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Real estate price and heterogeneous investment behavior in China

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ABSTRACT

We study the dynamic link between real estate prices and firms' investment behaviors in China using a new Keynesian dynamic stochastic general equilibrium model. The model features heterogeneous production sectors in which private firms face discriminatory borrowing constraints while state-owned firms are not. Fitted to China's quarterly data from 2005Q3 to 2014Q4, the quantitative general equilibrium model enables us to identify the driving forces behind and the macroeconomic variables interacting with land price. It confirms the existence of the "collateral channel" in the private sector without bearing the potential endogeneity problems in empirical studies. More importantly, we identify a "crowding out" channel between private and state-owned firms caused by discriminatory financial constraints. The "crowding out" channel implies a negative relationship between real estate prices and the investment of state-owned firms, which has been documented in empirical research but short of explanation so far.

1. Introduction

The remarkable long-lasting boom and the recent upheaval in housing and land markets in China has generated extensive interest in the relationship between real estate prices and firms' financing capacities. The so called "collateral channel", a practice of pledging collateral such as owned real estate can allow firms to borrow more and invest more under contract incompleteness (Barro, 1976; Stiglitz and Weiss, 1981; Hart and Moore, 1994; Fazzari et al., 2000), and can amplify the business cycle (Kiyotaki and Moore, 1997; Bernanke and Gertler, 1989). Empirical evidences on the United States and Japan (Chaney et al., 2012; Liu et al., 2013; Cvijanovi, 2014; Gan, 2007a,b) suggest the collateral channel leads to a positive correlation between real estate prices and firms' investment. For instance, Chaney et al. (2012) find U.S. firms raises their investment by six cents for every dollar increase in real estate collateral value.

However, the story may be different when it comes to China. A distinctive feature in China's economy is the heterogeneity in borrowing constraints between private firms and state-owned firms. Before starting the reform and opening up in 1979, China was in a highly centralized planned economic system. All the funds were allocated by the Central Planning Commission, a branch of the central government, and private firms were strictly restricted if not forbidden at all. After 1979, restrictions on private firms have been gradually relaxed. There have been massive entries of private firms and privatization of state-owned firms since then. By the end of 2015, private firms account for 64% of total fixed-asset investment and 60% of GDP, and contribute 80% of employment. However, private firms are still financially discriminated by state-owned banks. Pye and Lardy (2002) and Allen et al. (2005) argue that reforms in the financial markets have been much slower than those in the goods market and the labor market. Lin and Tan (1999) and Bai et al. (2006b) document that state-owned firms inherit some types of policy burdens from the previous planned economic system which can be used as a leverage to bargain with the government and state-owned banks for policy favors, among them the easy access of bank loans. Evidence provided by Brandt and Li (2003) shows that private firms have less access to bank loans on which more collateral is required compared to state-owned but their explanation is that state-owned banks have developed good channels for obtaining credit information about state-owned firms through their long business relationship. Cull and Xu (2005) find that State-owned firms continue to receive a disproportionately large share of the credit extended by the state-owned banks. Cull et al. (2015)'s empirical results suggest that state-owned firms have tight government connections and hence face substantially less severe financial constraints. Hale and Long (2010) also show that state-owned firms continue to enjoy significantly more generous external financing capabilities than other types of Chinese firms, and that private firms face more financial constraints. Poncet et al. (2010) employ a Chinese firm-level data with more than 20,000 firms to test whether firms face different credit constraints depending

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on their capital ownership. They find that private firms are credit constrained while state-owned firms are not. The severe financial impediments faced by private firms have drawn attention not only from academic, but also the Chinese leadership. For example, the current Premier of China, Keqiang Li, has reiterated this problem on many occasions, promising to "making efforts to ease financing difficulties for private firms" multiple times.[1] However, the discrimination persists and will exist in the foreseeable future due to China's special situation and historical burden. Therefore, different from the developed countries such as the United States and Japan, there are significant heterogeneous financing conditions between state-owned and private firms in China.

Given this distinctive situation, it is natural to inquiry whether the "collateral channel" exists and how it functions in China. Using an annual dataset of hundreds of listed firms from 2003 to 2011, Wu et al. (2015) find a statistically insignificant relationship between the real estate price and firms' borrowing and investment, implying no evidence of a collateral effect for the firms included in their data, whether firms are private or not. However, it is argued that since most of China's listed firms are either large corporations or state-owned, their financing activities rely less on collaterals. Chen et al. (2015) employ a much larger sample on an annual basis over the period of 1999–2007, mainly composed of non-listed firms without an equity financing channel and using bank loans as a proxy for firms' financial capacity. They find positive correlation between real estate price and bank loans obtained by private firms, and hence confirm the existence of collateral channel for the private sector. However, their baseline estimation also indicates negative correlation between real estate price and bank loans obtained by state-owned firms, which cannot be explained by the collateral channel and remains unanswered up to this point.

