shadow banking is a global one, and the macroprudential regulation framework is commonly implement in various countries, the purpose of our paper is to sort out the risk interaction of shadow banking in a single country with other markets. Since China's shadow banking problem has developed rapidly in recent years and has been poorly studied in the literature in the past, we attempt to take the Chinese economy as a starting point and use the data from China to find empirical evidences applicable to global economic stability.

[2] Source of data: *Annual Report on the Development of China's Real Estate 2020–2021*, National Academy of Economic Strategy, CASS.

the impact of financial cycles on business cycle changes (Borio and Shim, 2007; Borio, 2011). Dramatic macroprudential regulation changes are underway in most developed economies worldwide, and regulatory authorities have established specialized agencies to design relevant policy instruments. However, it is challenging to achieve consistent and comprehensive regulation given the diverse nature of firms that conduct shadow banking credit operations. The current framework of macroprudential regulation is yet to fully integrate shadow banks. Given the risks of shadow banks and their risk contagion with the housing market, there is an urgent need to investigate the necessity, policy transmission mechanism, and impact of incorporating shadow banks into the macroprudential regulation framework theoretically. Therefore, this study analyzes the impact of housing market volatility on shadow banks and the policy effects of including shadow banks in the macroprudential regulation framework.

First, we introduce the collateral channel for the transmission of housing market volatility and distinguish the heterogeneity of financial intermediaries in the traditional commercial and shadow banking sector, following Iacoviello (2005) and Gertler and Karadi (2011). Commercial and shadow banks have credit preferences for firms and face asymmetric regulation. Arguably, shadow banks are diverse firms engaging in various businesses outside the traditional commercial banking system. However, they transfer funds from depositors to borrowers like traditional commercial banks. Second, we established a generalized macroprudential regulation framework that includes shadow banks to analyze the policy effects of different macroprudential regulation frameworks. Finally, the sources affecting shadow banking risk are analyzed in two dimensions: stock size and leverage indicators and the policy effects of the macroprudential regulation framework to mitigate shadow banking risk.

This study contributes to the literature as follows. First, it incorporates housing market volatility into a dynamic stochastic general equilibrium (DSGE) model that considers heterogeneous financial institutions, analyzes the impact mechanism of housing market volatility, constructs a generalized macroprudential regulation framework that incorporates shadow banks, and links housing market volatility with credit system stability and macroeconomic stability. It expands theoretical studies on the housing market, shadow banks, and macro-financial stability while building a basic framework for future policies. Second, the dynamic characteristics of the benchmark model suggest that housing market volatility transmits to the credit intermediation sector through the collateral security channel, affecting the credit intermediation sector and macroeconomic stability; this provides a theoretical basis for effectively identifying the sources of risk in the banking system and macroeconomy. Finally, this study's generalized macroprudential regulation framework effectively mitigates fluctuations from monetary policy shocks and regulatory changes; meanwhile, the policy effect is insignificant for the impact of housing market volatility. It sheds light on the role of the housing industry in economic volatility and is essential for planning future regulatory and supervisory policies.

The remainder of this paper is organized as follows. Section 2 reviews DSGE models for financial intermediation modeling. Section 3 presents the model construction, including the benchmark models incorporating housing and heterogeneous financial institutions and two macroprudential regulation frameworks. Section 4 reports on the calibration and Bayesian estimation of the model parameters, describing the parameters. Section 5 discusses the model's dynamic economic characteristics, including its economic implications from two perspectives: the impact mechanism of housing market volatility and the policy effects of the macroprudential framework. Finally, Section 6 concludes the study, offering policy recommendations based on the dynamic economic characteristics analysis.

2. Literature Review

This section reviews DSGE models, including financial intermediation and financial frictions. Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) are among the first to incorporate financial intermediaries into DSGE models after the financial crisis. Gertler and Karadi (2011) build on the monetary DSGE model based on Smets and Wouters (2007) and Christiano *et al.* (2005), portraying the financial intermediation behavior between households and non-financial firms through financial intermediaries. They incorporate the financial friction of an agency problem between banks and households, allowing for banks to transfer household funds away from asset items for private gain. Given that households are aware of potential misconduct, banks have a limited ability to access funds through deposits. They show that, if such frictions in financial intermediation are included in the model, the impact of capital quality on output decline becomes more pronounced, providing room for unconventional credit market interventions by central banks. The model framework of Gertler and Kiyotaki (2011) was enhanced by adding liquidity risk.[3] However, their model does not incorporate nominal rigidity because they focus more on the role of credit market frictions and credit policy than on the effects of monetary policy.

Another variation of the DSGE model considers the financial friction between borrowers and financial intermediaries. Such models focus on the collateral constraints borrowers must establish with lenders to access credit facilities. Iacoviello (2005) and Guerrieri and Iacoviello (2017) use real estate assets as collaterals and relate the amount of loans to impatient entrepreneurs to changes in collateral value. Depending on the additional credit constraints faced by borrowers, adverse developments in the housing market and changes in collateral ratios in response to exogenous shocks may limit the amount of corporate lending and affect economic consumption and investment.

Furthermore, several other approaches to incorporate financial frictions into macro models have been proposed. Chen (2001), Meh and Moran (2010) and Silvo (2015) build on Holstrom and Tirole (1997) by incorporating both sides of the credit intermediation market of agency problems. The studies posit a moral hazard problem on the demand side of credit (between banks and entrepreneurs). Entrepreneurs can divert the funds that banks receive from their investment activities and gain a private interest in the banks' regulatory costs. Moreover, another agency problem on the supply side of credit (between banks and depositors) prevents households from ascertaining whether financial intermediaries effectively monitor firms' investment activities.

[3] See also in Kiyotaki and Moore (2012).

On the role of financial intermediaries in macro-prudence regulation, Angelini *et al.* (2014) embed collateral constraints in the NK model and assume that macro-prudence policymakers adjust capital requirements following simple rules. They find that macro-prudence policies are particularly effective in times of financial crisis. Christensen *et al.* (2011) find that strong countercyclical regulatory policies are more effective than time-sensitive regulation in maintaining financial stability when the economy faces shocks in the banking sector. Beau *et al.* (2012) examine whether financial stability reflects the monetary policy objectives and a separate institution of macroprudential regulation in the economy, defining four different policy regimes. They find that housing preference and credit shocks are the most important factors affecting macro-prudential policy stability.

Overall, the financial sector is modeled as a single intermediary. In recent years, the focus of research has gradually shifted to the heterogeneity of financial intermediaries. Gertler *et al.* (2016) strengthen the relatively standardized framework of Gertler and Karadi (2011) by replacing representative financial institutions with a bipolar banking system comprising wholesale and retail banks. They dictate that wholesale banks, representing the shadow bank segment, specialize in interbank lending and finance loans. Moreover, retail banks adopt a more traditional business model, collecting household deposits and lending to wholesale and non-financial sectors.[4]

Meeks *et al.* (2017) investigate how shadow and commercial banks affect overall credit through asset securitization by constructing a benchmark model. They find that the combination of securitized products and high leverage in the shadow banking sector may negatively impact macroeconomic stability. Verona *et al.* (2013) set up a model where shadows banks are intermediaries directly involved in financing households and firms. They assume shadow banks operate under monopolistic competition, where shadow banks' loans obtain a positive spread between the interest rate and the risk-free rate.[5] Furthermore, they find that consolidating shadow banks increase the momentum of economic prosperity and growth in response to a prolonged period of accommodative monetary policy.

In summary, a large number of studies examine shadow banks and monetary policy, but few consider heterogeneous financial institutions in the macro-prudential framework and combine housing market volatility with macro-prudence. Therefore, this study explores whether the macro-prudential framework can mitigate the impact of housing market volatility on shadow banks and macro-financial stability by elucidating how housing market volatility is transmitted to the credit intermediation sector.

3. Model

3.1. *Benchmark model*

To examine the impact of housing market volatilities on heterogeneous financial intermediation and how macroprudential policies influence regulation, the model embeds

[4] Gertler and Karadi (2011) already discussed interbank lending but did not clearly distinguish between wholesale and retail banks.

