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A DSGE Analysis

By **Qing He , Fangge Liu , Zongxin Qian and Terence Tai Leung. Chong**[*1]

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Abstract

We investigate the interaction between the real estate market and the business cycle volatility in China over the past two decades. A Bayesian dynamic stochastic general equilibrium (DSGE) model with nominal stickiness and collateral constraints is estimated. It is found that shocks from the housing market (e.g., loan-to-value ratio and housing preference shocks) affect the macroeconomy of China. The interactive feedback between credit constraints and housing prices amplifies the impact of various economic shocks, which plays an important role in explaining the business cycle volatility in China.

JEL Classification: E32; E42; R31

Keywords: housing prices; business cycle; DSGE; China

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1. Introduction

Over recent decades, the boom–bust cycles in the real estate market have been widely documented and discussed (Hirata et al., 2012). Considerable attention is paid by policymakers and researchers to the interaction between housing prices and business cycle fluctuations. For instance, Iacoviello (2005) analyses the collateral channel: rising housing prices lead to rising collateral value and increasing borrowing capacity, which promotes consumption and economic growth. Benito (2006) suggests that credit constraints play an important role in the housing market and significantly affect business cycle volatility. Iacoviello and Neri (2010) use a Bayesian approach to quantify the contribution of the housing market to business cycle fluctuations.

Previous studies have focused on developed countries, and little is known about emerging market economies. How real estate assets interact with business cycle volatility is an important issue yet to be fully understood. In this paper, we add to the literature by investigating how the housing market interacts with the shocks that drive economic fluctuations in China. The case of China is of interest for several reasons. First, China exhibits almost all of the notable features that characterize emerging market countries. For example, China's financial system is characterized by the repressive financial policies that are prevalent in many emerging countries. Small and medium-sized firms "rely" heavily on informal finance, a typical feature for most emerging market economies (He et al., 2016). Second, despite the financial repression, China's housing market has grown rapidly since 1998. The property prices in China have risen rapidly over the last decade. Home prices are 10 times the median household income and in Beijing the ratio is close to 22 times. Understanding the housing price dynamics and associated government policies in China provides valuable experiences for other emerging market economies. Finally, as China has played a significant role in the global market, the collapse of the housing market in China will have a devastating impact on the world economy. Therefore, how the Chinese government should prevent excessive speculation in the housing market and a subsequent housing market collapse has received increasing international attention.

To shed light on this issue, we develop a DSGE model based on Iacoviello (2005) to investigate the channels through which the housing market affects the economy in China. An important attribute of our model is that it takes into account the nominal price stickiness and collateral constraints, which allows us to study the interactions between the housing market and macroeconomic fluctuations. Specifically, we extend the model of Iacoviello (2005) in two aspects: first, we incorporate fiscal policy into the model so that the relative contribution of fiscal policy and monetary policy to macroeconomic fluctuations can be evaluated. Second, we allow a stochastic shock to loan-to-value ratio (LTV) so that impacts of shocks caused by central banks' monetary policy can be investigated.

The main finding of this paper is that the interactive feedback between credit constraints and housing prices magnifies the impact of various economic shocks. Because of the interactive effect, the shocks from the housing market, e.g., loan-to-value ratio and housing preference shocks, are the important determinants of business cycle volatility in China. Housing preference shocks are the most important drivers of housing price fluctuations. Policies which can affect the effective housing demand are therefore important for smoothing housing price fluctuations. However, such polices also lead to a decline in output and employment rate.

The rest of this paper is organized as follows: Section 2 presents basic facts on China's housing sector. Section 3 describes the DSGE model. Section 4 and 5 present the model estimation and inference results. Section 6 concludes this paper.

2. Housing Market in China

Over the last three decades, China has maintained a rapid economic growth rate. However, its private housing market did not exist until 1998. On July 18, 1994, The State Council issued the Decision on Deepening Urban Housing Reform and initiated the commercialization of urban houses. The government began to change the urban employee's compensation system by distributing money instead of houses according to their working performance. This reform has steadily promoted the privatization of housing in China by selling former state-owned properties to urban households. However, in the initial stage, most houses were still controlled by the government, and households still relied on the government house distribution system to obtain a property.

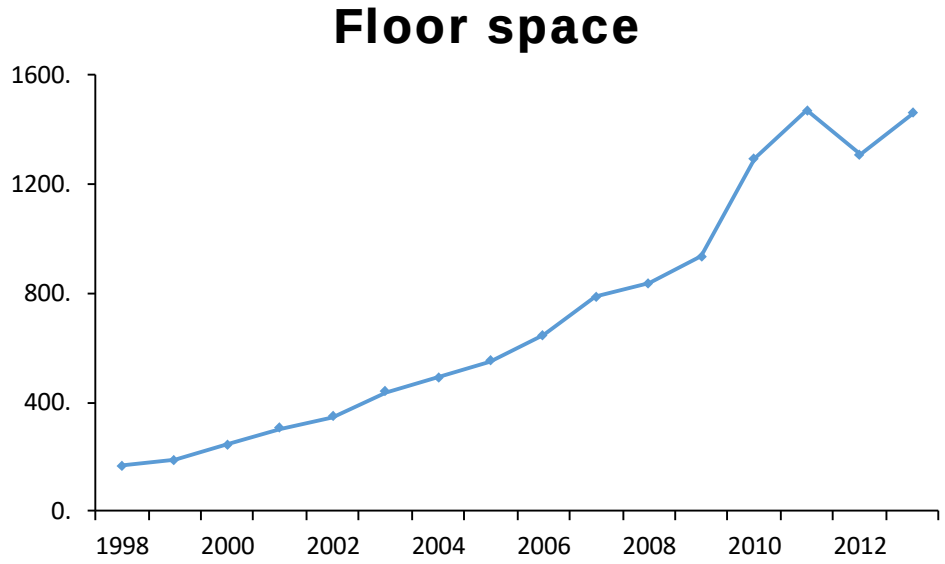
On July 3, 1998, the State Council issued the Notice on Further Deepening Urban Housing System Reform and Speeding up the Housing Construction. To remove the barrier for the commercial housing market, this reform abolished the house distribution system. Urban households had to enter the commercial housing market to purchase and sell their real estate assets. To encourage further development of residential houses for low-and-medium-income citizens, the State Council issued the Notice on Promoting the Sustainable and Healthy Development of the Real Estate Market. Several policies were implemented to solve the housing problem of urban, low-income families.

