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# Housing demand or money supply? A new Keynesian dynamic stochastic general equilibrium model on China's housing market fluctuations

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## HIGHLIGHTS

- We investigate the key driving force of housing price fluctuations in China using DSGE.
- We compare the role of housing demand shock and money supply shock.
- Housing demand instead of money supply drives China's housing price.
- A house price-augmented money supply rule is suggested for China's housing policy.

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## ABSTRACT

There is a bitter controversy over what drives the housing price in China in the existing literature. In this paper, we investigate the underlying driving force behind housing price fluctuations in China, especially focusing on the role of housing demand shock with that of money supply shock in explaining housing price movements, by a new Keynesian dynamic stochastic general equilibrium model. Empirical results suggest that it is housing demand, instead of money supply, that mainly drives China's housing price movements. Relevant policy implication is further discussed, namely, whether to consider the housing price fluctuations in the conduct of monetary policy. By means of the policy simulations, we find that a real house price-augmented money supply rule is a better monetary policy for China's economy stabilization.



## 1. Introduction

In the past decades, many scholars have observed that movements in housing market are not just the consequences of wider macroeconomic developments, but also the driving forces of business cycles [1,2]. Iacoviello and Neri [2] point out that researches on the housing market has finally become one of the mainstream studies in economics. Leung [3] provides a survey of the interactive nexus between housing market and the macroeconomy. The importance of housing market in explaining the macroeconomy fluctuations is not only acknowledged by the academia, but also by the policy makers, since it is crucially important for both researchers and policy makers to better understand the issue so that appropriate policy adjustments or policy suggestions can be made or proposed to stabilize the housing market and macroeconomy. Taylor [4] examines the relationship between monetary policy and housing markets/housing finance. In the existing literature, the housing market is found to be highly correlated with the macroeconomy and even a key source of the macroeconomy

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fluctuations. As the housing markets fluctuate remarkably in the short term and have boom–bust cycle in the long run, the macroeconomy would suffer a lot from housing market fluctuations [1]. Besides, in order to conduct the economic policy effectively, one must suit the policy to the situation. It is thereby of critical importance to find out the underlying driving force behind housing market volatilities before making policy to stabilize effectively the housing market and the macroeconomy.

However, there is no consensus on the foresaid problem in existing literatures. Clayton [5] derives a forward-looking rational expectation house price model to explain short-run fluctuations in real house prices, and suggests that prices may temporarily deviate from fundamental values in real estate price cycles. Ortalo-Magné and Rady [6] propose a life-cycle model with income heterogeneity and credit constraints to explain the observed co-movements of housing prices and owner occupancy rates in the UK. Capozza et al. [7] explore the determiner of the housing price dynamics, and find house prices react differently to economic shocks depending on such factors as growth rates, area sizes and construction costs. Ortalo-Magné and Rady [8] identify the ability of young households to afford the down payment on a starter home, and in particular their income as a powerful driving force of the housing market by a life-cycle model of the housing market with a property ladder and a credit constraint. Mankiw and Weil [9], however, focus for the first time on the demographic influences on housing demand and real housing prices. From an urbanization perspective, early urban economists, including Alonso [10] and Muth [11], attempt to investigate the interactions between housing markets and urban expansion. Beltratti and Morana [12] concentrate on the linkages between general macroeconomic conditions and the housing markets for the G-7 countries, and find that the US is an important source of global housing price fluctuations for real housing prices.

Unfortunately, it appears to be even more controversial on the main driving force of housing market fluctuations in China in the existing literature. Various models and theories are proposed, trying to explain house price movements in China; some focus on demand driven, while others consider growth of money supply.

The demand driven theory attributes house price movements to changes in housing demand, which are mostly fueled by changes in household income [13], competition among men in the marriage market [14], and rural–urban migration and urbanization [15]. Wei et al. [14] assume that housing is a status good in China's marriage market and examine the consequences for house prices. The authors find empirical evidence to support this hypothesis and further a rise in the sex ratio accounted for 30%–48% of the rise in urban house prices in China during 2003–2009. Chen et al. [15] explore the possible effects of rural–urban migration and urbanization on China's urban housing prices, and conclude that the different urbanization levels and the migration situations have significant effects on urban house prices in China. In summary, the demand driven theory believes that housing demand is caused by household income, marriage and migration/urbanization is one of important determining factors in explaining the housing price movements in China.

With respect to the role of money supply growth, many other scholars believe that China's monetary policies act as the key driving force behind the severe fluctuations of housing price in China. Using a nonlinear modeling approach, Zhang et al. [16] investigate determinants of housing prices in China over the period from January 1999 to June 2010, and show that monetary policies and price variables are the key factors influencing house prices in China, while other aggregate economic variables have relatively less significant impacts. Xu and Chen [17] examine empirically the impact of key monetary policy variables, including long-term benchmark bank loan rate, money supply growth, and mortgage credit policy indicator, on the real estate price growth dynamics in China, and find that faster money supply growth tends to accelerate the subsequent home price growth, and vice versa. By a standard multivariate dynamic model, Zhang [18] explores the causal relationship among monetary growth, house price inflation and consumer price inflation in China since 1998, and suggests that the recent real estate market boom is mainly driven by excessive monetary growth in China.

Inspired by the existing literatures [19–21], we endeavor to find out the answer to the foresaid problem, and to better understand the underlying driving force the housing price fluctuation in China. The main contributions of our work can thereby be summarized as follows: we answer the question in this paper by quantitatively investigating the contributions of housing demand and money supply shocks to housing price fluctuations within an integrated Keynesian DSGE framework; and based on our quantitative results from the empirical analyses and policy simulations, we find that a real house price-augmented money supply rule is a better monetary policy for China's economy stabilization. To do that, inspired by Burdekin and Siklos [20] and Zhang [21], we consider a money supply rule in this new Keynesian DSGE model. Using quarterly data from 2001:Q1 to 2012:Q4, we further estimate the model with Bayesian methods. Impulse response analysis and variance decomposition are applied to identify the relative importance of housing demand shock and money supply shock to housing price movements. Based on empirical results, relevant policy implication is also discussed, to better address this issue in the Chinese economy. In this regard, our model and findings pertinently address and attempt to solve the ongoing China's economic puzzle, and have potential applications to both theoretical housing market researches and practical monetary policy making in China (and possibly other emerging markets).