[5] The reason for the positive spread in shadow banking is that, relative to low-risk commercial bank deposits, the household sector is exposed to relatively higher default risk when saving funds in shadow banks.

elements of the housing market and financial intermediation based on Iacoviello (2005) and Gertler and Karadi (2011). Households save and act as the lender of credit funds, while the entrepreneur is the borrower of funds. However, households do not provide funds directly to borrowing entrepreneurs but deposit in intermediaries, lending funds to entrepreneurs. Households can allocate savings to two different financial intermediaries: traditional commercial and shadow banks. Commercial banks face the requirement of regulatory capital subject to market intervention in the process of adjusting deposit and lending rates. Shadow banks face an opposite trend. They are fully competitive, neither subject to macroprudential regulation nor government bailouts. Thus, savings in shadow banks are riskier for households. This implicit default risk induces households to demand higher returns when saving in shadow banks, resulting in a positive credit spread between shadow banks and commercial banks. Meanwhile, to describe the high dependence of shadow banks on market financing, the model embeds an incentive restraint mechanism (Gertler and Karadi, 2011) in the shadow banking sector; that is, unregulated shadow banks may misappropriate some of their borrowing funds, resulting in the remaining material default, leaving the investment loss to households. Once households are aware of this risk, they control their share of shadow bank savings to encourage shadow banks to continue operations rather than default and exit from the market.

We assume only commercial banks are subject to regulation in the credit market. Thus, entrepreneurs face certain constraints when borrowing from commercial banks; they can only obtain loans equivalent to a portion of the value of their collaterals but not the full value of their collaterals. Moreover, to connect the housing market with financial intermediation, we set collaterals held by entrepreneurs as real estate assets, following Iacoviello (2005) and Kiyotaki and Moore (1997). When commercial banks cannot meet the borrowing needs of entrepreneurs, entrepreneurs use the residual value of real estate assets to borrow from shadow banks. In the labor market, households provide labor, and wages are used to consume general goods and improve housing conditions and savings. Entrepreneurs use labor and real estate assets to produce intermediate products packaged by retailers and sold in commodity markets. Finally, the central bank implements a monetary policy and sets the policy rate per the Taylor rules.

3.1.1. *Households*

Representative households maximize their utility by consuming general goods, improving housing conditions, and providing labor, as expressed as follows:

$$\max_{C_t, H_t, N_t, D_t^c, D_t^s} E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t + j_t \ln H_t - \kappa \frac{N_t^{1+\varphi}}{1+\varphi} \right), \tag{1}$$

where C_t denotes the consumption of households, H_t is the house bought by households,[6] and labor hours are given by N_t. $\beta \in (0, 1)$ is the discount factor of households, κ is the labor disutility factor and φ is the reciprocal of labor supply elasticity. We denote j_t as the

[6] In our model, houses or real estate assets hold by households and entrepreneurs are act like consumption goods and production factors respectively, which means house is an endogenous determined variable.

shock to a household's taste for housing services. For convenience, we label j_t as the "housing demand shock," which is the source of the price fluctuations in the real estate market. Given the central role that housing demand shock play in our model, it is useful to discuss what this type of financial shock might represent. One interpretation is that a housing demand shock simply represents "an exogenous shift in the household's taste" seen in Iacoviello and Neri (2009), but we assume that the housing demand shock, like any other shocks in our model including technology shock and monetary policy shock, is a simplified form representation of friction or some "deeper" shock that are outside of the standardized model. It follows the autoregressive (AR [1]) process as follows:

$$\ln j_t - \ln j = \rho_j(\ln j_{t-1} - \ln j) + \varepsilon_t^j, \tag{2}$$

where $j > 0$ is a constant, ρ_j measures the persistence and ε_t^j is the i.i.d. standard normal process.

Cash flows in the household sector are subject to the following budgetary constraint:

$$C_t + q_t[H_t - (1-\delta_h)H_{t-1}] + D_t^c + D_t^s \leq w_t N_t + D_{t-1}^c(1 + r_{t-1}^{dc}) + D_{t-1}^s(1 + r_{t-1}^{ds}), \tag{3}$$

where expenditure items include consumption C_t, purchase of new houses with the price of q_t, savings in commercial banks D_t^c and savings in shadow banks D_t^s. Income items include remuneration for work, where w_t is the real wage, and interest returns from prior savings, where r_{t-1}^{dc} and r_{t-1}^{ds} are the deposit rates for commercial and shadow banks between $t-1$ and t, respectively. The first-order conditions for the representative households are detailed in Appendix A.1.[7]

3.1.2. *Entrepreneurs*[8]

Entrepreneurs use a Cobb–Douglas constant returns to scale technology that uses real estate and labor as inputs. They produce intermediate goods Y_t according to

$$Y_t = A_t(H_{t-1})^{\alpha}(N_t)^{1-\alpha}, \tag{4}$$

where H_{t-1} and N_t denote the inputs of real estate assets and labor, respectively. Parameter α measures the output elasticity of real estate assets. A_t is the total productivity, which is also an exogenous shock that follows the AR (1) process:

$$\ln A_t - \ln A = \rho_a(\ln A_{t-1} - \ln A) + \varepsilon_t^a. \tag{5}$$

The utility functions for entrepreneurs are as follows:

$$\max_{C_t^h, N_t, B_t^c, B_t^s} E_0 \sum_{t=0}^{\infty} (\beta_h)^t \ln C_t^h, \tag{6}$$

where β_h is the discount factor for entrepreneurs. We assume entrepreneurs are less patient than households; therefore, $\beta_h < \beta$. The entrepreneur's cash flow is subject to the

[7] Considering the length of the article and the completeness of the derivation process, we put some first-order conditions and derivation process of the model in Appendix A for readers to refer to.

[8] See first-order conditions in Appendix A.2.

following constraint:

$$C_t^h + w_t N_t + B_{t-1}^c(1 + r_{t-1}^{bc}) + B_{t-1}^s(1 + r_{t-1}^{bs}) + q_t H_t \leq \frac{Y_t}{x_t} + q_t(1 - \delta_h)H_{t-1} + B_t^c + B_t^s. \tag{7}$$

Regarding expenditure items, C_t^h is the consumption of entrepreneurs, $w_t N_t$ is the amount entrepreneurs must pay for the labor force; $B_{t-1}^c(1 + r_{t-1}^{bc})$ and $B_{t-1}^s(1 + r_{t-1}^{bs})$ are the interest generated from commercial and shadow bank loans in the previous period for entrepreneurs, respectively. $q_t H_t$ is the real estate asset held by entrepreneurs for production. Regarding income, Y_t/x_t is the sale of intermediate goods in the retail market, $x_t = P_t/P_t^w$ is defined as the price markup factor for retailers, P_t and P_t^w are final and intermediate commodity prices, respectively. Define δ_h as the depreciation factor of real estate assets; the loans received by entrepreneurs from commercial and shadow banks in the current period are B_t^c and B_t^s, respectively.

However, entrepreneurs face certain constraints when borrowing from commercial banks (Iacoviello, 2005), and the amount of loans depends on the value of the collaterals held by the entrepreneur. The value of collaterals is determined by the expected value of real estate assets held by entrepreneurs, denoted as $E_t[q_{t+1}(1 - \delta_h)H_t]$. The collateral ratio of commercial bank loans m_t is used to measure a certain degree of financial friction. Reviews of collateral-backed loans do not constrain shadow banks' credit processes. Given the positive credit spread between commercial and shadow banks, entrepreneurs' first choice is to borrow from commercial banks. They then borrow from the shadow bank when the collateral limit is reached, and the loan from the shadow bank equals the residual value of the collaterals. Thus, entrepreneurs face the following credit constraints:

$$(1 + r_t^{bc})B_t^c \leq m_t E_t[q_{t+1}(1 - \delta_h)H_t], \tag{8}$$

$$(1 + r_t^{bs})B_t^s \leq (1 - m_t)E_t[q_{t+1}(1 - \delta_h)H_t], \tag{9}$$

where the collateral rate of bank loans m_t is set by the regulator and follows the AR (1) process:

$$\ln m_t - \ln m = \rho_m(\ln m_{t-1} - \ln m) + \varepsilon_t^m. \tag{10}$$

Define λ_t as the shadow price[9] of the credit constraint at t.