After a series of reforms, the private housing market was established, and it has experienced a rapid expansion over the past decade. Panel A and B of Figure 1 show the annual changes in floor space of newly started commercial residential housing and the investment in residential housing respectively between 1998 and 2013. Note that there were only 166.375 million square meters of residential houses in 1998, while 1458.45 million square meters were built in 2013. During the same period, investment in residential housing increased 19.9 times, and accounts for more than 10 per cent of GDP at the end of 2013.

Figure 1

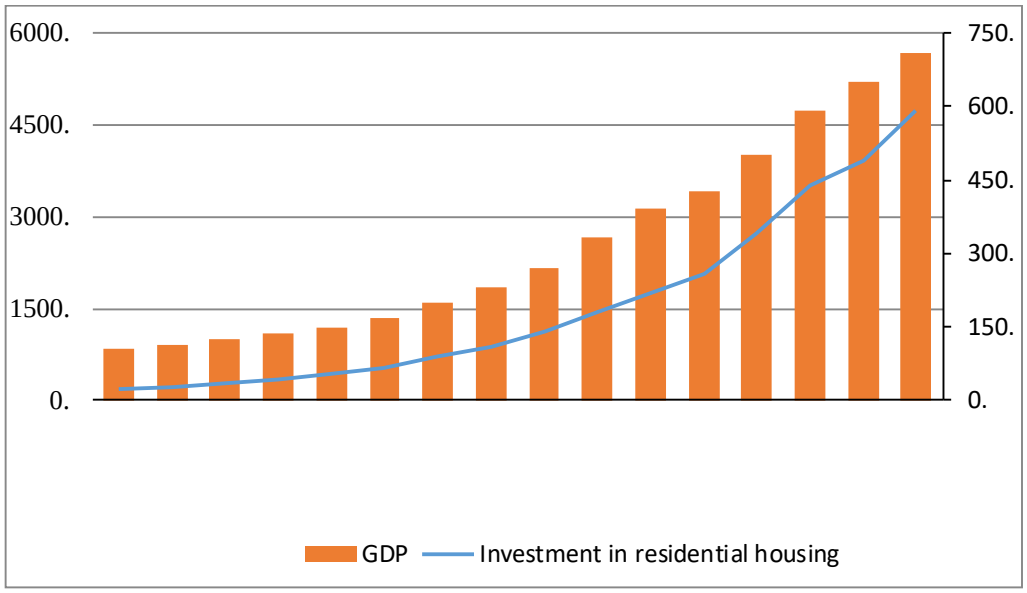
Panel A

Floor space of newly started of commercial residential housing (Million square meters)



Data source: CEIC

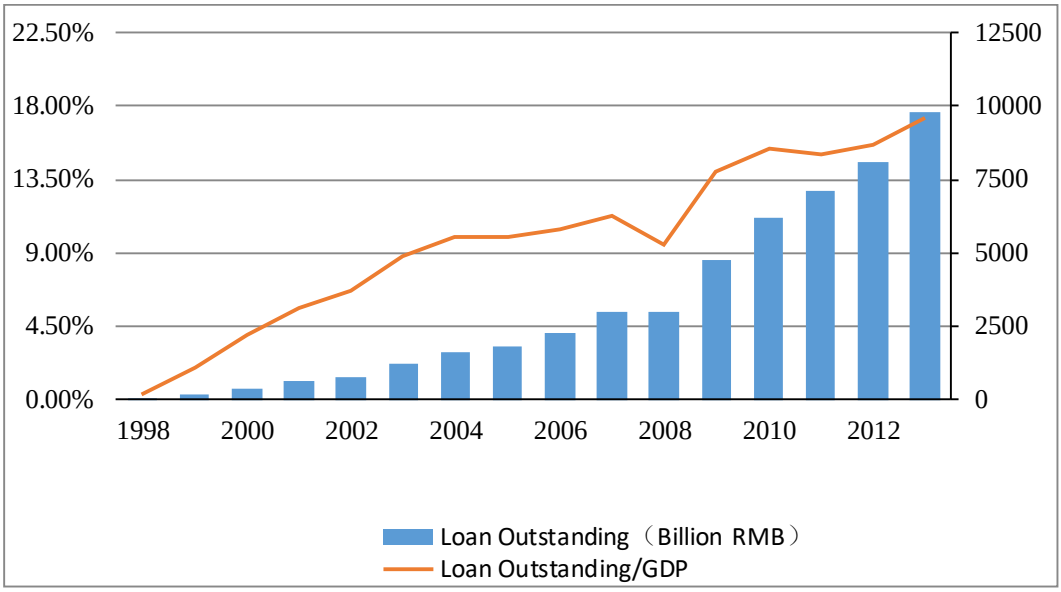
Panel B: Investment in residential housing (Billion RMB)



Data Source: CEIC

With the expansion of the housing market, bank credit plays an increasing role in financing the residential housing investment. Figure 2 shows that the ratio of bank loans to residential housing over GDP increases from less than 1% to more than 17.23%. The loan outstanding to residential housing was less than 100 billion RMB in 1998, and reached 9800 billion RMB at the end of 2013. The growth rate of residential housing loans is much higher than the growth rate of the money supply.[2] This suggests that an increasing percentage of money supply is channeled into the real estate market.