To explain these salient features of the micro data in China, we build a dynamic stochastic general equilibrium (DSGE) model to analyze the interplay between real estate prices and private/state-owned firms' investment. In our model, land is considered as a production input, so real estate price goes side by side with wage and capital price as the marginal cost for production. Our model assumes that private firms in China are suffering from borrowing constraints while state-owned firms are not. As pointed out by aforementioned literature, this is distinctive to China's financial and economic structure. The model also incorporates price stickiness to analyze the effect of monetary policy shocks on the real estate price and firms' investment behavior. In this respect, it is an improvement over Liu et al. (2013)'s real business cycle model with financial friction, which ignores the heterogeneity of production sectors and the effect of monetary factors on real macroeconomic variables.

It is worth noting that existing empirical methods have endogeneity problems in the sense that the dependent variable "investment" may impact the price and ownership decision of the real estate, which are key determinant factors of the independent variable "real estate value". Although instruments and separation strategy can be applied to deal with these endogeneity, it is difficult to find firm-level instruments that predict real estate ownership (Chaney et al., 2012). On the other hand, the dynamic stochastic general equilibrium framework can avoid this problem since it describes the behavior of the economy as a whole by analyzing the interaction of many microeconomic decisions in a dynamic setting. Therefore, this paper reveals new insights in the "collateral channel" literature through a quantitative general equilibrium model.

The results of our model feature a positive correlation between real estate price and the investment level of private firms, as well as a negative correlation between real estate price and the investment level of state-owned firms. By fitting our model to China's quarterly data from 2005Q3 to 2014Q4 using Bayesian techniques, we confirm the existence of collateral effect for private firms, in a way without endogeneity problems as mentioned above. What's more, we identify a "crowding out" channel through which the real estate price can exert an impact on the investment behavior of the state-owned firms. The concept "crowding out" originally arises from research of fiscal policy effectiveness, describing that a rise in public spending drives down or even eliminates private investment by increasing real interest rate.[2] There are other studies about the "crowding out" effect of FDI on investment (Moosa, 2002), foreign reserves accumulation on investment (Reinhart et al., 2016), government debt on investment (Traum and Yang, 2015), financial sector growth on real economic growth (Cecchetti and Kharroubi, 2015) and so on.

In this paper, we use this term to summarize our finding that an increase in land price alleviates private firms' financial constraint, leads to high demand of capital good for private firms, and thus raises the price of capital, so in consequence "crowd out" the investment of state-owned firms. This "crowding out" channel causes a negative relationship between the land price and state-owned firms' investment. So it provides a theoretical explanation to Chen et al. (2015)'s empirical conclusion. To the best of our knowledge, this is the first work that identify such "crowding out" channel for state-owned firms in China which fits into empirical findings.

Two "crowding out" channels for bank lending behavior related to our research has been found in Chakraborty et al. (2016) for the United States and Poncet et al. (2010) for China. Alongside confirming Chaney et al. (2012)'s results, Chakraborty et al. (2016)'s empirical study document a negative relationship between housing price and the depending firm's investment levels. In their story, financially constrained U.S. banks which are active in strong housing markets increase mortgage lending and hence "crowds out" commercial lending, leading to a reduction of the depending firm's investment. Poncet et al. (2010) find that stronger presence of state-owned firms makes it more difficult for private firms to access capital, suggesting that the external financing capability of private firms is crowded out by the state-owned firms. In stead of emphasizing the "crowding out" channel for bank lending, our paper focuses on the heterogeneous effect of financial constraint on the manufacturer sector in China, underlining that a relief of the private firms' financing constraint due to the appreciation of real estate price leads to an increase of their investment and crowds out the investment of state-owned firms. To this respect, our results adds new insight to the research concerning the crowding out effects.

The rest of the paper is organized as follows. Section 2 introduces the settings and the model. Section 3 presents the calibration and economic implication. Conclusion remarks are provided in Section 4. The appendix includes the details of the log-linearized equations, tables and figures containing the results of the calibration, variance decompositions and simulations.

2. The model

2.1. Households

A representative household derives utility from consumption $C_{H,t}$, land services $L_{H,t}$ and disutility in labor supply N_t, and aims to maximize his expected long-term utility:

$$E_t \sum_{j=0}^{\infty} \beta_H^j U(C_{H,t+j}, L_{H,t+j}, N_{t+j}) \tag{1}$$

where β_H is the discount factor for the household and $U(C_{H,t}, L_{H,t}, N_t)$ takes the form of:

[1] For example, see http://english.gov.cn/premier/news/2016/06/22/content_281475377697645.htm.