The rest of the paper is structured as follows. In Section 2 we describe the baseline model and estimate the parameters in Section 3. Section 4 represents the main results, including the main source of housing price fluctuations and implications for monetary policy. Section 5 concludes.

## 2. The model

In this section, we propose a new Keynesian DSGE model with money supply rule and credit constraint in order to capture some features of the Chinese economy. We consider a discrete time, infinite horizon economy, populated by households, entrepreneurs and retailers infinitely lived and of measure one. Households supply labor to entrepreneurs, demand housing

and money, and consume the final goods. Entrepreneurs produce a homogeneous intermediate good by combining labor, capital and housing. Apart from money, bond is the other financial asset, which can be traded between households and entrepreneurs. Retailers purchase intermediate goods from entrepreneurs in a competitive market, and differentiate them into final goods. The central bank conducts monetary policy by controlling the growth of money supply.

### 2.1. Households

Assume the households maximize the intertemporal objective function

$$E_t \sum_{i=0}^{\infty} \beta^i U_{t+i} \tag{1}$$

with

$$U_t = \ln c_t + j_t \ln h_t + \chi_t \ln\left(\frac{M_t}{P_t}\right) - \frac{1}{1+\eta} n_t^{1+\eta} \tag{2}$$

where $E_t$ is the expectation formed at period $t$, and $\beta \in (0, 1)$ is the discount factor. The households derive utility from consumption ($c_t$), housing ($h_t$), real money balances ($M_t/P_t$) and disutility from labor supply ($n_t$). The parameter $\eta$ denotes the inverse of the elasticity of work time with respect to real wage. The terms $j_t$ and $\chi_t$ represent shocks to housing demand and money holding preference, respectively. The shocks follow AR(1) processes:

$$\ln j_t = (1-\rho_j)\ln j + \rho_j \ln j_{t-1} + e_t^j; \qquad \ln \chi_t = (1-\rho_\chi)\ln \chi + \rho_\chi \ln \chi_{t-1} + e_t^\chi$$

where $e_t^j$ and $e_t^\chi$ are i.i.d. processes with variances $\sigma_j^2$ and $\sigma_\chi^2$. The households maximize the above utility subject to:

$$c_t + q_{h,t} h_t + b_t + \frac{M_t - M_{t-1}}{P_t} = w_t n_t + \frac{R_{t-1} b_{t-1}}{\pi_t} + q_{h,t} h_{t-1} + F_t \tag{3}$$

where $q_{h,t}$ is the real housing price, $w_t$ is the real wage, and $F_t$ are lump-sum profits received from retailers. $\pi_t = P_t/P_{t-1}$ denotes the gross inflation rate. The left-hand side of this budget constraint (in real terms) contains the outflow of funds: consumption, purchases of housing stock, loans lending to entrepreneurs and changes in real money balances. The right-hand side includes the inflow of funds: real wage income, the value of the housing stock, gross returns from lending and the lump-sum profits. The households choose $c_t$, $h_t$, $M_t$, $n_t$ and $b_t$ to maximize (1) subject to (3). Thus, the first order conditions for solving this problem are

$$\frac{q_{h,t}}{c_t} = \frac{j_t}{h_t} + E_t\left(\frac{\beta q_{h,t+1}}{c_{t+1}}\right) \tag{4}$$

$$\frac{\chi_t}{m_t} = \frac{1}{c_t} - E_t\left(\frac{\beta}{\pi_{t+1} c_{t+1}}\right) \tag{5}$$

$$n_t^\eta = \frac{w_t}{c_t} \tag{6}$$

$$\frac{1}{c_t} = E_t\left(\frac{\beta R_t}{c_{t+1}\pi_{t+1}}\right). \tag{7}$$

Eq. (4) is first order condition for housing holdings. Eq. (5) represents a standard money demand equation. Eq. (6) is the optimal condition for labor supply. Eq. (7) is the households Euler condition for consumption.

### 2.2. Entrepreneurs

The representative entrepreneur derives utility from consumption and maximizes the following objective function:

$$E_t \sum_{i=0}^{\infty} \left(\beta'\right)^i \ln c'_{t+i} \tag{8}$$

where $\beta' < \beta$. The budget set is described as

$$\frac{Y_t}{X_t} + b'_t = c'_t + q_{h,t}\left(h'_t - h'_{t-1}\right) + \frac{R_{t-1} b'_{t-1}}{\pi_t} + w_t n_t + q_{k,t} I_t \tag{9}$$

where $X_t = P_t/P_t^w$ denotes the markup of final over intermediate goods and $q_{k,t}$ is the shadow price of capital in terms of consumption goods. The left hand side of this budget constraint is the inflow of funds to the entrepreneur, which includes output ($Y_t$) and borrowed funds from the households ($b'_t$). The right hand side is the outflow of funds to the entrepreneur,

which consists of consumption ($c_t'$), real estate investment ($q_{h,t}(h_t' - h_{t-1}')$), debt repayment ($R_{t-1}b_{t-1}'/\pi_t$), wage payment ($w_t n_t$) and capital investment ($q_{k,t}I_t$). Entrepreneurs use a Cobb–Douglas constant returns to scale technology that combines capital ($k_{t-1}$), real estate ($h_{t-1}'$) and labor ($n_t$).

$$Y_t = A_t k_{t-1}^{\mu_k} h_{t-1}^{'\mu_h} n_t^{1-\mu_k-\mu_h}. \tag{10}$$

The aggregate technology shock $A_t$ follows the AR(1) process

$$\ln A_t = (1-\rho_A)\ln A + \rho_A \ln A_{t-1} + e_t^A \tag{11}$$

where $e_t^A$ is i.i.d. $N\left(0, \sigma_A^2\right)$. To produce intermediate goods, we assume that entrepreneurs need to accumulate capital. The law of motion for capital is given by

$$k_t = (1-\delta)\, k_{t-1} + \phi_t \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{12}$$

where $\delta$ is the depreciation rate. The function $S(\frac{I_t}{I_{t-1}})$ represents the adjustment costs in investment. We set $S\left(\frac{I_t}{I_{t-1}}\right) = \frac{1}{2}\psi\left(\frac{I_t}{I_{t-1}} - 1\right)^2$, which satisfies the conditions that in steady state $S = S' = 0$ and $S'' = \psi > 0$. The term $\phi_t$ represents shocks to the marginal productivity of investment and follows the AR(1) process