Figure 2 Personal Loan outstanding (Billion RMB)

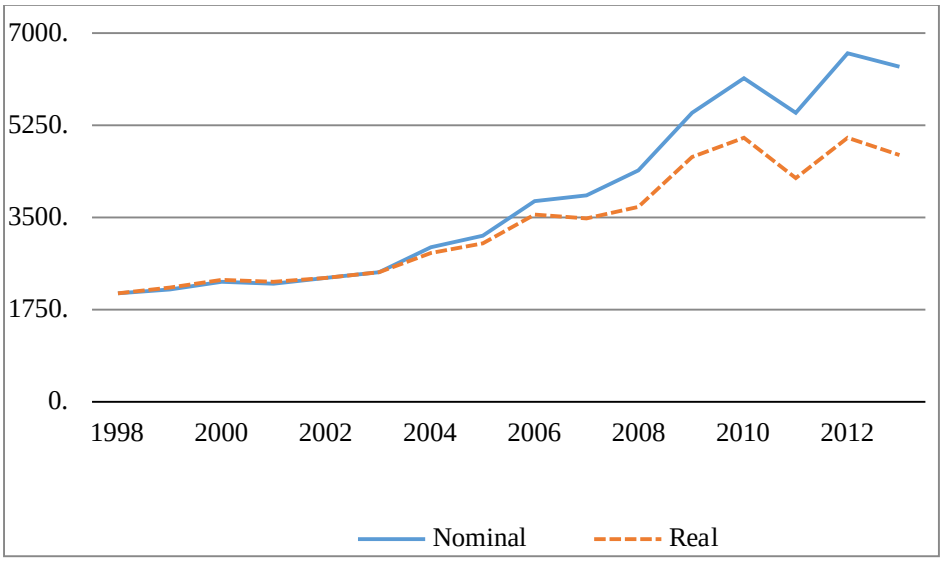


Data Source: CEIC

[2] The annual average growth rate of the money supply from 1998 to 2013 is 16.8%.

Figure 3 shows the annual changes in the nominal and real housing prices from 1998 to 2013, where the real housing prices are measured as the nominal housing prices deflated by the consumer price index. It can be seen that residential property prices rose rapidly, both in nominal and real terms, from 1998 to 2013. The average housing price almost tripled from 1998 to 2008. During the global financial crisis from 2008–2010, housing prices fell by 14%, but recovered rapidly owing to a number of stimulus policies, e.g., a lower interest rate and bank reserve ratio.[3] Housing prices have risen rapidly since 2010.

Figure 3 Residential house prices (RMB per square)



Data Source: CEIC

Due to the fear of asset bubbles, the Chinese government has adopted a series of policies, e.g., a tighter monetary policy, higher transaction taxes, a reduction in mortgage lending and increases in down payments,[4] to cool down the demand for real estate and reduce speculations in the housing market. Table 1 summarizes the primary policies adopted by the Chinese government to cool down the housing market.

[3] To offset adverse global economic conditions, the Chinese government launched a CNY 4-trillion stimulus plan on Nov. 9, 2008, to boost domestic demand. Due to the relationship between lending conditions and a lower interest rate, both developers and buyers were able to easily get loans to invest in the housing market.

[4] In March, 2013, the State Council made new policies to control house prices: (1) major cities should establish an annual housing price control target. (2) Banks should not give loans to developers who hoard land.

Table 1 Government policies

Time	Policy	Major Content
2005	Eight real estate market regulation measures	(1) stabilizing housing price; make governments responsible for housing price stability; (3) reform the supply structure; (4) control the passive housing demand, particularly housing deconstruction; (5) optimizing household housing demand; (6) monitoring developments of real estate market; (7)enforcing housing policies on both demand and supply; monitoring housing price stabilization policies.
2006	Six real estate market regulation measures	(1) adjust supply structure; (2) make better use of tax, credit and land policies; (3) control the size and progress of housing destruction, slow down the growth of passive housing demand; (4) restore market order in the real estate sector; (5) speed up the development of cheap renting housing, improve regulations on the housing with regulated prices, develop the secondary market and renting market; (6) more transparency.
2009	Four real estate market regulation measures	(1) increase effective supply; (2) support self-occupancy, suppress speculation, differentiate credit policies; (3) more market discipline; (4) support the development of welfare housing
2010	Eleven real estate market regulation measures	Strict regulation on second house purchase, the down payment has to be at least 40%, window guidance on credit extended to the real estate sector.
2012	New Eight real estate market regulation measures	(1)Further implement local government responsibility; (2) Increase of indemnificatory comfortable living engineering construction force (3)Adjust and improve the related tax policy, and strengthening tax collection and administration; (4) Strengthening decreases. it housing credit policy. (5) Strict housing land supply management (6) Reasonable guide housing demand (7) Implement housing safeguard and stable prices work interviews accountability mechanism;(8) Persistence and strengthen public opinion guide
2013	Five real estate market regulation measures	(1) Improve the responsibility to stabilize the housing prices, e.g., major cities should establish an annual housing price control target； (2) Resolutely curb speculative investment buyers e.g. In cities, where house price is higher than the control target price, People's Bank of China (PBOC) branches will increase down payment requirements； (3) To increase the supply of ordinary commodity housing and land.； (4) Accelerate the planning and construction of affordable housing projects； (5) Stretch market supervision

The Chinese government relies on administrative measures to control housing prices. One such measure is to control the down-payment ratio (loan-to-value ratio). Despite the efforts made by the government, the housing price level in China relative to household income is still very high compared to the rest of the world.

3. The Model

The model features four types of economic agents, namely entrepreneurs, retailers, patient and impatient households. The patient households are lenders while the impatient households and entrepreneurs are borrowers. The patient households have lower discount rates than impatient ones (Iacoviello, 2005). Retailers are directly owned by the lenders. Following Iacoviello (2005), the supply side is divided into a production sector and a retailing sector to simplify aggregation[5]. The flexible-price production sector, managed by the entrepreneurs, faces a borrowing constraint due to the same type of contract incompleteness as the one specified in Kiyotaki and Moore (1997). In the retailing sector, there is no contract incompleteness and borrowing constraint. The nominal price is sticky.