3.1.3. *Financial intermediary*[10]

We assume two types of financial intermediation between households and entrepreneurs: traditional commercial and shadow banks. Although both conduct credit activities similarly, their utility maximization is different. First, we assume commercial banks are subject to regulations and must meet statutory capital requirements. Second, assuming commercial banks are eligible for liquidity assistance guaranteed by the central bank or government,

[9] As in Iacoviello (2005), provide that $\beta_h < \beta$, λ will always be greater than 0, which implies that the credit constraints faced by entrepreneurs are always established.
[10] See first-order conditions in Appendix A.3.

they face little risk of bankruptcy; households and entrepreneurs are more inclined to deposit in or lend from commercial banks. However, shadow banks have no regulatory burden and are not subject to any assistance or guarantees; their operations highly depend on creditor trust. However, such trust faces the moral hazard problem: the shadow bank's infringement on household interests. This problem dominates the leverage indicator of shadow banks. Furthermore, commercial banks receive protection from default without sufficient liquidity; in the absence of equal preferential treatment, shadow banks may exit the market immediately during a bankruptcy given enormous financing pressures. Thus, we assume that commercial banks can operate sustainably, while shadow banks may enter and exit the market frequently.

(1) Commercial Banks
Commercial banks maximize their profits based on the balance sheet:

$$B_t^c = NW_t^c + D_t^c. \tag{11}$$

From the asset side, B_t^c denotes loans to enterprises. On the debt side, D_t^c denotes the household savings and NW_t^c, the net assets of the commercial bank. Therefore, the profit function of commercial banks is determined by the interest income of current loans and the interest expense of savings:

$$\max_{B_t^c, D_t^c} r_t^{bc} B_t^c - r_t^{dc} D_t^c - \frac{\Upsilon}{2}\left(\frac{NW_t^c}{B_t^c} - V_t^c\right)^2 NW_t^c. \tag{12}$$

Meanwhile, commercial banks are subject to regulation; they must retain part of the capital V_t^c. Getting out of regulation would impose additional costs on commercial banks, defined as $\frac{\Upsilon}{2}(\frac{NW_t^c}{B_t^c} - V_t^c)^2 NW_t^c$, where Υ is the regulatory cost parameter.

The equation for commercial banks' net asset accumulation is determined by Equation (13), where I_t^c is the total profit of commercial banks and δ_c is the cost of capital management:

$$NW_t^c = (1 - \delta_c) NW_{t-1}^c + I_t^c. \tag{13}$$

(2) Shadow Banks
The shadow banking system comprises different business intermediary units that work together like commercial banks. Given the high degree of flexibility and complexity of the shadow banking system, we assume shadow banks are fully competitive. Although shadow banks are not subject to regulation, they are subject to the moral hazard problem, limiting their willingness to provide funds. Thus, we assume shadow banks have limited survival time to avoid excessive accumulation of shadow bank equity and over-financing through equity rather than claims. We define γ as the shadow banks' survival probability.

The balance sheet of a shadow bank comprises loans to entrepreneurs B_t^s, household deposits in shadow banks D_t^s and net assets NW_t^s:

$$q_t B_t^s = D_t^s + NW_t^s. \tag{14}$$

The equation for the accumulation of the shadow bank's net assets is determined by the income of the shadow bank's asset side and the expenditure on the liability side:

$$NW^s_{t+1} = (1 + r^{bs}_t)q_t B^s_t - (1 + r^{ds}_t)D^s_t. \tag{15}$$

According to the balance sheet of the shadow bank, it can be rewritten as follows:

$$NW^s_{t+1} = (r^{bs}_t - r^{ds}_t)q_t B^s_t + (1 + r^{ds}_t)NW^s_t, \tag{16}$$

where r^{bs}_t is the interest rate of the shadow bank loans. For shadow banks, if the real return on loans $(r^{bs}_t - r^{ds}_t)$ is positive, the accumulated net assets are profitable before shadow banks exit the market. Thus, shadow banks maximize their expected value V_t before exiting the market:

$$\begin{aligned} V_t &= \max E_t \sum_{i=0}^{\infty}(1-\gamma)\gamma^i(\beta_s)^{i+1}NW^s_{t+1+i} \\ &= \max E_t \sum_{i=0}^{\infty}(1-\gamma)\gamma^i(\beta_s)^{i+1}[(r^{bs}_{t+i} - r^{ds}_{t+i})q_{t+i}B^s_{t+i} + (1 + r^{ds}_{t+i})NW^s_{t+i}]. \end{aligned} \tag{17}$$

However, given the moral hazard of shadow banks, in each period, they may not comply with saving contracts with households, transfer some of their assets, and exit the market directly, while households can only recover the remaining share of savings. Misappropriating funds is equivalent to declaring bankruptcy for shadow banks; thus, shadow banks misappropriate funds if the declared bankruptcy return is greater than the discounted future return on continuing operations. Thus, it is necessary to ensure the expected net assets of shadow banks meet the incentive compatibility constraints to avoid losses caused by shadow bank defaults (Gertler and Karadi, 2011):

$$V_t \geq \omega q_t B^s_t, \tag{18}$$

where ω is the default probability of the shadow bank. According to Gertler and Karadi (2011), Equation (18) can be rewritten as

$$V_t = v_t q_t B^s_t + \eta_t NW^s_t, \tag{19}$$

$$v_t = E_t[(1-\gamma)\beta_s(r^{bs}_t - r^{ds}_t) + \gamma\beta_s\chi_{t,t+1}v_{t+1}], \tag{20}$$

$$\eta_t = E_t[(1-\gamma) + \beta_s\gamma z_{t,t+1}\eta_{t+1}]. \tag{21}$$

We define $\chi_{t,t+i} = \frac{q_{t+i}B^s_{t+i}}{q_t B^s_t}$ as the growth rate of shadow bank assets and $z_{t,t+i} = \frac{NW^s_{t+i}}{NW^s_t}$ as the growth rate of shadow bank net assets. Shadow banks can continue to operate if the incentive constraint is met; that is, the accumulated net assets of the shadow bank are greater than the value of the transferable assets:

$$v_t q_t B^s_t + \eta_t NW^s_t \geq \omega q_t B^s_t. \tag{22}$$

If this incentive constraint is met, the assets available to shadow banks will be positively dependent on their net assets:

$$q_t B^s_t = \frac{\eta_t}{\omega - v_t} NW^{sh}_t. \tag{23}$$

We define $\phi_t^s = \frac{\eta_t}{\omega - v_t}$ as the leverage ratio of the shadow bank, reflecting the level of shadow bank risk. Even as the probability for shadow banks to transfer funds through leverage grows, Equation (23) limits shadow banks' leverage ratio to default and earnings. Thus, although shadow banks do not face external capital requirements that limit their leverage, they also face endogenous capital constraints that limit their ability to increase leverage. According to the definition of shadow bank leverage, the equation of net asset accumulation of shadow banks can be rewritten as

$$NW_{t+1}^s = [(r_t^{bs} - r_t^{ds})\phi_t^s + (1 + r_t^{ds})]NW_t^s, \tag{24}$$

$$z_{t,t+1} = (r_t^{bs} - r_t^{ds})\phi_t^s + (1 + r_t^{ds}), \tag{25}$$

$$\chi_{t,t+1} = \frac{\phi_{t+1}^s}{\phi_t^s} z_{t,t+1}. \tag{26}$$

Further, following Gebauer and Mazelis (2019), we embed a non-negative spread between the shadow and commercial bank deposit rate:[11]

$$1 + r_t^{ds} = \frac{1 + r_t^{dc}}{1 - \mu^s \varepsilon_t^{\mu}}, \tag{27}$$

where μ^s is the parameter that affects the credit spread of shadow banks, indicating their implied default rate. We introduce an exogenous shock ε_t^{μ} that affects the volatility of shadow bank spreads or the probability of default, which follows the AR (1) process.