[2] See Sen and Kaya (2014) for a detailed literature review.

$$U(C_{H,t}, L_{H,t}, N_t) = \ln(C_{H,t}) + \chi_{L,t}\ln(L_{H,t}) - \frac{\chi_{N,t}}{1+\eta}N_t^{1+\eta} \quad (2)$$

where η is the inverse Frisch elasticity of labor supply, $\chi_{L,t}$ represents the land service preference relative to consumption and $\chi_{N,t}$ represents the work preference. Similar to Liu et al. (2013), we label the shock to $\chi_{L,t}$ as "housing demand shock" and the shock to $\chi_{N,t}$ as "labor supply shock". Final goods are defined over a continuum of retailers ω's production:

$$C_{H,t} = \left[\int_0^1 c_t(\omega)^{\frac{\rho-1}{\rho}}d\omega\right]^{\frac{\rho}{\rho-1}} \quad (3)$$

here $\rho > 1$ represents the elasticity of substitution. The consumption-based index P_t can be defined as:

$$P_t = \left[\int_0^1 p_t(\omega)^{1-\rho}d\omega\right]^{\frac{1}{1-\rho}} \quad (4)$$

The household ends period $t-1$ with $L_{H,t-1}$ land in hand and deposit D_{t-1} in the bank. In period t, it receives gross interest income on deposit $D_{t-1}R_{t-1}$, wage income W_tN_t, a lump-sum transfer (tax) T_tP_t and a lump-sum profit received from the retailers F_tP_t. $Q_{L,t}$ is the nominal price of land and W_t is the nominal wage in period t. Define $\pi_{t+1} = \frac{P_{t+1}}{P_t}$ and $q_{L,t}$, w_t, d_t as the real term of $Q_{L,t}$, W_t, D_t. The budget constraint for the household in real term is given by:

$$d_t + C_{H,t} + q_{L,t}(L_{H,t} - L_{H,t-1}) = d_{t-1}\frac{R_{t-1}}{\pi_t} + w_tN_t + F_t + T_t \quad (5)$$

Optimality requires:

$$\frac{1}{C_{H,t}} = \beta_H E_t\frac{1}{C_{H,t+1}}\frac{R_t}{\pi_{t+1}} \quad (6)$$

$$\chi_{L,t}\frac{1}{L_{H,t}} = q_{L,t}\frac{1}{C_{H,t}} - \beta_H E_t q_{L,t+1}\frac{1}{C_{H,t+1}} \quad (7)$$

$$\chi_{N,t}N_t^{\eta}C_{H,t} = w_t \quad (8)$$

2.2. Private firms

Private firms use a Cobb–Douglas constant returns-to-scale technology to produce an intermediate good $y_{E,t}$ in a competitive market. They use labor $N_{E,t}$, land $L_{E,t-1}$ and capital $k_{E,t-1}$ as inputs:

$$y_{E,t} = A_{E,t}[L_{E,t-1}^{\phi}k_{E,t-1}^{1-\phi}]^{\nu}N_{E,t}^{1-\nu} \quad (9)$$

$A_{E,t}$ denotes technology used for production. A shock to $A_{E,t}$ is labeled as "private firm productivity shock". Following Kiyotaki and Moore (1997), we assume that if a private firm repudiates its debt obligation, bankers can repossess a fraction of its assets, given by $E_tm_t\left[\frac{q_{k,t+1}k_{E,t}\pi_{t+1}}{R_t} + \frac{q_{L,t+1}L_{E,t}\pi_{t+1}}{R_t}\right]$. $q_{k,t+1}$ is the real capital price in period $t+1$ and $m_t \le 1$ represent the transaction cost to liquidate the seized capital and land stock. A shock to m_t is labeled as "constraint shock". Thus, the maximum debt $b_{E,t}$ that the private firms can borrow satisfies:

$$b_{E,t} \le E_tm_t\left[\frac{q_{k,t+1}k_{E,t}\pi_{t+1}}{R_t} + \frac{q_{L,t+1}L_{E,t}\pi_{t+1}}{R_t}\right] \quad (10)$$

Following Iacoviello (2005), we assume that private firms discount the future more heavily than households, $\beta_E < \beta_H$, in order to obtain a steady state in which the borrowing constraints are binding. Private firms' problem is to maximize:

$$E_t\sum_{j=0}^{\infty}\beta_E^j\ln(C_{E,t+j}) \quad (11)$$

subject to the technology constraint, the borrowing constraint and the flow of funds which is given by:

$$y_{E,t}\frac{p_{E,t}}{P_t} + b_{E,t} = C_{E,t} + b_{E,t-1}\frac{R_{t-1}}{\pi_t} + q_{L,t}(L_{E,t} - L_{E,t-1}) + q_{k,t}[k_{E,t} - k_{E,t-1}(1-\delta)] + w_tN_{E,t} \quad (12)$$

where $p_{E,t}$ is the nominal price of goods $y_{E,t}$ and δ is the depreciation rate for capital goods. Optimality condition requires:

$$\lambda_{E,t} = \frac{1}{C_{E,t}} \quad (13)$$

$$\lambda_{E,t} = \beta_E E_t\lambda_{E,t+1}\frac{R_t}{\pi_{t+1}} + \lambda_{b,t} \quad (14)$$

$$\lambda_{E,t}q_{k,t} = \beta_E E_t\lambda_{E,t+1}\left[\nu(1-\phi)\frac{y_{E,t+1}}{k_{E,t}}\frac{p_{E,t+1}}{P_{t+1}} + q_{k,t+1}(1-\delta)\right] + \lambda_{b,t}m_tE_t\frac{q_{k,t+1}\pi_{t+1}}{R_t} \quad (15)$$

$$\beta_E E_t\lambda_{E,t+1}\left[\nu\phi\frac{y_{E,t+1}}{L_{E,t}}\frac{p_{E,t+1}}{P_{t+1}} + q_{L,t+1}\right] - \lambda_{E,t}q_{L,t} + \lambda_{b,t}m_tE_t\frac{q_{L,t+1}\pi_{t+1}}{R_t} = 0 \quad (16)$$

$$w_t = \frac{(1-\nu)y_{E,t}}{N_{E,t}}\frac{p_{E,t}}{P_t} \quad (17)$$

Here, $\lambda_{E,t}$ is the Lagrangian multiplier for the flow of funds constraint and $\lambda_{b,t}$ is the Lagrangian multiplier for the borrowing constraint.

2.3. State-owned firms

State-owned firms operates similar production function to produce another intermediate good $y_{S,t}$ in a competitive market. $A_{S,t}$ denotes technology used for production. A shock to $A_{S,t}$ is labeled as "state-owned firm productivity shock". The production function is:

$$y_{S,t} = A_{S,t}[L_{S,t-1}^{\phi}k_{S,t-1}^{1-\phi}]^{\nu}N_{S,t}^{1-\nu} \quad (18)$$

State-owned firms can obtain funds $B_{S,t}$ from banks for investment and land purchase at the same nominal interest rate as private firms but without any constraint, hence in real term $b_{S,t} = q_{k,t}(k_{S,t} - k_{S,t-1}(1-\delta)) + q_{L,t}(L_{S,t} - L_{S,t-1})$. Because of the implicit government guarantee, there is no default risk on the loans taken out by state-owned firms. The real profits Π_t of the state-owned firms in period t is given by:

$$\Pi_t = y_{S,t}\frac{p_{S,t}}{P_t} - b_{S,t-1}\frac{R_{t-1}}{\pi_t} - w_tN_{S,t} \quad (19)$$

The state-owned firm maximizes the present value of future's profit V_t:

$$V_t = E_t\sum_{j=0}^{\infty}\Lambda_{t,t+j}\Pi_{t+j} \quad (20)$$

where $\Lambda_{t,t+j}$ is the discount rate:

$$\Lambda_{t,t+j} \equiv \frac{\beta_H^jU_c(C_{H,t+j}, L_{H,t+j}, N_{t+j})}{U_c(C_{H,t}, L_{H,t}, N_t)} = \frac{\beta_H C_{H,t}}{C_{H,t+1}} \quad (21)$$

First-order conditions for the state-owned firm's optimizing problem are given by:

$$w_t = \frac{(1-\nu)y_{S,t}}{N_{S,t}}\frac{p_{S,t}}{P_t} \quad (22)$$

$$q_{k,t} = E_t\Lambda_{t,t+1}\left[\frac{\nu(1-\phi)y_{S,t+1}}{k_{S,t}}\frac{p_{S,t+1}}{P_{t+1}} + q_{k,t+1}(1-\delta)\right] \quad (23)$$

$$q_{L,t} = E_t\Lambda_{t,t+1}\left[\frac{\nu\phi y_{S,t+1}}{L_{S,t}}\frac{p_{S,t+1}}{P_{t+1}} + q_{L,t+1}\right] \quad (24)$$

2.4. Capital goods producer

The capital goods producer maximizes profit by producing capital goods with a quadric adjustment cost:

$$E_t\sum_{j=0}^{\infty}\Lambda_{t,t+j}\left[q_{k,t+j}\left[1-\frac{\gamma_I}{2}\left(\chi_{I,t+j}\frac{I_{t+j}}{I_{t+j-1}}-1\right)^2\right]I_{t+j}-I_{t+j}\right] \tag{25}$$

where γ_I is the adjustment cost parameter and $\chi_{I,t+j}$ represents the efficiency of investment. A shock to $\chi_{I,t+j}$ is labeled as "investment efficiency shock". Optimality requires:

$$\frac{1}{q_{k,t}}=1-\frac{\gamma_I}{2}\left(\chi_{I,t}\frac{I_t}{I_{t-1}}-1\right)^2-\gamma_I\left(\chi_{I,t}\frac{I_t}{I_{t-1}}-1\right)\chi_{I,t}\frac{I_t}{I_{t-1}}+\gamma_I E_t\Lambda_{t,t+j}\left[\left(\chi_{I,t+1}\frac{I_{t+1}}{I_t}-1\right)\chi_{I,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\frac{q_{k,t+1}}{q_{k,t}}\right] \tag{26}$$