$$\ln \phi_t = \left(1-\rho_\phi\right)\ln\phi + \rho_\phi \ln \phi_{t-1} + e_t^\phi \tag{13}$$

where $e_t^\phi$ is i.i.d. $N(0, \sigma_\phi^2)$. When entrepreneurs borrow from households, we assume that they face a borrowing constraint. Following Miao and Peng [22], we impose the borrowing constraint as

$$b_t' \le \gamma E_t \left(q_{h,t+1} h_t' \pi_{t+1}/R_t + q_{k,t}k_{t-1}\right) \tag{14}$$

where $\gamma$ is the loan-to-value ratio. The entrepreneur's problem is choosing the amount of labor, capital stock, capital investment, real estate investment, the amount of borrowing and consumption to maximize the objective function (8) subject to the technology constraint (10), the budget constraint (9), the borrowing constraint (14), and the capital stock accumulation equation (12). Define $\lambda_{1,t}$, $\lambda_{2,t}$ and $\lambda_{3,t}$ as the Lagrangian multipliers associated with the budget constraint, the borrowing constraint and the capital stock accumulation equation, respectively. Finally, we derive the first order conditions.

$$\partial h_t' : \frac{q_{h,t}}{c_t'} = \frac{\beta'}{c_{t+1}'}\left(q_{h,t} + \frac{\mu_h Y_{t+1}}{X_{t+1}h_t'}\right) + \frac{\lambda_{2,t}\gamma q_{h,t+1}\pi_{t+1}}{R_t} \tag{15}$$

$$\partial b_t' : \frac{1}{c_t'} = \lambda_{2,t} + \frac{\beta' R_t}{c_{t+1}'\pi_{t+1}} \tag{16}$$

$$\partial k_t : \frac{q_{k,t}}{c_t'} = \frac{\beta'\mu_k Y_{t+1}}{c_{t+1}' X_{t+1} k_t} + \lambda_{2,t+1}\gamma q_{k,t+1} + \frac{q_{k,t+1}}{c_{t+1}'}(1-\delta) \tag{17}$$

$$\partial n_t : w_t = \frac{(1-\mu_k-\mu_h)\, Y_t}{X_t n_t} \tag{18}$$

$$\partial I_t : \frac{q_{k,t}}{c_t'} = \frac{q_{k,t}}{c_t'}\phi_t\left(1 - \frac{1}{2}\psi\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) - \frac{q_{k,t}}{c_t'}\phi_t\psi\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right) + \frac{\beta' q_{k,t+1}}{c_{t+1}'}\phi_{t+1}\left(\frac{I_t}{I_{t-1}}\right)^2\left(\frac{I_t}{I_{t-1}} - 1\right) \tag{19}$$

where $q_{k,t} = \frac{\lambda_{3,t}}{\lambda_{1,t}}$ implying $\lambda_{3,t} = \frac{q_{k,t}}{c_t'}$.

### 2.3. Retailers

A continuum of retailers of unit 1, indexed by $j$, buy intermediate goods $Y_t$ from entrepreneurs at the price $P_t^w$ in a competitive market, differentiate the goods at no cost into $Y_t(j)$, and sell them at a markup $X_t = P_t/P_t^w$ over the marginal cost. Final goods are composites of the differentiated goods according to the CES function. Consumers minimize the cost of the bundle of differentiated goods for a given level of composite consumption. Then the demand for good $j$ is described as $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\frac{1+\theta}{\theta}} Y_t^f$. Each period, a fraction $1-\omega$ of retailers set prices optimally, while a fraction $\omega$ cannot do so, and index prices to the previous period inflation rate with an elasticity equal to $\delta_p$. As in Smets and Wouters [23], we can augment the Calvo model by assuming that retailers who cannot reset prices optimally adjust their prices according to an indexation

rule $P_{t+k}(j) = \left(\frac{P_{t+k-1}}{P_{t-1}}\right)^{\delta_p} P_t(j)$. The retailers that can adjust their prices at time $t$ re-optimize price $P_t^*(j)$ to maximize the expected discounted value of their real profits. The optimal price then reads

$$E_t \sum_{k=0}^{\infty} \omega^k \Lambda_{t+k} Y_{t+k}(j) \left[ \frac{P_t^*(j)}{P_{t+k}} \left( \frac{P_{t+k-1}}{P_{t-1}} \right)^{\delta_p} - (1+\theta) \frac{1}{X_{t+k}} \right] = 0 \tag{20}$$

where $\Lambda_{t+k} = \beta^k (c_t / c_{t+k})$ is the stochastic discount factor, and $X_t = P_t / P_t^w$. One can drop the index $j$ in $P_t^*(j)$ as the optimal price is the same for each retailer $j$. The aggregate price index is an average of the price charged by the fraction $(1-\omega)$ of retailers resetting their prices optimally in period $t$ and the average of the remaining fraction $\omega$ of all retailers that do not adjust their prices optimally in period $t$. Thus, we know that the aggregate price at $t$ is

$$P_t = \left[ (1-\omega) \left(P_t^*\right)^{1-\theta} + \omega \left(P_{t-1} V_{t-1}\right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{21}$$

where $V_{t-1} = (\frac{P_{t-1}}{P_{t-2}})^{\delta_p}$. Log-linearizing Eqs. (20) and (21), and dropping $P_t^*$, we can derive the following Phillips curve:

$$\hat{\pi}_t = \frac{\beta}{1+\beta\delta_p} E_t \hat{\pi}_{t+1} + \frac{\delta_p}{1+\beta\delta_p} \hat{\pi}_{t-1} + \frac{(1-\omega)(1-\omega\beta)}{\omega\left(1+\beta\delta_p\right)} \left(-\hat{X}_t\right). \tag{22}$$

### 2.4. Monetary policy

The demand for real money is defined by Eq. (5). As showed in Burdekin and Siklos [20], the monetary policy in China appears to be an augmented McCallum rule that takes into account the rate of money supply growth. We follow Zhang [21] to specify the rule as follows:

$$\hat{m}_t = \hat{m}_{t-1} - \hat{\pi}_t + v_t \tag{23}$$

$$v_t = \mu_v v_{t-1} - \mu_\pi E_t \hat{\pi}_{t+1} - \mu_Y \hat{Y}_t + \chi_{v,t} \tag{24}$$

where $v_t$ denotes the deviation of nominal money growth from its value in steady state. $Y_t$ represents the total output. $\chi_{v,t}$ is assumed to be an AR(1) process

$$\chi_{v,t} = \rho_v \chi_{v,t-1} + e_t^v, \quad 0 < \rho_v < 1.$$

In this paper, we explore to what extend modifications of the money supply rule can be more beneficial in terms of stabilizing economic fluctuations. To this end, assuming that the People's Bank should set nominal money growth in response to real house prices, we therefore suggest the following real house price-augmented money supply rule:

$$v_t = \mu_v v_{t-1} - \mu_\pi E_t \hat{\pi}_{t+1} - \mu_Y \hat{Y}_t - \mu_q \hat{q}_t + \chi_{v,t}. \tag{25}$$