3.1.4. *Other sectors*

Price stickiness is introduced in the retail sector based on the Calvo pricing model (Calvo, 1983) in our paper.[12] The final commodity pricing formula is

$$P_t = [(1 - \theta)P_t^{*1-\varepsilon} + \theta P_{t-1}^{\varepsilon}]^{\frac{1}{1-\varepsilon}}, \tag{28}$$

where $\varepsilon > 1$, $(1 - \theta)$ is the probability for each retailer to adjust the price per period. This condition states that P_t^* equals expected discounted marginal revenue to expected discounted marginal cost.

The central bank sets the policy rate[13] r_t per the Taylor rule:

$$(1+r_t) = (1-\phi^r)(1+r) + \phi^r(1+r_{t-1}) + (1-\phi^r)[\phi^{\pi}(\pi_t - 1) + \phi^y(\ln Y_t - \ln Y_{t-1})] + \varepsilon_t^r.$$

We define $\pi_t = \frac{P_t}{P_{t-1}}$ as the inflation rate. ϕ^{π} and ϕ^y are the inflation and output Taylor rule coefficients, respectively. ϕ^r is the smoothing factor of the interest rate and ε_t^r is the monetary policy shock.

[11] Gebauer and Mazelis (2019) assumed neither financial intermediary has a negative savings situation. Given the moral hazard of shadow banks, depositors demand a greater risk return than commercial banks; thus, $(1 + r_t^{ds})p \geq 1 + r_t^{dc}$, where p is the probability that a shadow bank will not default (no-default probability). It can be rewritten into an equal form to get $1 + r_t^{ds} = \frac{1+r_t^{dc}}{p}$. Define $\mu^s = 1 - p$ as a parameter that affect the default probability of shadow banks; thus, Equation (27) can be obtained in the absence of an exogenous shock.

[12] See detailed derivation process in Appendix A.4.

[13] As noted, the policy rate set here is equivalent to the deposit rate of the commercial banking sector.

Market clearance conditions are subject to the total amount of resources and comprise the consumption of general goods and houses by the household sector, the consumption of enterprises, and various costs incurred in the economic system:

$$Y_t = C_t + C_t^h + q_t[H_t - (1-\delta_h)H_{t-1}] + \delta_c NW_{t-1}^c + \Upsilon\left(\frac{NW_t^c}{B_t^c} - V_t^c\right)\left(\frac{NW_t^c}{B_t^c}\right)^2 + I_t^c.$$

3.2. *Macroprudential regulatory framework*

First, the regulatory framework mainly considers the core elements of Basel III; that is, in response to volatility in the macroeconomic cycle, credit intermediaries must increase the countercyclical buffer based on the original capital requirements. According to Basel III, we set the stable capital requirement of commercial banks to 10.5%[14] and introduce the external impact of capital requirements to characterize the countercyclical buffering regulatory policy. The calibration and estimation results for the other key parameters remain unchanged. According to Basel III, when the credit size of the banking sector is above a certain level, macroprudential authorities raise capital requirements to cope with possible macro instability. Although Basel III does not explicitly state that this provision applies only to commercial banks, most countries focus on commercial banks in implementing this policy requirement. Further, significant structural and professional differences exist between shadow and commercial banks; therefore, the macroprudential framework, which includes common instruments such as capital requirements, may not apply to shadow banks. Accordingly, we construct two different macroprudential regulatory frameworks — those that only consider commercial banks and those that incorporate shadow banks — to analyze the impact of different economic shocks on macroeconomic variables under different regulatory frameworks.

3.2.1. *Narrowed (moderate) macroprudential regulation framework*

In the narrowed or moderate macroprudential regulation framework, regulators are aware of shadow banks. However, in setting capital requirements for commercial banks, they only consider the credit scale of commercial banks. Following Angelini *et al.* (2014), we set the capital requirements for commercial banks under the narrowed framework:

$$V_t^c = (1-\rho^v)\overline{V^c} + (1-\rho^v)\left[\chi_v\left(\frac{B_t^c}{Y_t} - \frac{\overline{B^c}}{\overline{Y}}\right)\right] + \rho^v V_{t-1}^c + \varepsilon_t^v.$$

Regulators must set capital requirements V_t^c based on the ratio of commercial banks' credit scale to output that deviates from the steady-state value. χ_v is the response factor to capital changes, used to measure the sensitivity of regulation policies. ε_t^v is the exogenous impact of capital requirements. Assuming the impact gradually decreases and smooths out

[14] According to the Guidance on the Implementation of New Regulatory Standards in China's Banking Sector, issued by CBRC in April 2011, under normal circumstances, the minimum total capital adequacy ratio of (non-)systemically important banks is (10.5)11.5%. However, the model results show no significant difference in the influence trend of higher capital adequacy ratio on economic variables. Therefore, we set the capital adequacy ratio requirement at 10.5% based on Basel III.

during the capital requirement adjustment process, ρ^v is the smoothing coefficient of the exogenous capital requirements shock. ε_t^v is subject to AR (1) process. A narrowed macroprudential regulatory framework better depicts the current regulatory situation: the regulatory authorities are aware of and accept the existence of shadow banks, but most do not explicitly consider their impact when regulating commercial banks.

3.2.2. *Generalized macroprudential regulation framework*

The generalized macroprudential regulatory framework incorporates shadow banks into the decision-making equation of commercial bank capital requirements. In adjusting commercial banks' capital, regulators should consider the credit scale of commercial and shadow banks for stringent regulation, expressed as follows:

$$V_t^c = (1-\rho^v)\overline{V^c} + (1-\rho^v)\left[\chi_v\left(\frac{B_t^c + B_t^s}{Y_t} - \frac{\overline{B^c} + \overline{B^s}}{\overline{Y}}\right)\right] + \rho^v V_{t-1}^c + \varepsilon_t^v.$$

4. Estimation

Following the convention for solving dynamic general equilibrium models, we log-linearized the model around the steady state and calibrated and estimated the parameters involved. The parameters that can be calibrated are determined based on the relevant study results or macroeconomic data. For parameters that cannot be calibrated, we use the Bayesian method to estimate them.[15] Given that the macroprudential regulatory framework is based mainly on the new regulatory framework pattern that emerged after the 2008 financial crisis, we select macroeconomic data after the 2008 financial crisis, covering the range between Basel II and Basel III to estimate whether the model can reflect changes before and after the implementation of the new regulatory measures. The selected observation variables are GDP, total retail sales of consumer goods, and inflation rate. We adopt the data of observation variables in the past 14 years, make quarterly adjustments, and employ the Hodrick–Prescott filter to eliminate the time trend. The sample covers the period from 2008 (Q1) to 2021 (Q2).[16]

4.1. *Calibration*

Most of the model parameters were calibrated following Iacoviello (2005) and Gertler and Karadi (2011). Some parameters with significant regional differences, such as discount factors, were calibrated following China's macroeconomic data and policies. Thus, to reflect the varying degrees of patience between households and entrepreneurs, the discount factor for households (entrepreneurs) β (β_h) is set to 0.9943 (0.975). The specific parameter calibration is shown in Table 1.

[15] The estimation process includes converting the data into a form suitable for calculating the likelihood function, selecting prior parameter distributions, and estimating the posterior distribution.

[16] This paper also considers the impact of the COVID-19 pandemic on economic stability since 2020, but according to Li (2018), small changes in the time series interval do have little impact on the parameter calibration; for rigor considerations, we also shorten the time series (2008–2019) to re-run the Bayesian estimation and find no significant difference in the results. Therefore, for reasons of timeliness, data from 2008 (Q1) to 2021 (Q2) are selected for this paper.