2.5. Retailers

There is a continuum of retailers of mass 1, indexed by ω, who buy intermediate goods $y_{E,t}$ at the price of $p_{E,t}$ from private firms and $y_{S,t}$ at the price of $p_{S,t}$ from state-owned firms. Retailers repackage the input goods at zero cost and produce final goods $y_t(\omega)$. Retailer ω sell his final goods to the household and firms for a price of $p_t(\omega)$. Retailer ω's production function is given by:

$$y_t(\omega)=\left[\gamma_E^{\frac{1}{\xi}}y_{E,t}^{\frac{\xi-1}{\xi}}+(1-\gamma_E)^{\frac{1}{\xi}}y_{S,t}^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}} \tag{27}$$

where γ_E measures the share of inputs produced by private firms and ξ is the elasticity of substitution. Retailer's cost minimization problem involves minimizing total cost: $y_{E,t}p_{E,t}+y_{S,t}p_{S,t}$, subject to the production function $y_t(\omega)$:

$$\psi_t(\omega)=[\gamma_E p_{E,t}^{1-\xi}+(1-\gamma_E)p_{S,t}^{1-\xi}]^{\frac{1}{1-\xi}} \tag{28}$$

Optimality requires:

$$y_{E,t}(\omega)=\gamma_E\left(\frac{p_{E,t}}{\psi_t(\omega)}\right)^{-\xi}y_t(\omega) \tag{29}$$

$$y_{S,t}(\omega)=(1-\gamma_E)\left(\frac{p_{S,t}}{\psi_t(\omega)}\right)^{-\xi}y_t(\omega) \tag{30}$$

where $\psi_t(\omega)$ denotes the marginal cost of $y_t(\omega)$.

Each retailer chooses a sale price $p_t(\omega)$ taking $p_{E,t}$, $p_{S,t}$ and demand curve as given. The sale price can be modified with probability $1-\theta$ in each period. To obtain the optimal price $p_t(\omega)$, retailers solve the following optimization problem:

$$E_t\sum_{j=0}^{\infty}\theta^j\Lambda_{t,t+j}\left[\frac{p_t(\omega)}{P_{t+j}}-\frac{\psi_{t+j}(\omega)}{P_{t+j}}\right]y_{t+j}(\omega) \tag{31}$$

where $y_{t+j}(\omega)=\left(\frac{p_t(\omega)}{P_{t+j}}\right)^{-\rho}Y_{t+j}$ is the demand function for retailer ω and Y_{t+j} is the final good for consumption and investment at period $t+j$. Since all retailers adjust prices in period t facing the same problem, all adjusting retailers will set the same price. The first order condition can be written as:

$$E_t\sum_{j=0}^{\infty}\theta^j\Lambda_{t,t+j}\left[(1-\rho)\frac{p_t(\omega)}{P_{t+j}}+\rho\frac{\psi_{t+j}(\omega)}{P_{t+j}}\right]\frac{1}{p_t(\omega)}\left(\frac{p_t(\omega)}{P_{t+j}}\right)^{-\rho}Y_{t+j}=0 \tag{32}$$

2.6. The central bank

The central bank policy rule takes the form following Zhang (2009):

$$\hat{i}_t=\gamma_i\hat{i}_{t-1}+\gamma_{\Delta\pi}(E_t\hat{\pi}_{t+1}-\hat{\pi}_t)+\gamma_\pi E_t\hat{\pi}_{t+1}+\gamma_Y\hat{Y}_t+\epsilon_{i,t} \tag{33}$$

here $\epsilon_{i,t}$ represents the monetary policy shock.

2.7. Equilibrium

In equilibrium, private firms and state-owned firms share the labor force:

$$N_t=N_{E,t}+N_{S,t} \tag{34}$$

An equilibrium in the goods market requires that:

$$Y_t=C_{H,t}+C_{E,t}+I_t \tag{35}$$

For the capital goods market equilibrium:

$$k_{E,t}+k_{S,t}-(1-\delta)(k_{E,t-1}+k_{S,t-1})=\left[1-\frac{\gamma_I}{2}\left(\chi_{I,t}\frac{I_t}{I_{t-1}}-1\right)^2\right]I_t \tag{36}$$