### 2.5. Equilibrium

In order to clear the two markets, the conditions must be satisfied as:

$$c_t + c_t' + q_{k,t} I_t = Y_t. \tag{26}$$

In addition, the loan market clears ($b_t = b_t'$), the housing market clears ($h_t + h_t' = 1$) and the relevant transversality conditions.

## 3. Parameters estimation

Following the work of Iacoviello [19], we parameterize the model by calibration and Bayesian estimation using data during the period 2001Q1: 2012Q4 to quantitatively analyze the model. The estimated parameters are divided into two groups: calibrated parameters and parameters estimated by Bayesian approach. The calibrated parameters are depreciation rate ($\delta$), capital and housing shares in the production functions ($\mu_k$ and $\mu_h$), the household's preference parameters ($j$ and $\eta$), the mark-up ($X$) and loan-to-value ratio ($\gamma$) in the steady state, the degree of price rigidity ($\omega$), and the discount factors ($\beta$ and $\beta'$). With these parameters, we calculate the consumptions, investment, capital, loan, real estate stocks to output ratios in the steady state. Except for the calibrated parameters, other parameters are estimated using the real data in China by the Bayesian estimation approach.

**Table 1**
Calibrated parameters.

| Parameter | Value | Description |
|---|---|---|
| $\beta$ | 0.99 | Household's discount factor |
| $\beta'$ | 0.97 | Entrepreneur's discount factor |
| $\mu_k$ | 0.46 | Capital share in production function |
| $\mu_h$ | 0.04 | Entrepreneurial housing share in production function |
| $\gamma$ | 0.85 | Loan to value ratio |
| $\delta$ | 0.025 | Depreciation rate |
| $\omega$ | 0.67 | Degree of price rigidity |
| $4R-1$ | 5.87% | Annual lending rate |
| $X$ | 1.15 | Steady state markup |
| $j$ | 0.06 | Housing's weight in the utility function |
| $m/(4\times Y)$ | 1.55 | Real money balance/output |

### 3.1. Calibration

In the steady state $R\beta = 1$. During the period of our study, the average annual lending rate is 5.87%, which implies a quarterly rate of 1.015%. This gives us $\beta = 0.99$. Following Iacoviello [19], we fix the discount factor of the entrepreneurs $\beta'$ at 0.97, which implies three times as big as the equilibrium interest rate. We fix $X = 1.15$, implying a steady-state markup of 15%. As in Chen and Gong [24], we set $\omega$ at 0.67, implying that in each period, about two thirds of entrepreneurs do not adjust their prices. The depreciation rate $\delta$ is set equal to 0.025 meaning an annual depreciation rate of 10%. To be aligned with the literature on Chinese economy [22,25,26], we set $\mu_k = 0.46$ and $\mu_h = 0.04$. The weight on housing in the utility function is set at 0.06, as in Iacoviello [19]. Following Iacoviello and Neri [2], we set the loan to value ratio $\gamma = 0.85$. The steady state ratio of real money balances to output is 6.2 over the range of our data set. Other ratio parameters can be obtained by solving the model in steady state. The calibrated parameters are summarized in Table 1.

### 3.2. Bayesian estimation

The parameters that characterize the shock processes, the structural parameters ($\eta$, $\psi$, and $\delta_p$) and the parameters to describe behaviors of monetary policy ($\mu_v$, $\mu_\pi$, and $\mu_Y$) are estimated by the Bayesian method. We impose prior distributions on the parameters so that the prior distributions can cover reasonable values taken by the parameters. The prior distributions are chosen according to the existing literature. The prior distribution of $\psi$ is gamma with mean 4 and standard deviation 0.1 [27]. The prior distributions of $\delta_p$ and $\eta$ are $N(0.5, 0.1)$ and $N(1.6, 0.1)$, respectively [23]. We set the prior distributions and initial values of the parameters that determine the monetary policy according to Zhang [21]. The prior distributions for the shock processes are given as commonly applied in the literature.

We use five time series as observable variables: the demeaned inflation rate, and the demeaned log forms of real GDP, real broad money supply, real housing price and real investment. All the data are seasonally adjusted. We use the HP filter to get the variables' percentage deviations from steady state and log-linearize the equilibrium conditions, to match the transformed data and the model's variables.

Table 2 reports the key statistics of prior and posterior distributions. The posterior distributions of structural parameters are close to the priors. The parameters that determine the monetary policy dynamics are similar to those in Zhang [21]. Money and housing demand shocks are very persistent, while the persistency of investment shocks is moderate. Compared to other shocks, money demand shocks contain the most volatile disturbances.

## 4. Results

In this section, we use the estimated DSGE model, trying to address two questions. One, what is the main driving force of fluctuations in the housing market for China? Two, can a real house price-augmented money supply rule help to stabilize economic fluctuations? We investigate the first question by reporting the relative importance of different shocks according to the results of impulse response analysis and variance decomposition. Policy simulations are carried out to answer the second question.