3.1 Households Sectors

The patient households maximize their expected lifetime utility given by:

$$E\sum_{t=0}^{\infty}\beta^{'t}(\ln c_t^{'} + j_t \ln h_t^{'} - \frac{L_t^{'\eta}}{\eta}), \tag{1}$$

subject to the constraint:

$$c_t^{'} + q_t \nabla h_t^{'} - b_t^{'} = -\frac{R_{t-1} b_t^{'}}{\pi_t} + w_t^{'} L_t^{'} + F_t^{'} - \tau_t^{'} - \varepsilon_{h,t}^{'}, \tag{2}$$

where $\beta^{'}$ is the subjective discount factor; $c_t^{'}$ is the consumption at time t, $h_t^{'}$ is the real estate stock; j_t is the weight on the real estate stock which is assumed to be time varying to allow for a preference shock; $L_t^{'}$ are the number of working hours; $q_t \equiv \frac{Q_t}{P_t}$ is the real housing price; R_{t-1} is the nominal gross interest rate; $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation rate; $-b_t^{'}$ is the real stock of lending provided by the household; $w_t^{'}$ is the real wage rate; F_t is the lump-sum profit from the retailers; $\tau_t^{'}$ is tax paid to the government; $\varepsilon_{h,t}^{'} \equiv \phi_h (\nabla h_t^{'} / h_{t-1}^{'})^2 q_t h_{t-1}^{'} / 2$ is the housing adjustment cost; ϕ_h,

[5] One might be concerned that Iacoviello's (2005) four economic agents framework may not fit well Chinese economy, as Chinese economy has many distortions and government regulations. To explicitly model those features, some more preliminary micro level studies are needed for the calibration and prior setup of key parameters. Building a complicated model without precise parameter settings might lead to less reliable results. Chari, Kehoe and McGrattan (2007) shows that many models in detailed economies are equivalent to a prototype growth model with different types of distortions and shocks. Following Chari, Kehoe and McGrattan (2007), we instead take a residual approach to account for distortions in Chinese economy. We further calibrate the parameters by employing the Metropolis–Hastings Bayesian method with Chinese data. We also add a discussion on the difference between China and the US in Section 4 and 5.

η are constant parameters. Equation (2) states that in each period, the households receive loan repayments, working wages, profits from the retailing sector and use them to buy consumption goods, purchase houses, issue new loans and pay taxes.

The impatient households have to borrow to purchase houses since their discount factor is $\beta^{"} < \beta^{'}$. If a borrower breaches the contract, the lender can obtain the net value of the real estate by paying transaction costs. Therefore, the firm's borrowing cannot exceed the net present value of the real estate times a loan-to-value ratio. The gross interest rate is nominally specified in the loan contract. Therefore, inflation can reduce the real value of the debt.

More specifically, the impatient households maximize

$$E\sum_{t=0}^{\infty}\beta^{"t}(\ln c_t^{"} + j_t \ln h_t^{"} - \frac{L_t^{"\eta}}{\eta}), \tag{3}$$

subject to the budget constraint:

$$c_t^{"} + q_t \Delta h_t^{"} - b_t^{"} = -\frac{R_{t-1} b_t^{"}}{\pi_t} + w_t^{"} L_t^{"} - \tau_t^{"} - \varepsilon_{h,t}^{"}, \tag{4}$$

and the borrowing constraint:

$$b^{"} \le m^{"} E_t(q_{t+1} h_t^{"} \pi_{t+1} / R_t)\xi_{LTV,t} \tag{5}$$

where $b^{"}$ is the borrowing of the impatient households; $w_t^{"}$ is their wage rate; $\tau_t^{"}$ is tax paid to the government; $\varepsilon_{h,t}^{"} \equiv \phi_h(\Delta h_t^{'} / h_{t-1}^{'})^2 q_t h_{t-1}^{'} / 2$ is the housing adjustment cost; $m^{"}$ is the loan-to-value ratio; $\xi_{LTV,t}$ is a shock to the loan-to-value ratio. In each period, the impatient households receive loans and wage payments and use the money to buy consumption goods, purchase houses, pay taxes and repay the debt.

Before we carry on, it is important to have some discussion on the housing preference parameter j_t. First, it is assumed to be the same across both household sector, so a shock to it is an aggregate shock. Second, since we have used the representative agent approach to aggregate both the patient and impatient household sectors, j_t not only reflects unexpected changes in individual households' preferences, but also reflects anything that affect the transformation of each individual household's preferences into the aggregate effective housing demand. An important Chinese macro-prudential policy which can affect the effective housing demand is restrictions on housing purchase (see Table 1). Even if individual households have very strong preference for housing, administrative restrictions will prevent that strong preference from forming a strong effective demand for housing. Therefore, by studying the effects of the housing preference shocks, we can analyze the effects of this kind of macro-prudential policies.[6]

Another shock which is related to government policies is the loan-to-value shock. The loan-to-value ratio $m^{"}$ measures the amount of loan a representative house buyer

[6] Assuming that the patient and impatient households have the same housing preference is a way to model the housing preference shock as an aggregate shock. Following Iacoviello (2005), we use the same setting.

can obtain with a given market value of the house. Obviously, at least two government credit policies can affect the aggregate loan-to-value ratio. The first policy is the minimum down payment requirement (see Table 1). The second is the administrative policy which directly affects aggregate credit supply. Suppose the loan-to-value ratio set by an individual bank for the bank's own risk management purpose is 0.8, it does not mean a potential borrower with a collateral valued at 6 million RMB can borrow 4.8 million. If the down payment is set to be 40 percent, at least 2.4 million has to be paid by the buyer herself, so the actual loan-to-value ratio will be lower than 0.8. In practice, the Chinese central bank usually applies administrative policies to influence the commercial banks' aggregate credit supply. Suppose a bank's loan-to-value ratio is 0.8 and there is no down payment requirement, it could be that a house buyer's target house has a collateral value of 6 million but she cannot borrow up to 4.8 million. This is because there may be too many borrowers whose loan demand adds up to a total amount higher than the total supply the bank can offer. The credit policies work through changing the gap between the demand and supply.

3.2 Production and retailing sectors

Entrepreneurs produce wholesale goods. Retailers buy the wholesale goods at price P^{w}_{t} and re-sell them at price P_t.