And for the land market equilibrium:

$$\overline{L}=L_{H,t}+L_{E,t}+L_{S,t} \tag{37}$$

where $\overline{L}$ is normalized to 1. Banks are competitive. They receive deposits D_t from households at the gross nominal interest rate R_{t+1} and initiate loans $B_{E,t}$ ($b_{E,t}$ in real term) to private firms and loans $B_{S,t}$ ($b_{S,t}$ in real term) to state-owned firms at the same rate. Bank's balance sheet is given by:

$$D_t=B_{E,t}+B_{S,t} \tag{38}$$

Around the steady state, the model can be reduced to the following linearized system according to the algorithm developed by Uhlig (2001). Define $x_{E,t}=\frac{p_{E,t}}{P_t}$, $x_{S,t}=\frac{p_{S,t}}{P_t}$ and $x_t=\frac{\psi_t}{P_t}$. Exogenous variables include $\{\chi_{L,t}, \chi_{N,t}, \chi_{I,t}, A_{E,t}, A_{S,t}, m_t\}$ and endogenous variables are $\{Y_t, y_t, y_{E,t}, y_{S,t}, C_{H,t}, N_t, L_{H,t}, \lambda_{E,t}, C_{E,t}, k_{E,t}, N_{E,t}, \lambda_{b,t}, N_{S,t}, k_{S,t}, b_{E,t}, b_{S,t}, d_t, L_{E,t}, L_{S,t}, L_t, I_t, q_{k,t}, q_{L,t}, i_t, r_t, \pi_t, x_{E,t}, x_{S,t}, x_t, w_t\}$. All log-linearized equations and exogenous shocks are listed in Appendix A.

3. Calibration and model implication

3.1. Calibration

The values of all the behavior parameters in the model are either from the relevant literature or calibrated to China's data at quarterly frequency. We set the discount factors of households β_H and entrepreneurs β_E to 0.993 and 0.985 respectively, in line with empirical observations of average one year deposit rate 2.8% and lending rate 6% over the period 2005–2015. This is also consistent with Iacoviello (2005). According to the average ratio of capital depreciation to GDP from 2005 to 2014, the rate of capital depreciation δ is assigned a value of 0.03, which is within the range [0.025, 0.4] of the related literature (Bai et al., 2006a; Zhang, 2009; Song et al., 2011; Guo et al., 2015). Following Dollar and Wei (2007) and Song et al. (2011), we fix the value of labor income share of GDP $1-\nu$ to 0.5, close to the average ratio of labor income to GDP 0.45 over the period 2005–2015. The parameter ϕ is calibrated to 0.25 according to the average ratio of real estate investment versus the overall investment except real estate sector over the period 2000–2015. We set the inverse Frisch elasticity of labor supply η with to a value of 6.16 according to Zhang (2009). Following Guo et al. (2015), the land preference parameter χ_L is assigned a value of 0.77. Since the private economy is growing rapidly and already takes more than 60% of the GDP (Song et al., 2011), we set the weight of produced goods from private firms γ_E as 0.6. Consistent with Zhang (2009) and Guo et al. (2015), the substitution parameters ρ and ξ are both set to 4.61 and the price stickiness parameter θ is calibrated to 0.84. γ_I is set to 1.8 according to Guo et al. (2015)'s estimation. The productivity ratio of private firms versus state-owned firms in the steady state $\frac{A_E}{A_S}$ is assigned a value of 1.03 based on Dollar and Wei (2007)'s estimation. Because the bank's loan to value ratio is normally less than 70% for real estate and less than 50% for capital good, the percentage of capital and land in the steady state that private firms can pledge to repay, also named as the borrowing constraint, m, is assigned a value of 0.6.

All the parameters governing the shock process are estimated using Bayesian techniques. There are seven observables that our model aims to match: China's real GDP, loan rate, real house price index, the number of employment and the real investments in the state-owned firms sector and private firms sector. These data are from Wind Economic Database, collected quarterly from the 3rd quarter of 2005 to the 4th quarter of 2014. It is the longest available data. All observables are seasonally adjusted except the loan rate. We use percentage deviations from their respective trends obtained via HP filter for estimation. There are seven shocks considered to be the underlying driving forces of economic fluctuations. They are productivity shocks in the state-owned firm sector and private firm sector, a housing demand shock, a labor supply shock, an investment efficiency shock, a monetary policy shock and a constraint shock. Some prior values of the parameters are assigned according to the recent empirical works in the literature. Following the estimation of Zhang (2009), we set the rest of prior values to $\gamma_R = 0.75$, $\gamma_{\Delta\pi} = 0.65$, $\gamma_\pi = 0.1$, $\gamma_Y = 0.15$. The calibrated and estimated parameters are reported in Tables 1 and 2 in Appendix B.

3.2. Model implication

Based on the calibrated parameters, we identify the main driving forces behind the land prices through variance decompositions, and illustrate the joint dynamic between land prices and macroeconomic variables by impulse response graphs, emphasizing the heterogeneous investment behavior for state-owned firms and private firms.