### 4.1. Source of housing price fluctuations in China

Fig. 1 displays the impulse responses of housing price to different shocks. Positive housing demand and money supply shocks lead to increments in housing prices, which are easy to understand. In response to the money demand or investment shock, the housing price decreases rapidly in the first few periods and then returns to its steady state (slowly for housing demand shock and quickly for investment shock). A negative response of housing price to a positive money demand shock occurs because housing and real money balances are substituted in the utility. The housing price responses negatively to a positive investment shock results from that the investment shock causes rising in housing stock and then reduces the

**Table 2**
Prior distributions and posterior estimates.

| Parameters | Prior mean | Posterior mean | Confidence interval | | Prior distribution | Standard deviation |
|---|---|---|---|---|---|---|
| $\rho_j$ | 0.8000 | 0.9978 | 0.9960 | 0.9994 | beta | 0.1000 |
| $\rho_\chi$ | 0.8000 | 0.9173 | 0.8624 | 0.9825 | beta | 0.1000 |
| $\rho_A$ | 0.8000 | 0.6614 | 0.5910 | 0.7287 | beta | 0.1000 |
| $\rho_\phi$ | 0.8000 | 0.2588 | 0.1643 | 0.3371 | beta | 0.1000 |
| $\rho_v$ | 0.8000 | 0.4972 | 0.3789 | 0.6189 | beta | 0.1000 |
| $\eta$ | 0.6000 | 0.6510 | 0.5312 | 0.7789 | normal | 0.1000 |
| $\psi$ | 4.0000 | 3.9854 | 3.8248 | 4.1212 | normal | 0.1000 |
| $\delta_p$ | 0.5000 | 0.5742 | 0.4619 | 0.7183 | normal | 0.1000 |
| $\mu_v$ | 0.8000 | 0.8852 | 0.7861 | 0.9793 | gamma | 0.1000 |
| $\mu_\pi$ | 1.0000 | 0.8601 | 0.7439 | 1.0039 | gamma | 0.1000 |
| $\mu_Y$ | 0.5000 | 0.7037 | 0.5554 | 0.8543 | gamma | 0.1000 |
| $\sigma_m$ | 0.3000 | 0.0488 | 0.0392 | 0.0610 | inverse gamma | infinite |
| $\sigma_j$ | 0.3000 | 0.2764 | 0.2172 | 0.3400 | inverse gamma | infinite |
| $\sigma_\chi$ | 0.3000 | 1.2246 | 0.6957 | 1.6067 | inverse gamma | infinite |
| $\sigma_A$ | 0.3000 | 0.0791 | 0.0653 | 0.0898 | inverse gamma | infinite |
| $\sigma_\phi$ | 0.3000 | 0.5403 | 0.4392 | 0.6393 | inverse gamma | infinite |

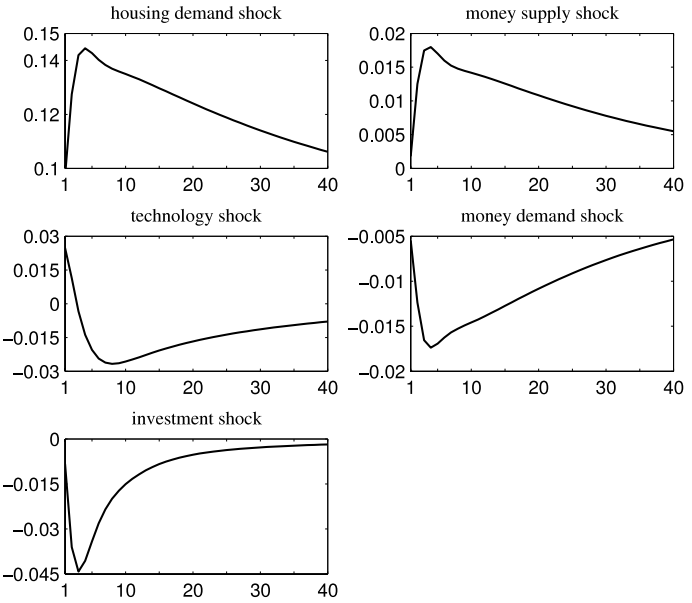


**Fig. 1.** Impulse responses of housing price to different shocks.

housing price. A positive technology shock increases the housing price in the first period and then subsequently decreases below its trend and finally returns to its steady state slowly. The housing price suddenly rises because of the direct effect of the technology shock through increasing household's profits from firms. But then the technology shock decreases the marginal product of factor inputs and thus the demand for factor inputs, and after that reduces the labor income of household, and finally decreases the housing price. The different speed of shocked housing prices return to the steady state corresponds with the estimated persistency of the shocks as in Table 2. In levels, housing demand shock causes the biggest volatility of housing price compared with other shocks.

To quantitatively assess the relative importance of the shocks in explaining the fluctuations of housing price, we conduct the variance decomposition. Table 3 shows the variance decomposition results, which gives out the contribution of each shock to the variance of housing price at different horizons (one-quarter, one-year, three-years, five-years and ten-years). In every horizon, housing price fluctuations are mainly driven by housing demand shocks, with a contribution above 90% (highest 95%). This result indicates that demand shocks have immediate impact on the housing price in China, which is also supported by other works [14,15]. With the results from Table 2, high persistency of housing demand shocks may be the reason for the huge contribution of housing demand shocks. In our opinion, highly persistent shocks to housing demand can be explained by unmodeled demand factors that have been considered in the empirical literature as important determinants of China's house prices [13–15]. Compared with housing demand shock, the money supply shock contributes much less to the housing price fluctuations. However, some studies suggest that money supply growth is the main driving force of housing price in China [16–18]. A reasonable explanation for this result is that shock to housing demand is not considered and compared with the money supply growth shock in one framework in these works. As we know, it is hard to represent

**Table 3**
Variance decomposition of aggregate variables (in %).

| | Shocks | | | | |
|---|---|---|---|---|---|
| | Housing demand | Money supply | Investment | Technology | Money demand |
| Period 1 | | | | | |
| Output | 0.21 | 30.21 | 11.82 | 6.36 | 51.40 |
| Inflation | 49.53 | 2.55 | 34.47 | 6.67 | 6.79 |
| Housing price | 92.91 | 0.03 | 0.68 | 6.08 | 0.30 |
| Investment | 0.03 | 0.23 | 99.02 | 0.52 | 0.20 |
| Capital | 26.39 | 7.50 | 29.35 | 28.59 | 8.16 |
| Period 4 | | | | | |
| Output | 18.72 | 21.23 | 10.64 | 28.26 | 21.16 |
| Inflation | 38.01 | 4.67 | 26.52 | 14.78 | 16.01 |
| Housing price | 89.93 | 1.06 | 6.71 | 1.28 | 1.02 |
| Investment | 0.39 | 0.11 | 93.16 | 6.29 | 0.05 |
| Capital | 30.41 | 8.79 | 19.10 | 32.18 | 9.52 |
| Period 12 | | | | | |
| Output | 20.93 | 24.36 | 6.35 | 25.81 | 22.56 |
| Inflation | 33.13 | 5.15 | 23.97 | 16.30 | 21.44 |
| Housing price | 91.63 | 1.09 | 3.68 | 2.49 | 1.11 |
| Investment | 5.04 | 0.12 | 81.92 | 12.67 | 0.25 |
| Capital | 33.47 | 10.34 | 12.28 | 32.94 | 10.96 |
| Period 20 | | | | | |
| Output | 16.87 | 24.43 | 5.39 | 30.76 | 22.55 |
| Inflation | 31.13 | 6.22 | 22.35 | 17.40 | 22.91 |
| Housing price | 93.12 | 1.00 | 2.46 | 2.41 | 1.02 |
| Investment | 11.54 | 0.29 | 74.56 | 13.07 | 0.54 |
| Capital | 33.7 | 11.23 | 10.31 | 33.06 | 11.71 |
| Period 40 | | | | | |
| Output | 18.13 | 23.24 | 4.61 | 32.56 | 21.45 |
| Inflation | 33.34 | 6.98 | 19.54 | 18.21 | 21.93 |
| Housing price | 95.13 | 0.78 | 1.47 | 1.84 | 0.79 |
| Investment | 22.05 | 0.53 | 64.53 | 12.10 | 0.80 |
| Capital | 31.92 | 12.32 | 9.15 | 33.99 | 12.61 |