Table 1. Calibrated Parameters

Parameter	Description	Value	Calibration Basis
β	Discount Factor Households	0.9943	Shown above
β_h	Discount Factor Entrepreneurs	0.975	Shown above
κ	Labor Dis-utility Parameter	1	Gao and Gong (2017)
φ	Reciprocal of labor supply elasticity	0.7381	Gao and Gong (2017)
δ_h	Depreciation Rate Real Estate	0.01	Iacoviello and Neri (2009)
α	Real Estate Output Elasticity	0.03	Iacoviello (2005)
Υ	Regulation Cost	10.05	Gebauer and Mazelis (2019)
V^c	Capital Adequacy Ratio (CAR)	0.105	CBRC in April 2011[a]
δ_c	Bank Capital Management Cost	0.1049	Gebauer and Mazelis (2019)
γ	SB Survival Probability	0.9685	Gertler and Karadi (2011)
ω	Fraction of fund that can be diverted	0.281	Gertler and Karadi (2011)[b]
μ^s	SB Implied Default Rate	0.05	Gebauer and Mazelis (2019)
χ_v	Reaction Factor Capital Requirements	7	Angelini *et al.* (2014)
ρ^v	Smoothing Factor Capital Requirements	0.9	Angelini *et al.* (2014)
θ	Calvo Parameter	0.75	Calvo (1983)
ε	Elasticity of Substitution	1.3	Calvo (1983)
j	Steady-State House Demand	0.01	Iacoviello (2005)
A	Steady-State TFP	1	Recognized Practices
m	Steady-State Mortgage Rate	0.3	Iacoviello (2005)

Notes: [a]The Guidance on the Implementation of New Regulatory Standards in China's Banking Sector issued by the CBRC in April 2011.
[b]Since Gertler and Karadi (2011) used the macroeconomic data of the dollar-zone, which is 0.381, direct application to the benchmark model may not comply with the realistic characteristics of China's economy. Thus, we reduced the default probability of shadow banks (by 1%), reflecting a stronger protection for creditors and stricter supervision of shadow banks of China under the new Asset Management Regulations.

4.2. *Posterior distributions*

By convention, we set the prior distribution of the interest rate smoothing coefficient to the beta distribution. The 90% probability intervals indicate that all parameters in the model are tightly estimated. Table 2 shows the parameter estimation results.

5. Dynamic Economic Characteristics Analysis

As described in the model construction section, we construct a DSGE model linking the housing market and financial intermediaries and introduce a macroprudential regulation framework based on the benchmark model. This section analyzes the dynamic economic characteristics of the benchmark model using the impulse response plots of each economic variable. First, this study analyzes the impact of exogenous housing demand shocks on other macroeconomic variables, especially housing price and shadow banks. Second, it introduces the macroprudential regulation framework into the analysis by considering different framework policy effects on macroeconomic variables under the three major influences of exogenous housing demand shock, monetary policy shock, and regulation

Table 2. Prior and Posterior Distribution

		Prior Distribution			Posterior Distribution	
		Distribution	Mean	Std. dev.	Mean	90 perc. Confidence Interval
Monetary Policy Parameters						
ϕ^{π}	TR Coefficient π	Gamma	1.5	0.5	1.9617	[1.9312, 1.9978]
ϕ^{y}	TR Coefficient y	Gamma	0.2	0.05	0.2122	[0.2058, 0.2193]
ϕ^{r}	Smoothing Factor Rate	Beta	0.75	0.1	0.7489	[0.7142, 0.7835]
Exogenous Shocks (AR Coefficients)						
ρ^{j}	House Demand	Beta	0.8	0.1	0.9996	[0.9994, 0.9998]
ρ^{a}	Technology	Beta	0.8	0.1	0.9626	[0.9614, 0.9638]
ρ^{m}	Mortgage Rate	Beta	0.8	0.1	0.9040	[0.8996, 0.9082]
ρ^{μ}	SB Implicit Default Rate	Beta	0.8	0.1	0.8146	[0.8055, 0.8234]
ρ^{r}	Monetary Policy	Beta	0.8	0.1	0.8817	[0.8636, 0.9001]
Exogenous Shocks (Standard Deviations)						
σ^{j}	House Demand	InvGamma	0.1	0.05	0.0583	[0.0561, 0.0608]
σ^{a}	Technology	InvGamma	0.1	0.05	0.0015	[0.0012, 0.0017]
σ^{m}	Mortgage Rate	InvGamma	0.1	0.05	0.0042	[0.0030, 0.0049]
σ^{μ}	SB Implicit Default Rate	InvGamma	0.1	0.05	0.0061	[0.0021, 0.0092]
σ^{v}	Capital Requirements	InvGamma	0.1	0.05	0.1051	[0.1021, 0.1082]
σ^{r}	Monetary Policy	InvGamma	0.1	0.05	0.0046	[0.0036, 0.0055]

shock. It also ascertains which exogenous shocks have a greater impact on the shadow banking system across two dimensions: the size of shadow bank credit stock and leverage indicators and whether a generalized macroprudential framework that integrates shadow banks effectively mitigates the risks therein and macroeconomic instability. Hence, the section better identifies the close relationship between the housing market and shadow banks, identifies the sources of risks of shadow banks, and finds ways to control shadow banking risks and maintain macroeconomic stability. The horizontal coordinates of all impulse response plots in this study are quarters, whereas the vertical coordinates represent the percentage deviation of the economic variables from their steady-state values.

5.1. *Impact mechanism of housing market volatility*[17]

From Figure 1, a unit of positive housing demand shock in the household sector inevitably increases demand in the entire housing market, pushing up housing prices. To clarify the impact mechanism, it is important to understand the economic intuition of why housing demand shock can drive the housing price and cause volatility. Consider an example in

[17] The impact mechanisms are sorted under the framework of the narrowly-defined macroprudential supervision, and the housing market volatility discussed in this paper is defined as price and scale volatility caused by changes in housing market demand. Therefore, the terms housing demand shock and housing market demand change in the following part of the paper cause house price and housing market size volatility, respectively.

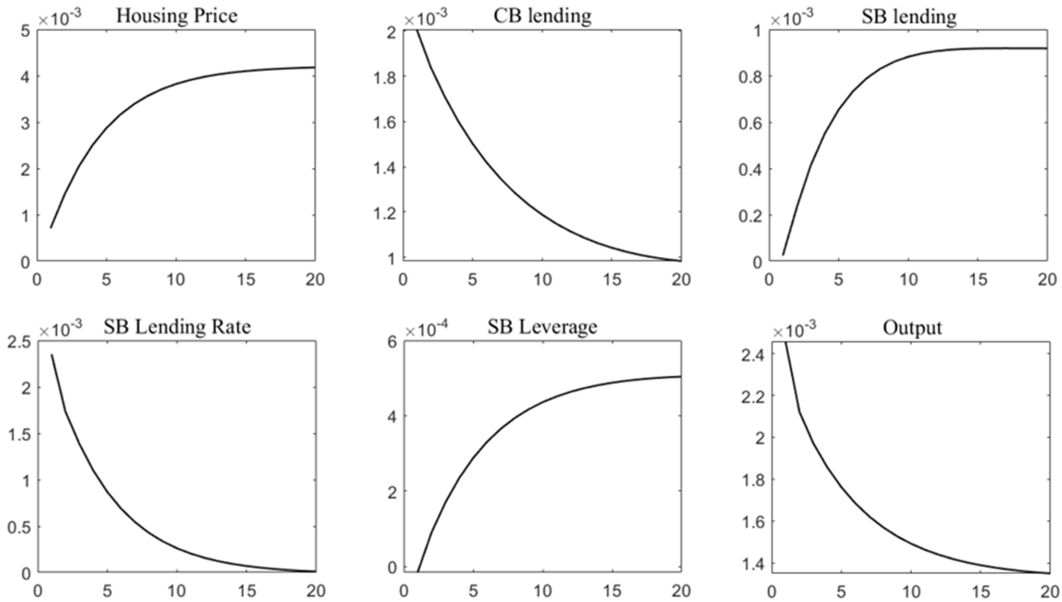

Figure 1. Impact Mechanism of Housing Demand Shock

which the household has linear utility in consumption and improving housing condition, which is given by $U(C,H) = C + jH$. Suppose the taste transfer j is constant. The housing demand function implies that housing price is a discounted sum of future marginal rates of substitution between consumption and house. In this case, the marginal rates of substitution are constant and equal to j. Since the interest rate is constant, the housing price is simply $q_t = \frac{j}{1-\beta}$, which is constant unless j changes. Therefore, in this example, the housing price does not respond to any shocks other than the housing demand shock. This intuition carries over to a more general case with curvatures in the utility function as set in our model with log-utility in consumption and housing services.