Entrepreneurs choose consumption c_t, investment $I_t = K_t - (1-\delta)K_{t-1}$, housing h_t, employment of two types of labors $L^{'}$ and $L^{"}$ to maximize their expected lifetime utility

$$E\sum_{t=0}^{\infty}\gamma^t \ln c_t \tag{6}$$

subject to the production technology

$$Y_t = A_k K_{t-1}^{\mu} h_{t-1}^{\nu} L_t^{'\alpha(1-\mu-\nu)} L_t^{(1-\alpha)(1-\mu-\nu)} \tag{7}$$

the budget constraint

$$Y_t / X_t + b_t = c_t + q_t \nabla h_t + R_{t-1} b_{t-1} / \pi_t + w_t^{'} L_t^{'} + w_t^{"} L_t^{"} + I_t + \tau_t + \varepsilon_{e,t} + \varepsilon_{K,t} \tag{8}$$

and the borrowing constraint[7]

$$b \le mE_t(q_{t+1} h_t \pi_{t+1} / R_t)\xi_{LTV,t}, \tag{9}$$

where $\gamma < \beta^{'}$ is the discount factor; δ is the capital depreciation rate; K_t is the

[7] One might be concerned that China's enterprises, particularly for SOEs, face a "soft budget constraint". The government usually bail out unprofitable SOEs through state-owned banks to avoid SOE bankruptcy and laying off workers (Lau et al., 2000; Brandt and Zhu 2000). The 15th Congress of the Chinese Communist Party held in 1997 sectioned the ownership reform and legalized private economy. The Chinese government reduced its commitment to support SOEs and allow many SOEs to go bankrupt or privatized (Brandt and Zhu, 2000). Since then, private enterprise grow rapidly in China. By the end of 2010, private sectors accounts for 77% of total urban employment in China (Allen et al., 2012). The non-state sectors contributed more than two thirds of China's GDP, while state sectors only account 30% of the GDP in 2009 (Allen, et al., 2012). Our sample period is between 1998 and 2013. In this period, state sectors has been shrinking in both output and employment. More importantly, even SOEs were allowed to go bankrupt without further government support. Both private enterprises and SOEs faced a tighter budget constraint and stronger market competition in the post-1998 (Zhu, 2012). Thus, it is appropriate to assume there are borrowing constraints faced by enterprises.

capital stock; A_t is the technology parameter; $X_t \equiv \frac{P_t}{P_t^w}$ is the markup of retail price over the whole sale price; τ_t is tax paid to the government; $\varepsilon_{e,t} \equiv \phi_e(\nabla h_t / h_{t-1})^2 q_t h_{t-1}/2$ is the housing adjustment cost of entrepreneurs; $\varepsilon_{K,t} \equiv \varphi(I_t / K_{t-1} - \delta)^2 K_{t-1}/(2\delta)$ is the capital adjustment cost; m is the loan-to-value ratio faced by entrepreneurs; α, μ, ν, ϕ_e, and ϕ are constant parameters. The entrepreneurs receive sales revenue and loans and use them to buy consumption goods, purchase houses, repay debt, pay salaries and taxes and make investment.

The retailing sector features monopolistic competition. The mass of retailers is 1. Indexing the retailers by z, the final goods are $Y_t^f = (\int_0^1 Y(z)^{\varsigma-1/\varsigma} dz)^{\varsigma/\varsigma-1}$, where $\varsigma > 1$. Assuming that the retail price can change in every period only with probability of 1-θ and denoting the reset price by $P_t^*(z)$, the retailer's optimization problem is to choose $P_t^*(z)$ to maximize the net present value of its lifetime profit flows. The first order condition to this optimization problem is as follows:

$$\sum_{k=0}^{\infty} \theta^k E_t\{\Lambda_{t,K}[\frac{P_t^*(z)}{P_{t+k}} - \frac{X}{X_{t+K}}]Y_{t+K}^*(z)\} = 0 \tag{10}$$

where $\Lambda_{t,K} \equiv \frac{\beta c_t^{'}}{c_t^{"}}$ is the stochastic discount factor, $X \equiv \frac{\varsigma}{\varsigma - 1}$ is the steady-state markup. Combining this result with the aggregate price index $P_t = [\theta P_{t-1}^e + (1-\theta)P_t^*]^{1/1-\varsigma}$ and log-linearizing, we obtain the usual New Keynesian Phillips curve $\hat{\pi}_t = \beta \hat{\pi}_{t+1} + \kappa \hat{X}_t$, where $\kappa = (1-\theta)(1-\beta\theta)/\theta$. We add a cost-push term u_t to the right hand side of the Phillips curve as an additional source of business cycle fluctuations in our model.

3.3 Equilibrium, monetary policy and shock processes

The market clearing conditions for the labor market, housing market, final goods market, and the loan market are respectively:

$$L_t^{'} + L_t^{"} = L_t, \tag{11}$$

$$h_t + h_t^{'} + h_t^{"} = H, \tag{12}$$

$$c_t + c_t^{'} + c_t^{"} + I_t + G_t = Y_t \tag{13}$$

$$b_t + b_t^{'} + b_t^{"} = 0 \tag{14}$$

The monetary policy on interest rate follows

$$R_t = (R_{t-1})^{r_R}[\overline{rr}\,\pi_{t-1}^{1+r_\pi}(Y_{t-1}/Y)^{r_Y}]^{1-r_R} e_{R,t}, \tag{15}$$

where H is the fixed supply of houses; $\overline{rr}$ and Y are the steady-state real interest rate and output respectively; $e_{R,t}$ is the monetary policy shock with a variance σ_R^2.

The government budget constraint is $G_t = \tau_t + \tau_t^{'} + \tau_t^{''}$.

The government expenditure evolves as follows:

$$\ln G_t = (1-\lambda_g)\ln \overline{G} + \lambda_g \ln G_{t-1} + e_{g,t} \tag{16}$$

where $\overline{G}$ is the steady-state government expenditure, $e_{g,t}$ is a i.i.d. shock with variance σ_g^2.