housing demand by an economic variable. However, by a Bayesian DSGE approach we are able to take into account the housing demand shock easily (a shock to household's preference on housing in utility) and estimate the model through real economic data to figure out the relative importance of each shock. In this paper, a significant effect of money supply growth on housing price is also found (see Fig. 1), but low persistency and volatility of money supply shocks lead to the minor role money supply played in explaining the housing price fluctuations when compared with housing demand shocks.

As for other macroeconomic variables, in the very short run (one-quarter horizon), output fluctuations are mainly driven by money demand shocks, money supply shocks and investment shocks. They explain 51.4%, 30.21% and 11.82% of output fluctuations, respectively. The Chinese people prefer to holding real money balances, so a shock to this preference can be used to stimulate the output in the short run. At the one-year horizon, the contribution of technology shocks to output fluctuations increases to 28.26%, while the contributions of money demand shocks and money supply shocks reduce to 21.16% and 21.23%, respectively. Over the medium to the long run, the contribution of technology shocks increases further, and up to the ten-years horizon, technology shocks become the major source explaining one third of output movements. The volatility of investment is mainly driven by investment shocks, which is a reasonable result. Investment shocks explain 93.16% of investment movements in the short run and 64.53% of investment fluctuations in the long run.

### *4.2. Implication for monetary policy*

In this subsection, we explore to what extent modifications of the money supply rule can be more beneficial in terms of stabilizing economic fluctuations. He et al. [28] reveal that using asset prices to formulate monetary policy would not help to improve monetary authorities' performance in lowering the volatilities of output growth and inflation, however, the asset prices therein are referring to stock prices. In fact, the Law of the People's Bank of China (PBC) states that the objective of China's monetary policy is to maintain price stability so as to promote economic growth, while the objective to maintain asset price stability is presently not included in the statement. A counter-factual scenario is thereby intriguing: will the PBC's performance be improved in stabilizing the economy, if the objective to maintain asset price stability (in our case, the real housing price) is considered?

Here, we propose that the central bank should set nominal money growth in response to real house prices and therefore suggest the real house price-augmented money supply rule as in Eq. (25). To explore the benefits of the augmented monetary policy relative to a standard money supply rule, we report how standard deviations of real output and inflation change when we alter the real house price coefficient $\mu_q$, while all other parameters are fixed at their baseline values. Additionally, we

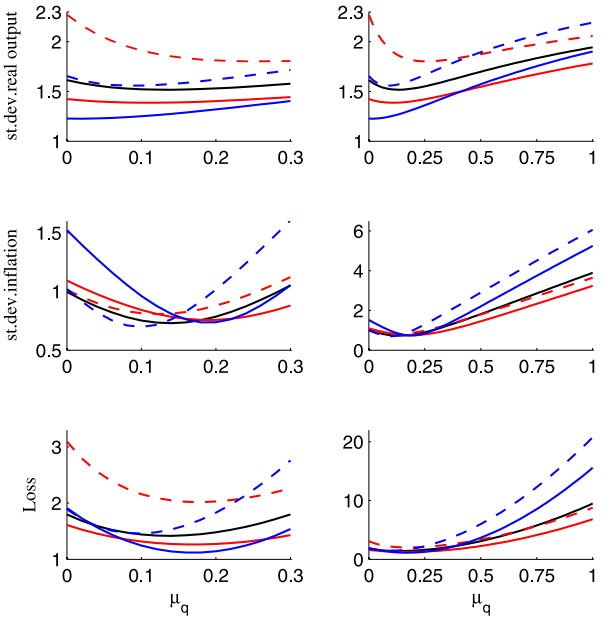


**Fig. 2.** The house price-augmented money supply rule under $\mu_q = [0 : 0.3]$ (left column) and $\mu_q = [0 : 1]$ (right column). The black solid lines refer to the baseline values for $\mu_Y$ and $\mu_\pi$. The blue solid lines denote $\{\mu_Y, \mu_\pi\} = \{1, 0.5\}$, and the blue dashed lines stand for $\{\mu_Y, \mu_\pi\} = \{0.5, 0.5\}$. For the red solid lines it means that $\{\mu_Y, \mu_\pi\} = \{1, 1\}$, and the red dashed lines present the combination $\{\mu_Y, \mu_\pi\} = \{0.5, 1\}$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

report the corresponding statistics for changing the output coefficient $\mu_Y$, or the inflation coefficient $\mu_\pi$, relative to their baseline values. We test the values $\mu_Y = \{0.5; 1\}$ for the output coefficient and the values $\mu_\pi = \{0.5; 1\}$ for the inflation coefficient. To give a more meaningful analysis in terms of monetary policy evaluation, we summarize the evidence by comparing the monetary policy rules against a prespecified objective function based on the assumption that the ultimate goal of monetary policy is to reduce real output and inflation variabilities. The objective function can be written as

$$Loss = \lambda\sigma^2\left(\hat{Y}_t\right) + (1-\lambda)\,\sigma^2\left(\hat{\pi}_t\right)$$

where the parameter $\lambda$ governs the policymakers' relative preferences. We choose to set $\lambda = 0.5$ such that policymakers attach an equal weight to minimizing output and inflation volatilities.