The housing market further expands and shows an accelerating upward trend as the demand shock continues to absorb the spillover demand from the housing market and satisfy the household sector's willingness to improve housing conditions. Given that entrepreneurs' credit is highly dependent on real estate assets as collateral, rising house prices and the expansion of the size of the housing market imply more adequate collateral assets for corporate credit and a corresponding increase in demand for corporate loans. Accordingly, it induces positive volatility in the credit size of commercial banks in response to demand shocks, and volatility in the housing market transmits to the credit intermediation sector through the collateral channel.

However, given regulatory credit tightening measures, entrepreneurs face a degree of "financing constraints" when borrowing from commercial banks. Thus, to maximize the value of collateral assets, firms must turn to shadow banks, causing the credit size of shadow banks to fluctuate positively under the influence of housing demand.

Meanwhile, the fluctuation of the credit size of commercial banks under regulatory constraints gradually declines with the continued influence of housing demand, as the fluctuation of shadow bank credit shows an upward trend. The expansion of an entrepreneur's demand for shadow banking loans brings positive volatility in shadow banking rates. Moreover, the positive leverage indicator volatility, measuring shadow banking risk, is more pronounced with the continued influence of housing demand, implying that shadow banking risk increases under the influence of housing market volatility. Finally, high demand in the housing and credit markets further stimulates the economy and induces positive volatility in the aggregate output level.

In summary, market volatility from housing market demand changes first pushes up the housing price and then transmits to the financial intermediation sector via the collateral channel; the expansion of credit stimulates the economy, raising the aggregate output level. However, commercial banks' limited ability to conduct credit activities under regulatory constraints induces economic variables in the shadow banking sector fluctuating more significantly under the influence of housing demand shocks, exacerbating shadow banking risks. Thus, housing market volatility affects the credit intermediation sector and macroeconomy stability.

5.2. *Policy effects of the macroprudential regulation framework*

This section compares the respective policy effects of the two regulatory frameworks regarding the credit size of shadow banks and dynamic leverage indicators. The narrow macroprudential regulation framework considers only the credit size of commercial banks, while the generalized macroprudential regulation framework[18] incorporates shadow bank credit into the capital decision equation and considers the overall credit size. This study attempts to analyze whether the impact of exogenous shocks on economic variables, especially those of shadow banks, have different policy implications under different prudential frameworks. First, based on monetary policy shocks, as shown in Figure 2, consistent with most of the DSGE model literature incorporating monetary policy, a positive monetary policy shock implies a tightening of monetary policy in the narrow macroprudential regulation framework. Thus, the policy rate rises, and consumption and aggregate output face greater downward pressure.

Rising interest rates and deteriorating aggregate demand tightened the overall credit size, with negative volatility in credit size for commercial and shadow banks.[19] The tightening of shadow bank credit size further reduced shadow bank lending rates and worsened the asset position of shadow banks, ultimately pushing up the leverage ratio of shadow banks. However, the impact of tight monetary policy on commercial banks is significantly larger than that on shadow banks; thus, monetary policy regulation has limited effectiveness on shadow banks. Per the capital countercyclical regulation setting in this

[18] The terms generalized regulatory framework, generalized macroprudential, and generalized countercyclical regulation have a consistent connotation with the generalized macroprudential regulation framework; that is, the macroprudential regulation framework that considers the scale of shadow banking credit.

[19] Some studies on the credit spillover mechanism of shadow banking argue that a decline in the size of commercial bank credit induces a large flow of credit to the shadow banking sector. However, since this study focuses on the risks of shadow banking and macroeconomic stability, it considers the extent of volatility in the size of shadow banking credit, not just the increase or decrease in the size of the stock.

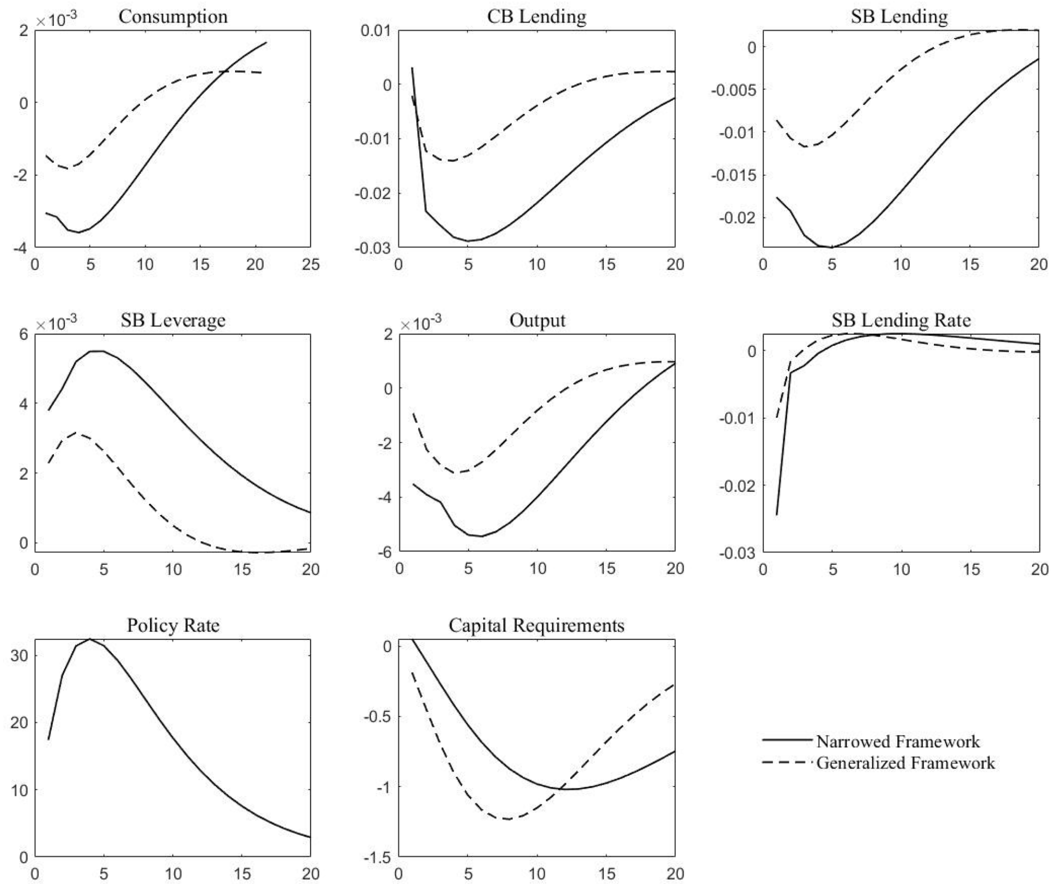

Figure 2. Monetary Policy Shock

study, the capital requirements of commercial banks are relaxed by the decline in the size of commercial banks' credit and total output.

Relative to the narrow macroprudential regulation framework, the overall credit size is less volatile when the regulatory framework focuses on commercial and shadow banks. The increase in shadow banks' leverage ratio declines, and the downward pressure on consumption and aggregate output eases. In the initial stage, as the overall credit size of commercial and shadow banks declines, capital requirements fluctuate negatively, and countercyclical regulation is appropriately relaxed. As monetary policy shocks persist, the generalized regulatory framework capital requirements adjust to countercyclical responses, and the degree of capital requirement response exceeds that of the narrow regulatory framework. Therefore, the generalized macroprudential regulation framework can mitigate the macroeconomic volatility from the impact of monetary policy and maintain the stability of the economic system.