Other shock processes follow:

$$\hat{j}_t = \rho_j \hat{j}_{t-1} + e_{j,t} \tag{17}$$

$$\hat{\mu}_t = \rho_\mu \hat{\mu}_{t-1} + e_{\mu,t} \tag{18}$$

$$\hat{A}_t = \rho_a \hat{A}_{t-1} + e_{a,t} \tag{19}$$

$$\hat{\xi}_{LTV,t} = \rho_{LTV} \hat{\xi}_{LTV,t-1} + e_{ltv,t} \tag{20}$$

where hat denotes percentage deviation from the steady-state; variances of $e_{j,t}$, $e_{\mu,t}$, $e_{a,t}$, $e_{ltv,t}$ are σ_j^2, σ_μ^2, σ_a^2, σ_{ltv}^2, respectively.

4. Calibration and Estimation

Table 2 lists the calibrated parameters of the model. For standard parameters, the values are set within the range considered in the real business cycle literature. The discount factors (β′, β″) of the patient and impatient households are set to 0.99 and 0.985, respectively, to match China's interest rates on savings and personal housing mortgages. The discount factor for entrepreneurs is set as 0.95 to match the Chinese firms' housing mortgage rate, 21%, which is the average housing mortgage rate of the informal finance sector through our sample period. period.[8] As the official lending rate is highly regulated in China, most small and medium-sized firms find it difficult to access external finance from the formal financial sector in China (Allen et al.,

[8] Data obtained from the CEIC.

2005). The official lending rate is less likely to reflect the actual borrowing cost of the firms.[9]

δ is set to be 0.025, corresponding to an annual capital depreciation rate of 0.1 (Bai et al., 2006). Housing share (ν) and capital share (μ) are 0.11 and 0.39 respectively. The sum of those two parameters equals 0.5, the same as the value estimated by Bai et al. (2006). We set the housing share to be the value estimated by Huang et al. (2008). The values of other calibrated parameters follow Iacoviello (2005).

Table 2 Calibrated Parameters

Description	Parameter	Value
Discount factor, patient households	β'	0.99
Discount factor, impatient households	β''	0.985
Discount factor, entrepreneurs	γ	0.95
Capital depreciation rate	δ	0.025
Steady-state markup	X	1.05
Housing share	ν	0.11
Capital share	μ	0.99
Capital adjustment cost	φ	2

Other parameters are estimated by with 10,000 burn-in draws and 100,000 iterations. Due to the stylized nature of DSGE models, maximum likelihood estimation often generates absurd parameters which are at odds with prior information. The Bayesian method can avoid this problem. Moreover, prior information adds curvature into the posterior density surface so that numerical maximization can better identify model parameters than the maximum likelihood estimation when the likelihood function is flat around some parameter values.

We employ quarterly data of five macroeconomic variables from 1998Q1 to 2013Q4: real GDP (Y), consumer price inflation (π), real government expenditure (G), investment (I), and the interest rate (R). Our data are drawn from the CEIC database. Real variables are at constant prices in 1998. All variables are seasonally adjusted by the US Census X12 method. The HP filter is employed to detrend the data.

The summary statistics of the prior and posterior distributions are summarized in Table 3. The prior mean of the housing preference parameter *j* is set to be 0.2, much higher than the US level. We set a relatively large prior standard error of this parameter to reflect the uncertainty of its true value. Priors of the monetary policy parameters are set to be the OLS estimates. Prior means of housing adjustment cost parameters are set to 1, higher than the US level (0), to reflect the heavy regulations and higher transaction costs on housing stock adjustment in China. However, the prior standard deviations of these adjustment parameters are set relatively large to provide

[9] We also set the discount factor for entrepreneurs to match the official lending rate. It turns out that our primary results remain qualitatively unchanged.

room for the data to adjust to the prior.

Table 3 Prior and posterior distributions of the structural parameters

	Prior			Posterior		
Parameters	Distribution	s.d.	mean	Mean	10%	90%
Housing preference j	Beta	0.05	0.2	0.3069	0.221	0.3866
LTV ratio（entrepreneurs） m	Beta	0.05	0.6	0.4748	0.4076	0.5486
LTV ratio（patient households） $m"$	Beta	0.05	0.6	0.4332	0.3701	0.5063
Wage share of patient households α	Beta	0.1	0.7	0.6881	0.5171	0.8518
Housing adjustment cost（entrepreneurs） ϕ_e	Inverse-Gamma	0.5	1	0.6988	0.4187	0.972
Housing adjustment cost（impatient households） ϕ_h	Inverse-Gamma	0.5	1	0.3691	0.2878	0.4518
Calvo stickiness parameter θ	Beta	0.5998	0.67	0.5485	0.5119	0.5998
Monetary policy coefficient (output gap） ρ_Y	Normal	6.38	6.74	5.5252	1.1764	9.8252
Monetary policy coefficient（inflation） ρ_π	Normal	0.02	0.04	0.0389	0.0029	0.0701
Monetary policy coefficient（lagged interest rate） ρ_R	Beta	0.1	0.75	0.9647	0.9402	0.9903
Autoregressive coefficient of the preference shock ρ_j	Beta	0.1	0.8	0.6607	0.5505	0.7524
Autoregressive coefficient of the cost-push shock ρ_u	Beta	0.1	0.8	0.9434	0.9002	0.988
Autoregressive coefficient of the technology shock ρ_a	Beta	0.1	0.8	0.5208	0.412	0.6111
Autoregressive coefficient of the LTV shock ρ_{ltv}	Beta	0.1	0.8	0.9232	0.8665	0.9751
S.d. of the monetary policy σ_R	Inverse-Gamma	0.01	0.001	0.0046	0.0038	0.0053
S.d. of the preference shock σ_j	Inverse-Gamma	0.01	0.001	2.1962	1.4492	2.8736
S.d. of the cost-push shock σ_u	Inverse-Gamma	0.01	0.001	0.0034	0.0009	0.0058
S.d. of the technology shock σ_a	Inverse-Gamma	0.01	0.001	0.0875	0.0708	0.1039
S.d. of the LTV shock σ_{ltv}	Inverse-Gamma	0.01	0.001	0.086	0.0678	0.1062

5. Empirical Results

5.1 Impulse response

Figure 4 reports the economic response to various structural shocks.[10] Note that after a positive technology shock, inflation goes down while output goes up. The interest rate goes down as a reaction to falling inflation. Output expansion pushes up housing prices.