Fig. 1 shows the variance decomposition of the land price, suggesting the housing demand shock and monetary policy shock are the main shocks driving land price dynamics (up to 90%). A less important shock is the constraint shock, accounting for about 5% of land price volatility. The investment efficiency shock, labor supply shock and productivity shocks from the state-owned firm sector and private firm sector do not contribute much to the land price fluctuations (about 5%); however, they do cause business cycle fluctuations, as shown in Figs. 2 and 3. This is consistent with related literatures (Kocherlakota, 2000; Cordoba and Ripoll, 2004; Jermann and Quadrini, 2012; Liu et al., 2013).

With the driving forces for land price fluctuation identified, we further examine the “collateral channel”. The monetary policy shock not only changes household's real estate asset holding behavior but also alters private firms' ability to borrow by adjusting the expected present value of its holding asset, and hence complicate the procedure to identify the collateral effect. For this reason, we focus on the housing demand shock. A housing demand shock raises land price but has little direct effect on private firms' financing ability. Fig. 4 exhibits the impulse response graph of macroeconomic variable to the housing demand shock. Increased land price enhances private firms' collateral value and alleviates its borrowing constraint, allowing them to borrow more for capital investment. Hence, the private firms' capital investment rises as well, showing the existence of the “collateral channel” in China, which is consistent with the empirical literature.

However, the impulse response function shows that the housing demand shock leads to reduced investment of state-owned firms, implying a negative relationship between the real estate price and state-owned firms' investment. The “collateral channel” allows private firms to raise their investment following the increase of land price. Increased capital demand raises the price of the capital good, crowding out the investment of state-owned firms. Similarly, an increase in investment enhances marginal product of labor for private firms, leading to higher real wage which crowds out employment in the state-owned firms. Since land, capital and labor are complementary factors of production, reduced land input and employment both serve to decrease marginal product of capital for state-owned firms, reinforcing the shrink of investment. Even though the state-owned firms are not financially constrained, they are negatively affected by the increased land price. We call this the “crowding out” channel. It provides a reasonable explanation for Chen et al. (2015)'s empirical finding, where there is a negative effect of real estate price appreciation on state-owned firms' financial capacity.

4. Conclusions

Heterogeneous borrowing constraints in the production sector alters the traditional transmission mechanism of macroeconomic shocks in several aspects. In this paper, we construct a DSGE model including land as a production input with heterogeneous sectors tailored to the China economy, and use it to explain the dynamic link between real land price and heterogeneous investment behavior found in empirical literature. Our quantitative general equilibrium model confirms the existence of the “collateral channel” for private firms in China, in a way that avoids the potential endogeneity problems embedded in existing empirical methods. A new “crowding out” channel has been identified through simulation analysis, which gives a legitimate explanation to the negative relationship between real estate price and state-owned firm's investment. The findings in this paper have important policy implications. For example, the government is advised to take into account accordingly the induced change of investment behavior of the state-owned and private firms before implementing measures to influence real estate price. As the capital reallocation in production sectors may incur unintended welfare loss to the whole economy.

Our model can also be applied to other countries with heterogeneous production sectors, where private firms tend to face more severe financial constraints than state-owned firms and the government tends to play an important role in directing financial resources to state-owned firms in its favor. As pointed out by Dethier et al. (2011) and Ayyagari et al. (2012), this theme is relevant in quite a few developing countries. The model in its current form rules out firms' entry and exit behavior, which can be significant in developing countries and may amplify the heterogeneous effect of real estate price on state-owned and private firms' investment behavior. For instance, Corradin and Popov (2015) and Schmalz et al. (2016) find that a rise in collateral value of housing leads to a higher probability of a home owner becoming an entrepreneur. It has also been showed that endogenizing firm's entry and exist behavior in a DSGE model introduces new implications to monetary shocks (Bilbiie et al., 2008; Bergin and Corsetti, 2008). Given those considerations, a promising avenue for future research is to consider models with entry and exit of firms, although at the expense of added model complexity.

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Appendix A. Linearized equations

$$\hat{c}_{H,t} = E_t\hat{c}_{H,t+1} - E_t\hat{r}_t$$

$$\chi_L \frac{Y}{q_L L_H}(\hat{\chi}_{L,t} - \hat{L}_{H,t}) = \frac{Y}{C_H}(\hat{q}_{L,t} - \hat{c}_{H,t}) - \beta_H \frac{Y}{C_H}E_t(\hat{q}_{L,t+1} - \hat{c}_{H,t+1})$$

$$\hat{\chi}_{N,t} + \eta\hat{N}_t + \hat{c}_{H,t} = \hat{w}_t$$

$$\hat{y}_{E,t} = \hat{A}_{E,t} + v\phi\hat{L}_{E,t-1} + v(1-\phi)\hat{k}_{E,t-1} + (1-v)\hat{N}_{E,t}$$