Second, the policy effects of the two regulatory frameworks under regulatory impact are discussed. From Figure 3, based on regulation shock, positive regulatory shock implies more stringent capital requirements for macroprudential regulation, which is significantly

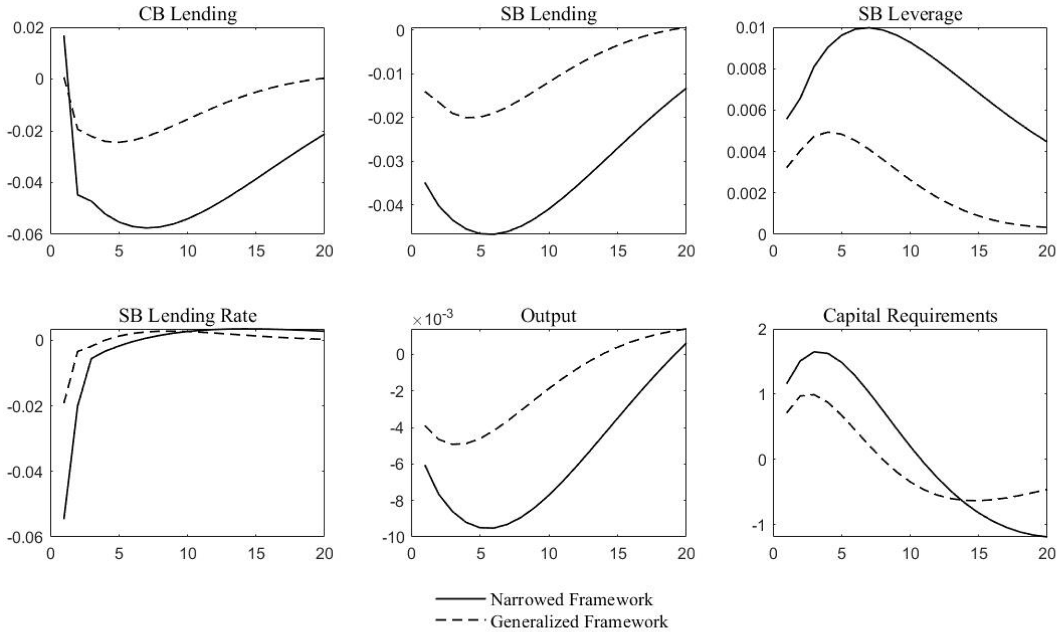

Figure 3. Regulation Shock

higher under narrow and generalized regulatory frameworks. Given that the capital setting of the generalized macroprudential framework is more stringent than the narrow regulatory framework, the degree of countercyclical regulatory response of the generalized regulatory framework at the beginning of the period is smaller. Regarding the credit size of commercial banks, the credit size of commercial banks under the narrow regulatory framework fluctuates positively at the beginning of the period and plummets with significant volatility. Meanwhile, the credit size of commercial banks under the generalized regulatory framework is less volatile. Relative to commercial banks, the credit size of shadow banks also shrank during the implementation of countercyclical regulation, but the shrinkage was significantly smaller than that of commercial banks. Regarding credit proportion, further tightening of regulations led to a partial flow of credit from commercial to shadow banks. Although the size of the credit stock of shadow banks shrinks as capital requirements increase, its leverage ratio shows positive volatility.

Relative to the narrow regulatory framework, the generalized regulatory framework can effectively mitigate the positive fluctuation in the leverage ratio of shadow banks. With more stability on the asset side of commercial banks, the situation where shadow banks sharply lower interest rates to attract investment is also slightly mitigated, and the risk of shadow banks is somewhat moderated. The level of aggregate output fluctuates slightly negatively, as the overall credit size contracts and market demand are suppressed. Relative to the narrow macroprudencial regulation, the output level is less volatile under generalized macroprudential regulation, and the countercyclical regulation of capital is more effective.

In summary, the generalized macroprudential framework can effectively mitigate the volatility of macroeconomic variables when monetary policy and regulations tighten.

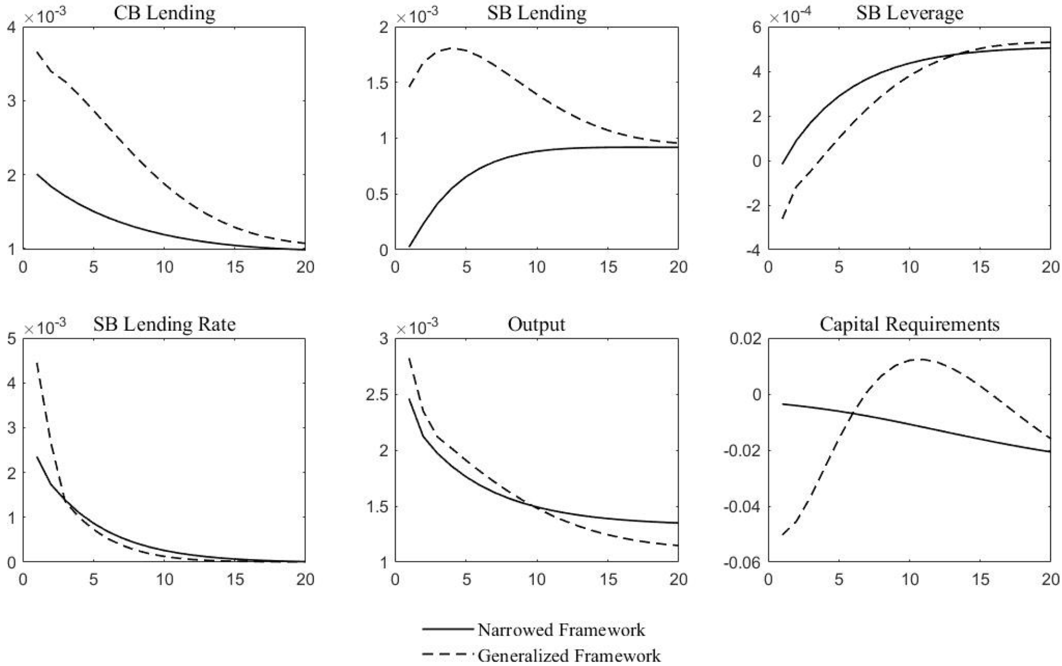

Figure 4. Housing Demand Shock

Next, we discuss the policy effects of the generalized macro-prudential framework regarding the risks associated with housing market volatility. From Figure 4, the positive volatility in overall credit size is more pronounced under the generalized macroprudential regulation framework, influenced by the housing demand shock. A plausible explanation is that the market is aware of stricter regulations and is can better ensure financial security and more inflated credit demand. However, in the benchmark model, the generalized macroprudential regulation framework is not effective in mitigating the impact of housing market volatility on the stability of the credit intermediation sector's stock size.

Regarding the shadow bank leverage indicator, the macroprudential regulation framework that considers shadow bank credit can effectively reduce the impact of housing demand shocks on the leverage of shadow banks in the short run. However, the leverage gradually increases as the impact continues. Thus, the generalized regulatory framework is time-sensitive in controlling the leverage ratio of shadow banks.

Further, under the generalized regulatory framework, aggregate output increases, and positive volatility becomes more dramatic. As the level of total output increases more significantly, even if the credit size expands, the capital requirements of countercyclical regulation under the generalized regulatory framework at the beginning of the period are relaxed. The capital requirements increase significantly after approximately five periods. Thus, the countercyclical regulation policy responds to the housing market volatility with a relative lag, and macroprudential regulation cannot mitigate the impact of housing demand shocks on macroeconomic variables.

Therefore, for the credit stock size of shadow banks, tightening the monetary policy and strengthening regulations shrink the credit size of shadow banks significantly, while the housing market volatility from the rise in housing demand further expands their credit size. Relative to the narrow macroprudential regulation framework, the generalized macroprudential regulation framework can effectively mitigate fluctuations in the credit scale of shadow banks under the influence of monetary policy and regulation. However, countercyclical regulatory measures incorporating shadow banks' credit statistics are ineffective in the short run against housing demand shocks and are not dissimilar to the narrow regulatory framework in the medium to long run.

Regarding the leverage indicator of shadow banks, under the tightening of monetary policy and regulation, entrepreneurs are forced to turn to shadow banks for loans because of the relatively smaller credit size of commercial banks, pushing up the leverage ratio of shadow banks. Even so, countercyclical regulation curbs commercial banks' leverage volatility in the medium to long term; thus, the leverage volatility is short-lived. When the housing market is more volatile, and the risk of default of shadow banks rises, the leverage indicator of shadow banks fluctuates positively. However, the impact of housing market volatility on shadow banks' leverage cannot be mitigated over time. Relative to the narrow regulatory framework, the generalized regulatory framework can effectively mitigate the impact of monetary and regulatory policy changes on the leverage ratio of shadow banks. Nevertheless, for the negative impact of housing market volatility and rising default risk of shadow banks, the generalized countercyclical regulatory measures can only be effective in the short term, and macroprudential regulation measures that only consider capital remain ineffective in the medium and long term.