After a positive housing preference shock, housing prices rise. The housing boom leads to output expansion and inflation, and a subsequent increase in interest rates. As we have discussed above, the government's restrictions on housing purchase can cause a negative housing preference shock, so our results suggest that those restrictions can effectively slow down the housing price increase, but also reduce output. Therefore, it is important to pay attention to the coordination between the macro-prudential policy which aims at smoothing house price fluctuations and regular macroeconomic policies which aims at fighting recession and maintaining full employment.

A positive loan-to-value shock leads to more lending and aggregate demand. The increasing demand leads to higher output level. The output expansion raises the nominal interest rate, and lowers the consumption and housing demand of the patient households. Therefore, the housing price drops, although output expansion leads to a stronger industrial demand for housing. Inflation gradually climbs to a level higher than the steady-state level and stays above the steady-state level for a long time. As the industrial demand for housing increases, it finally offsets the decline in the housing demand of the savers, and the housing price increases. As we discussed above, both a higher down payment requirement and a tighter administrative credit supply policy cause a negative loan-to-value shock. Therefore, our results suggest that if the aim is to slow down the housing price increase, such policies only become effective with lags. In the first few quarters after the introduction of the policies, housing price will be even higher. Moreover, these policies will have a negative impact on output and employment[11].

A contractionary monetary policy shock raises the nominal interest rate, which leads to lower output level and inflation. The housing price also declines. It turns out that the impact of the unexpected monetary tightening is more persistent on output than on inflation. Inflation soon starts to increase again after a temporary decline. The rising inflation reduces the real debt value of the borrowers and encourages investment in capital goods and housing. As a result, both housing price and output gradually recover.

A cost-push shock leads to higher inflation, output and housing price. On the one hand, the increase in cost lowers profit, prevents investment and industrial housing demand. On the other hand, inflation lowers the real value of nominal debt, which loosens the external financing constraint, encourages investment and increases industrial housing demand. The debt devaluation effect also increases the housing demand of impatient households. When the cost-push shock hit the economy, the latter effect dominates, so aggregate demand increase, which pushes up both output and housing price. But as time goes by, the negative impact of the cost increase on

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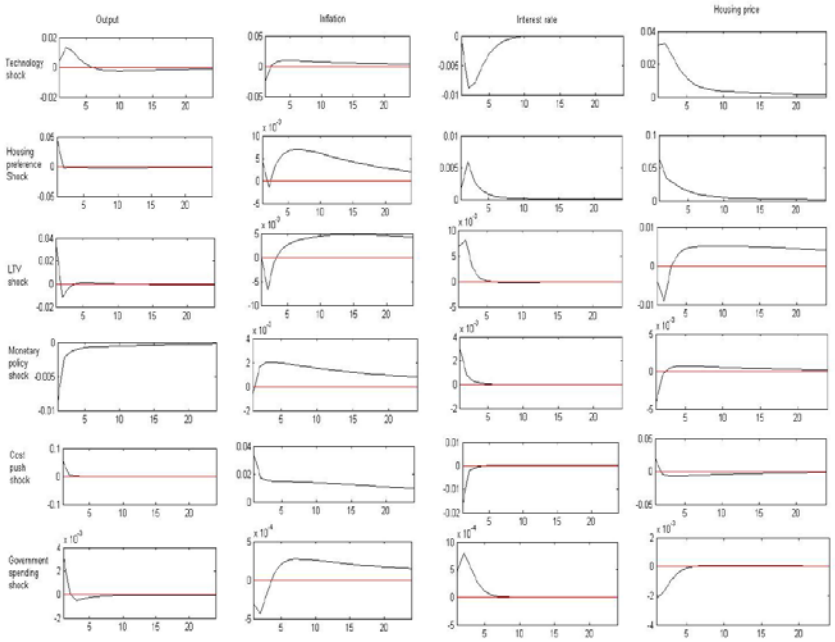
[10] Unlike the recursive VAR models, the identification of structural shocks in our paper does not rely on the Cholesky decomposition. Therefore, we do not rely on a specific ordering of the variables to identify the model. Detailed elaborations on the identification of the DSGE-VAR model can be found in An and Schorfheide (2008).

[11] Our impulse response functions shows that the impact of the LTV and housing preference shocks seems to be short-lived. Note that even if a shock's impact is short-lived, if the same type of shocks are large enough in size and happen frequently enough, they can contribute a lot to business cycle fluctuations. Table 3 also shows that the estimated posterior standard deviation of the housing preference shock and LTV shock are much larger than other shocks.

profit and investment becomes more and more important. Therefore, both output and housing price decrease towards the steady-state values.

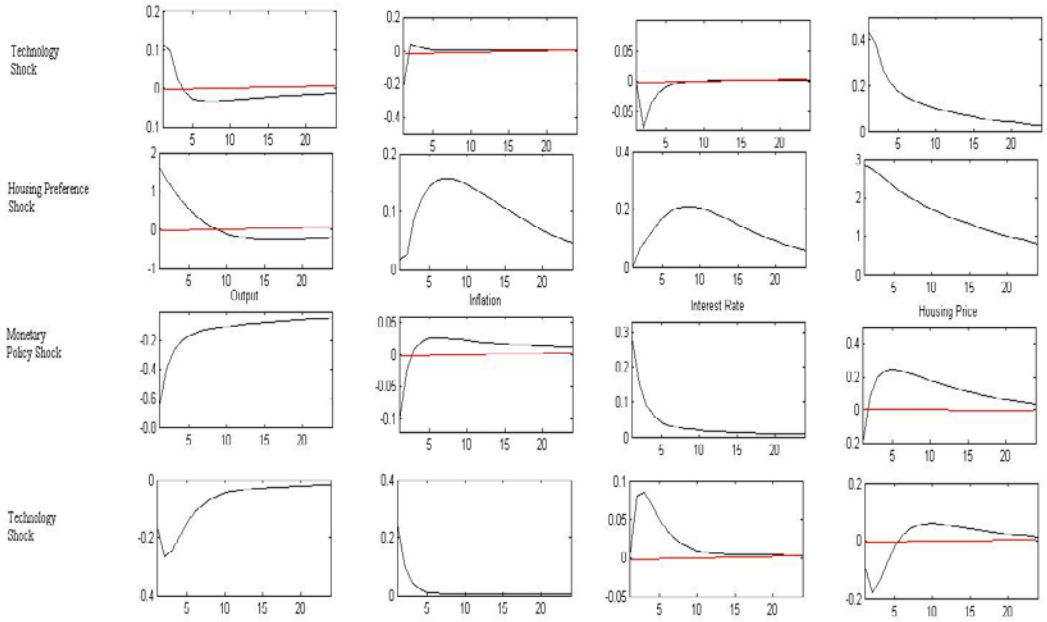
An increase in government spending increases both output and interest rate. The increase in the interest rate lowers inflation rate. Because the government spending increases taxation, it lowers consumption and housing demand. As a result, the output expansion effect is limited and the housing price declines.