Fig. 2 summarizes the policy simulation results. Starting from the case $\mu_q = [0 : 0.3]$ (see the left column of Fig. 2), we observe declines in the volatilities of output and inflation when the real house price coefficient $\mu_q$ rises, however, the volatility of inflation increases as soon as $\mu_q$ reaches a critical threshold. The curves in terms of the central bank's loss show shapes of 'U', which are similar with those for the volatility of inflation. This result indicates that a proper response to real housing price might be a promising strategy to reduce the central bank's loss. To see these results in a bigger horizon, we expand the range of $\mu_q$ and plot the results in the right column of Fig. 2. The change in the volatility of output is moderate when $\mu_q$ rises, and we still can find the U curves. However, the loss and volatility of inflation increase rapidly in cases where $\mu_q$ exceeds 0.3. In conclusion, we find that by properly reacting to real house price the central bank is able to reduce the economic fluctuations, and the proper value of real house price coefficient is correlated with the values of $\mu_Y$ and $\mu_\pi$. It might be a good choice for the central bank to set the growth of money supply in response to real housing price movements, but not a promising strategy to over react (i.e., $\mu_q$ should be small).

## 5. Conclusions

In this paper, we identify the impacts of major sources of housing price fluctuations in China within one integrated Keynesian DSGE framework, and propose a policy implication for money supply rule implemented by the Chinese government to stabilize the economy. First, we find that housing demand shocks are the major driving forces of housing price fluctuations in China. Compared with housing demand shocks, shocks to growth of money supply contribute much less to housing price movements. In our opinion, high persistency of housing demand shocks accounts for the dominant role housing demand played in explaining the housing price fluctuations, while low persistency and volatility of money supply growth shocks cause its minor contribution to housing price volatility. Second, we suggest that it is a promising strategy to incorporate the real housing price into monetary policy making. Our policy simulations reveal that there is a U shape curve relationship between central bank's loss and the real housing price coefficient in small values. The central bank is able to improve its performance in lowering the economic fluctuations by properly responding to the real housing price fluctuations. We

thereby conclude that a combination of real housing price and money supply rule (i.e. the PBC should set growth of money supply moderately in response to real housing price movements) can improve the role of the central bank in stabilizing China's economy. Our findings and policy suggestion may have potential applications to both theoretical housing market researches and practical monetary policy making in China and possibly other emerging markets.

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**Appendix A. Data description**

| Variables | Period | Data source |
|---|---|---|
| Output | 2001Q1–2012Q4 | National Bureau of Statistics of China |
| CPI | 2001Q1–2012Q4 | National Bureau of Statistics of China |
| Investment | 2001Q1–2012Q4 | National Bureau of Statistics of China |
| Housing price | 2001Q1–2012Q4 | National Bureau of Statistics of China |
| M2 | 2001Q1–2012Q4 | National Bureau of Statistics of China |

Notes:
1. Investment refers to fixed capital investment.
2. Housing price refers to national average housing price. Quarterly data on housing price during the period of our work are not directly available. However, monthly data of the value of sales on housing and sale volume on housing can be directly obtained from National Bureau of Statistics of China. We add up the monthly data and calculate one quarter's housing price by dividing the value of housing sales by its sale volume in one quarter.
3. M2 means the broad money supply in China.

**Appendix B. Steady state**

Assuming $q_k = 1, A = 1$ and $\pi = 1$ (so that $\beta R = 1$), the steady state will be described by:

$$\frac{q_h}{c} = \frac{j}{h} + \frac{\beta q_h}{c} \tag{B.1}$$

$$\frac{\chi}{m} = \frac{1}{c} - \frac{\beta}{\pi c} \tag{B.2}$$

$$n^{\eta} = \frac{w}{c} \tag{B.3}$$

$$\beta R = 1 \tag{B.4}$$

$$c + b = wn + \frac{Rb}{\pi} + \frac{X-1}{X}Y \tag{B.5}$$

$$\frac{q_h}{c'} = \frac{\beta'}{c'}\left(q_h + \frac{\mu_h Y}{Xh'}\right) + \lambda_2 \frac{\gamma q_h \pi}{R} \tag{B.6}$$

$$\frac{1}{c'} = \lambda_2 + \frac{\beta' R}{c'\pi} \tag{B.7}$$

$$\frac{q_k}{c'} = \frac{\beta' \mu_k Y}{c' X k} + \lambda_2 \gamma q_k + \frac{\beta' q_k}{c'}(1-\delta) \tag{B.8}$$

$$w = \frac{(1-\mu_k-\mu_h)Y}{Xn} \tag{B.9}$$

$$\frac{q_k}{c'} = \frac{q_k}{c'}\phi \tag{B.10}$$

$$\frac{Y}{X} + b = c' + \frac{Rb'}{\pi} + wn + q_k I \tag{B.11}$$

$$b = \gamma \left( q_h h' \frac{\pi}{R} + q_k k \right) \tag{B.12}$$

$$Y = A k^{\mu_k} h'^{\mu_h} n^{1-\mu_k-\mu_h} \tag{B.13}$$

$$k = (1-\delta)k + \phi I \tag{B.14}$$

$$h + h' = 1 \tag{B.15}$$

$$c + c' + q_k I = Y. \tag{B.16}$$

By (B.10), we have $\phi = 1$. By (B.7), we obtain $\lambda_2 = \frac{1}{c'}(1 - \frac{\beta' R}{\pi})$, and with (B.8), we then have

$$\frac{k}{Y} = \frac{\beta' \mu_k}{X\left[1 - \left(1 - \frac{\beta' R}{\pi}\right)\gamma\beta' - \beta'(1-\delta)\right]}.$$

With (B.14), we obtain

$$\frac{I}{Y} = \delta \frac{k}{Y}.$$

By (B.9), then

$$\frac{wn}{Y} = \frac{1-\mu_k-\mu_h}{X}.$$

Rewriting (B.6), we have

$$\frac{q_h h'}{Y} = \frac{\beta' \mu_h}{\left(1 - \beta' - \frac{\gamma\pi}{R} + \beta'\gamma\right) X}.$$

The ratios of other variables to output in steady state are determined by the above equations.

$$\text{(B.12)} \Rightarrow \frac{b}{Y} = \frac{\gamma\pi}{R}\frac{q_h h'}{Y} + \gamma\frac{k}{Y}$$

$$\text{(B.11)} \Rightarrow \frac{c'}{Y} = \frac{1}{X} + \frac{b}{Y} - \frac{R}{\pi}\frac{b}{Y} - \frac{wn}{Y} - \delta\frac{k}{Y}$$

$$\text{(B.5)} \Rightarrow \frac{c}{Y} = (R-1)\frac{b}{Y} + \frac{wn}{Y} + \frac{X-1}{X}$$

$$\text{(B.1)} \Rightarrow \frac{q_h h}{Y} = \frac{j}{(1-\beta)}\frac{c}{Y}.$$

The rest of the steady state can be easily solved.