6. Conclusions and Policy Recommendations

This study embedded housing market volatility and heterogeneous financial intermediaries in the same benchmark model, introduced the macroprudential regulation framework, analyzed the impact mechanism of housing market volatility on macroeconomic variables, and dynamically analyzed shadow banks from two dimensions (shadow bank stock size and leverage indicators). The policy effects of the two macroprudential regulation frameworks were compared. By analyzing the dynamic economic characteristics of the model, this study reached the following conclusions.

House price volatility transmits to the financial intermediation sector through the collateral channel, amplifying macro-financial volatility. Given that housing assets are the main collateral for firms, the increase in house prices because of the rise in housing market demand further expands the size of the housing market, and the rise in the value of firms' collateral expands the overall credit size. However, under the credit constraints of commercial banks, firms are forced to turn to shadow banks for loans; thus, the size of shadow bank credit is positively volatile, and leverage is on the rise. Driven by the housing market and credit market demand, the aggregate output level is more volatile, affecting macro-financial stability.

Regarding tighter monetary policy and stricter regulation, the macro-prudential framework incorporating shadow banks can control the leverage ratio of shadow banks and maintain macroeconomic stability. Currently, the countercyclical regulation of capital is more effective. However, the generalized macroprudential regulation framework is not sufficient to mitigate the impact of housing market volatility on shadow banks and macro-financial stability.

Regarding the risk of shadow banks, from the perspective of the stock size of shadow banks, only the impact of the housing demand shock induces positive volatility in the stock size of shadow banks, and the generalized macroprudential regulation framework cannot avoid volatility in the housing market under shadow banks. Regarding the leverage indicators of shadow banks, monetary policy contraction, regulation contraction, and the housing market volatility raise the leverage of shadow banks. However, the housing market volatility has the most profound impact on the risk of shadow banks. When shadow banks are regulated, the macro-prudential framework can effectively mitigate the positive volatility of shadow banks' leverage under changes in monetary and regulatory policies. However, macroprudential regulation can only be effective in the short run for volatility in the housing market and changes in shadow banks' structural risks.

Hence, this study proposes the following policy recommendations. Regarding an irreversible rise in the house price, the government must continue implementing housing market regulation and control policies, abide by the "housing without speculation" principle, make comprehensive use of various means to improve the housing system, effectively increase housing supply, reasonably release domestic demand in the housing market, and prevent overall macroeconomic volatility from excessive house price increases.

The government can also incorporate shadow banks into the macroprudential regulation framework, appropriately eliminate regulatory asymmetries, supplement capital through multiple channels, and improve the ability to withstand risks. Moreover, to formulate a generalized macroprudential regulation policy, the credit scale should be considered, and capital requirements of commercial banks should be relaxed per the credit scale of shadow banks to alleviate the pro-cyclicality of the financial system and promote economic growth.

Furthermore, assessing the risk of shadow banks from a dynamic perspective, the government must establish flexible and professional rules for shadow bank regulation. Given the complexity and professionalism of shadow bank operations, the countercyclical regulation of commercial bank capital can mitigate risks under specific circumstances. Therefore, it is necessary to identify the risk sources behind shadow banks, implement different regulatory policies for different risk sources, and realize "one solution for each case" rather than seeking "all-round solutions."

Housing market regulation, macroprudential regulation, and monetary policies must be coordinated to promote information sharing, tool complementarity, and crisis resilience among market regulations. Further, the government must maximize the cross-market effect between different regulation measures, effectively block the risk contagion between different markets, and maintain macro-financial and economic stability.

Appendix A. First-Order Condition of the Model

A.1. *Households*

The representative households pursue the maximization of their utility under budget constraints and obtain the following first-order conditions:

$$\beta E_t \frac{(1+r_t^{dc})}{C_{t+1}} = \frac{1}{C_t}, \tag{A.1}$$

$$\kappa N_t^{\varphi} = \frac{w_t}{C_t}, \tag{A.2}$$

$$\frac{j_t}{H_t} + \frac{\beta E_t(1-\delta_h)q_{t+1}}{C_{t+1}} = \frac{q_t}{C_t}, \tag{A.3}$$

where Equation (4) is the Euro equation of consumption, Equation (5) is the labor supply equation and Equation (6) is the housing demand equation.

A.2. *Entrepreneurs*

The optimal conditions for entrepreneurs are the Euler equation of consumption (4), the real estate assets demand Equation (5) and the labor demand Equation (6):

$$\frac{1}{C_t^h} = E_t \frac{\beta_h(1+r_t^{bc})}{C_{t+1}^h} + \lambda_t(1+r_t^{bc}), \tag{A.4}$$

$$\frac{1}{C_t^h} q_t = E_t \left\{ \frac{\beta_h}{C_{t+1}^h} \left[\alpha \frac{Y_{t+1}}{H_t x_{t+1}} + q_{t+1}(1-\delta_h) \right] + \lambda_t m_t^c q_{t+1}(1-\delta_h) \right\}, \tag{A.5}$$

$$w_t = \frac{(1-\alpha)Y_t}{N_t x_t}. \tag{A.6}$$

A.3. *Commercial banks*

Based on the profit maximization function and balance sheet constraint of commercial banks, the optimization conditions of commercial banks are as follows:

$$r_t^{bc} = r_t^{dc} - \Upsilon \left(\frac{NW_t^c}{B_t^c} - V_t^c \right) \left(\frac{NW_t^c}{B_t^c} \right)^2. \tag{A.7}$$

Moreover, we assume the difference between commercial and shadow banks lies in the regulation and their ability to obtain superior liquidity assistance. Therefore, we assume the deposit rate of commercial banks must be equal to the risk-free policy interest rate set by the central bank:

$$r_t^{dc} = r_t. \tag{A.8}$$

The credit spread of a commercial bank can be expressed as:

$$r_t^{bc} = r_t - \Upsilon \left(\frac{NW_t^c}{B_t^c} - V_t^c \right) \left(\frac{NW_t^c}{B_t^c} \right)^2, \tag{A.9}$$

which implies that the marginal benefit of commercial bank loans must equal the marginal cost of borrowing funds. When the net assets held by commercial banks deviate from regulatory requirements, the regulation cost increases.

A.4. *Retailer*

Assuming a continuum of retailers of mass 1, indexed by (z), buy intermediate goods Y_t from entrepreneurs at P_t^w in a competitive market, we differentiate the goods at no cost into $Y_t(z)$ and sell $Y_t(z)$ at price $P_t(z)$.

The final goods are $Y_t^f = (\int_0^1 Y_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz)^{\frac{\varepsilon}{\varepsilon-1}}$, where $\varepsilon > 1$. Given this aggregate output function, the price of the final goods is $P_t = (\int_0^1 P_t(z)^{1-\varepsilon} dz)^{\frac{1}{1-\varepsilon}}$, so that each retailer faces an individual demand curve of $Y_t(z) = (P_t(z)/P_t)^{-\varepsilon} Y_t^f$.

Each retailer chooses a sale price of $P_t(z)$, taking P_t^w and the demand curve as given above. Each retailer has a probability of $(1-\theta)$ to adjust the price per period. $P_t^*(z)$ is used to denote the reset price and $Y_{t+k}^*(z) = (P_t^*(z)/P_t)^{-\varepsilon} Y_{t+k}^f$ to denote the corresponding demand curve. The optimal $P_t^*(z)$ solves:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,k} \left(\frac{P_t^*(z)}{P_{t+k}} - \frac{x_t}{x_{t+k}} \right) Y_{t+k}^*(z) \right\} = 0, \tag{A.10}$$

where $\Lambda_{t,k} = \beta \frac{C_t}{C_{t+k}}$ is the random discount factor and x_t is the markup, which in steady state equals $x = \frac{\varepsilon}{\varepsilon-1}$. This condition states that P_t^* equals expected discounted marginal revenue to expected discounted marginal cost. The final commodity pricing formula is

$$P_t = [(1-\theta) P_t^{*1-\varepsilon} + \theta P_{t-1}^{\varepsilon}]^{\frac{1}{1-\varepsilon}}. \tag{A.11}$$

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