Figure 4 Impulse response (China)



To compare our findings with existing literatures, we also report the impulse responses to various structural shocks of the US model calibrated by using the parameters in Iacoviello (2005). Note that Iacoviello (2005) does not include the government spending shock and LTV shock in his model. No results related to the two shocks are reported in the US model. Figure 5 shows that the impulse responses to all shocks except the cost-push shock are qualitatively similar in both our Chinese model and the US model of Iacoviello (2005). The cost-push shock increases inflation in both countries. However, the impulse responses of output, and housing price differ qualitatively in the two countries. While output and housing price initially increase in response to the cost-push shock in China, the initial impulse responses of those two variables are negative in the US model. It may indicate that the size of debt devaluation effect of inflation was limited in the US.

Figure 5. Impulse response (US)



5.2 Variance decomposition

Table 4 presents results from variance decomposition. Panel A reports the results for China. It shows that the monetary policy shock based on interest rate adjustment has limited impact on China's business cycle fluctuations. By contrast, the loan-to-value (LTV) shock plays a notable role. The LTV shock partly reflects changes in the PBOC's credit policy. Therefore, this result suggests that the credit policy has more influence on China's business cycles than the interest rate policy. The cost-push shock explains nearly half of China's business cycle fluctuations. Such shocks are related to various administrative policies, which directly affect the price level. The housing preference shock also plays an important role. As we have discussed above, this shock is also related to government regulations. Putting together, those results suggest that administrative policies of the Chinese government have contributed a lot to China's business cycle fluctuations. In the future, the government needs to transform its policy to make it more market-oriented which can help better manage the expectations of economic agents and smooth the business cycles.

In addition, we also observe that the housing preference shock is the most important source of fluctuations in both the housing price and investment. Recall that a positive housing preference shock increases both housing price and output. Therefore, the Chinese government faces a tough policy tradeoff: a policy aimed at smoothing the housing price might dampen investment, cause output fall and unemployment.

Panel B of Table 4 reports the variance decomposition results taken from Iacoviello and Neri (2010). Similarly, it shows that cost-push shocks are important drivers of the business cycle fluctuations in both China and the US. However, we also find notable differences across these two countries. Compared to the US, the central bank's interest rate policy shocks do not play a major role in China's business cycle fluctuations. This is consistent with the general observation that administrative measures are more effective in adjusting the real economy and price level in China (He et al., 2013). As a proxy of the PBOC's administrative measures, the LTV shock explains a large part of

China's business cycle fluctuations. The housing preference shock plays a much larger role in China than in the US with regards to investment and house price fluctuations. There are two possible explanations. First, compared to the US, the Chinese government relies more on administrative policies to fight economic fluctuations (He et al., 2013). Housing preference is likely to be influenced by administrative policies. Second, house sector has a larger weight in the Chinese households' utility function. Thus, the shocks to housing preference play an important role on driving house price and business cycle volatilities.

Table 4 Variance decomposition

	Monetary Policy	Housing preference	Cost-push	Technology	LTV	Government spending
Panel A: China						
Output	1.07	26.37	50.11	4.46	17.92	0.08
Investment	0.64	43.07	33.57	1.12	21.52	0.08
Inflation	0.42	2.67	84.01	7.00	5.89	0.02
Housing price	0.20	59.67	7.13	23.80	8.95	0.15
Panel B: US						
Output	22.6	2.0	23.2	24.5	-	-
Investment	14.8	0.1	18.6	43.8	-	-
Inflation	5.4	0.4	59.0	4.9	-	-
Housing price	11.5	27.3	13.0	29.5	-	-

Notes: reported numbers are percentages. US results are taken from Table 6 of Iacoviello and Neri (2010). They have a more disaggregated decomposition on different types of technology shocks. The LTV shock and government spending shock are not considered in their paper.

6. Conclusion

This paper investigates the interaction between the housing market and the real economy in China. It is found that the shocks related to the housing market, e.g., loan-to-value ratio and housing preference shocks, are important determinants of business cycle fluctuations in the country. The housing preference shock is also the most important driver of housing price fluctuations.

These results have valuable policy implications for the Chinese economy. Although China has adopted a series of government policies to avoid overheating its housing market, most of them are heavily related with government administrative

interventions. These policies might be effective in slow down the housing price increase and prevent excessive speculations in the housing market from creating a systemic financial risk, they also contribute to output fluctuations. Particularly, due to the economy's heavy dependence on the housing sector, downward changes of the housing price dampen investment and cause output falls. Although this is not a problem, sometime even desirable, when the economy is overheated and face the threat of inflation, it will pose a tough policy choice for the government when the economy is in recession and there is the threat of unemployment. In this sense, the entire economy is captured by the housing sector. To relax the policy constraint for the government, future policies should encourage innovation and technological improvements which help the economy grow without a heavy dependence on the housing sector. Moreover, compared with the administrative policies, market-oriented interest rate policy has limited impact on the business cycle fluctuations in China. Future reforms are necessary to increase the effectiveness of the market-oriented policies.

It should be noted that our analysis is at country level. China's large geographical scale leads to great diversity in its regional economies. Therefore, future studies along this line should focus on the provincial level analysis and urban–rural comparison.

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