## References


[1] B.S. Bernanke, Housing, mortgage markets, and foreclosures, in: The Federal Reserve System Conference on Housing and Mortgage Markets, Washington, D.C, 2008.
[2] M. Iacoviello, S. Neri, Housing market spillovers: evidence from an estimated DSGE model, Am. Econ. J. Macroecon. 2 (2) (2010) 125–164. http://dx.doi.org/10.1257/mac.2.2.125.
[3] C. Leung, Macroeconomics and housing: a review of the literature, J. Hous. Econ. 13 (4) (2004) 249–267. http://dx.doi.org/10.1016/j.jhe.2004.09.002.
[4] J.B. Taylor, Housing and monetary policy, working paper 13682, NBER, w13682, December 2007. http://dx.doi.org/10.3386/w13682.
[5] J. Clayton, Rational expectations, market fundamentals and housing price volatility, Real Estate Econ. 24 (1996) 441–470. http://dx.doi.org/10.1111/1540-6229.00699.
[6] F. Ortalo-Magné, S. Rady, Boom in, bust out: Young households and the housing price cycle, Eur. Econ. Rev. 43 (4–6) (1999) 755–766. http://dx.doi.org/10.1016/S0014-2921(98)00091-9.
[7] D.R. Capozza, P.H. Hendershott, C. Mack, C.J. Mayer, Determinants of real house price dynamics, working paper 9262, NBER, w9262, October 2002. http://dx.doi.org/10.3386/w9262.
[8] F. Ortalo-Magné, S. Rady, Housing market dynamics: on the contribution of income shocks and credit constraints, Rev. Econom. Stud. 73 (2) (2006) 459–485.
[9] N.G. Mankiw, D.N. Weil, The baby boom, the baby bust, and the housing market, Reg. Sci. Urban. Econ. 19 (2) (1989) 235–258. http://dx.doi.org/10.1016/0166-0462(89)90005-7.
[10] W. Alonso, The historic and the structural theories of urban form: their implications for urban renewal, Land Econ. 40 (2) (1964) 227–231.
[11] R.F. Muth, Cities and Housing, University of Chicago Press, Chicago, 1969.
[12] A. Beltratti, C. Morana, International house prices and macroeconomic fluctuations, J. Bank. Financ. 34 (3) (2010) 533–545. http://dx.doi.org/10.1016/j.jbankfin.2009.08.020.
[13] A. Ahuja, L. Cheung, G. Han, N. Porter, W. Zhang, Are house prices rising too fast in China? Working paper, International Monetary Fund, 10/274, 2010.
[14] S.-J. Wei, X. Zhang, Y. Liu, Status competition and housing prices, working paper 18000, NBER, w18000, April 2012. http://dx.doi.org/10.3386/w18000.
[15] J. Chen, F. Guo, Y. Wu, One decade of urban housing reform in China: urban housing price dynamics and the role of migration and urbanization, 1995-2005, Habitat Int. 35 (1) (2011) 1–8. http://dx.doi.org/10.1016/j.habitatint.2010.02.003.
[16] Y. Zhang, X. Hua, L. Zhao, Exploring determinants of housing prices: a case study of Chinese experience in 1999–2010, Econ. Model. 29 (6) (2012) 2349–2361. http://dx.doi.org/10.1016/j.econmod.2012.06.025.

[17] X.E. Xu, T. Chen, The effect of monetary policy on real estate price growth in China, Pac.-Basin Financ. J. 20 (1) (2012) 62–77. http://dx.doi.org/10.1016/j.pacfin.2011.08.001.
[18] C. Zhang, Money, housing, and inflation in China, J. Policy Model. 35 (1) (2013) 75–87. http://dx.doi.org/10.1016/j.jpolmod.2012.04.006.
[19] M. Iacoviello, House prices, borrowing constraints, and monetary policy in the business cycle, Am. Econ. Rev. 95 (2005) 739–764. http://dx.doi.org/10.1257/0002828054201477.
[20] R.C. Burdekin, P.L. Siklos, What has driven Chinese monetary policy since 1990? investigating the People's bank's policy rule, J. Int. Money Financ. 27 (5) (2008) 847–859. http://dx.doi.org/10.1016/j.jimonfin.2008.04.006.
[21] W. Zhang, China's monetary policy: quantity versus price rules, J. Macroecon. 31 (3) (2009) 473–484. http://dx.doi.org/10.1016/j.jmacro.2008.09.003.
[22] J. Miao, T. Peng, Business cycles and macroeconomic policies in China: evidence from an estimated DSGE model, South Western University of Finance and Economics Discussion Paper, 2011.
[23] F. Smets, R. Wouters, Comparing shocks and frictions in US and euro area business cycles: a bayesian DSGE approach, J. Appl. Econometrics 20 (2) (2005) 161–183. http://dx.doi.org/10.1002/jae.834.
[24] Q. Chen, L. Gong, Sticky prices models and the simulation with Chinese data, J. Quant. Tech. Econ. (8) (2006) 106–117. (in Chinese).
[25] Y. Hu, F. Liu, Labor adjustment cost, liquidity constraints and Chinas economic fluctuations, Econ. Res. J. (10) (2007) 32–43. (in Chinese).
[26] W. Xu, B. Chen, Bank lending and economic fluctuations in China: 1993–2005, China Econ. Q. (3) (2009) 969–994. (in Chinese).
[27] A. Justiniano, G.E. Primiceri, A. Tambalotti, Investment shocks and business cycles, J. Monet. Econ. 57 (2) (2010) 132–145. http://dx.doi.org/10.1016/j.jmoneco.2009.12.008.
[28] P. He, G. Nie, G. Wang, X. Zhang, Optimal monetary policy in China, China World Econ. 19 (1) (2011) 83–105. http://dx.doi.org/10.1111/j.1749-124X.2011.01228.x.