$$\hat{y}_{S,t} = \hat{A}_{S,t} + v\phi\hat{L}_{S,t-1} + v(1-\phi)\hat{k}_{S,t-1} + (1-v)\hat{N}_{S,t}$$

$$\hat{\lambda}_{E,t} = -\hat{C}_{E,t}$$

$$\frac{b_E}{y_E}\hat{b}_{E,t} = m\beta_H \frac{q_k k_E}{y_E}(\hat{m}_t + E_t\hat{q}_{k,t+1} + E_t\hat{k}_{E,t} - E_t\hat{r}_t) + m\beta_H \frac{q_L L_E}{y_E}(\hat{m}_t + E_t\hat{q}_{L,t+1} + E_t\hat{L}_{E,t} - E_t\hat{r}_t)$$

$$x_E\left(\hat{y}_{E,t} + \hat{x}_{E,t} + \frac{b}{y_E}\hat{b}_{E,t} = \frac{c_E}{y_E}\hat{C}_{E,t} + \frac{b_E}{y_E}(\hat{b}_{E,t-1} + \hat{r}_{t-1}) + \frac{q_L L_E}{y_E}(\hat{L}_{E,t} - \hat{L}_{E,t-1}) + \frac{q_k k_E}{y_E}\left(\delta\hat{q}_{k,t} + \hat{k}_{E,t} - (1-\delta)\hat{k}_{E,t-1}\right) + \frac{wN_E}{y_E}(\hat{w}_t + \hat{N}_{E,t})\right.$$

$$\hat{\lambda}_{E,t} = \beta_E(1+r)E_t(\hat{\lambda}_{E,t+1} + \hat{r}_t) + \lambda_{bE}\hat{\lambda}_{b,t}$$

$$\hat{q}_{k,t} + \hat{\lambda}_{E,t} = \beta_E v(1-\phi)\frac{y_E}{q_k k_E}x_E E_t(\hat{\lambda}_{E,t+1} + \hat{y}_{E,t+1} - \hat{k}_{E,t} + \hat{x}_{E,t+1}) + \beta_E(1-\delta)E_t(\hat{\lambda}_{E,t+1} + \hat{q}_{k,t+1}) + \lambda_{bE}m\beta_H(\hat{\lambda}_{b,t} + \hat{m}_t + E_t\hat{q}_{k,t+1} - E_t\hat{r}_t)$$

$$\beta_E v\phi\frac{y_E}{L_E}\frac{x_E}{q_L}E_t(\hat{\lambda}_{E,t+1} + \hat{y}_{E,t+1} - \hat{L}_{E,t} + \hat{x}_{E,t+1}) + \beta_E E_t(\hat{\lambda}_{E,t+1} + \hat{q}_{L,t+1}) - (\hat{\lambda}_{E,t} + \hat{q}_{L,t}) + \lambda_{bE}m\beta_H(\hat{\lambda}_{b,t} + \hat{m}_t + E_t\hat{q}_{L,t+1} - E_t\hat{r}_t) = 0$$

$$\hat{y}_{E,t} - \hat{N}_{E,t} + \hat{x}_{E,t} = \hat{w}_t$$

$$\hat{y}_{S,t} - \hat{N}_{S,t} + \hat{x}_{S,t} = \hat{w}_t$$

$$\hat{q}_{k,t} = \beta_H\frac{v(1-\phi)y_S}{q_k k_S}x_S E_t(\hat{c}_{H,t} - \hat{c}_{H,t+1} + \hat{y}_{S,t+1} - \hat{k}_{S,t} + \hat{x}_{S,t+1}) + \beta_H(1-\delta)E_t(\hat{c}_{H,t} + \hat{q}_{k,t+1} - \hat{c}_{H,t+1})$$

$$\hat{q}_{L,t} = \beta_H\frac{v\phi y_S}{L_S}\frac{x_S}{q_L}E_t(\hat{c}_{H,t} - \hat{c}_{H,t+1} + \hat{y}_{S,t+1} - \hat{L}_{S,t} + \hat{x}_{S,t+1}) + \beta_H E_t(\hat{c}_{H,t} - \hat{c}_{H,t+1} + \hat{q}_{L,t+1})$$

$$\hat{\pi}_t = \frac{(1-\theta)(1-\theta\beta_H)}{\theta}\hat{x}_t + \beta_H E_t\hat{\pi}_{t+1}$$

$$\hat{x}_t = \gamma_E\left(\frac{x_E}{x}\right)^{1-\xi}\hat{x}_{E,t} + (1-\gamma_E)\left(\frac{x_E}{x}\right)^{1-\xi}\hat{x}_{S,t}$$

$$\hat{d}_t = \frac{b_E}{d}\hat{b}_{E,t} + \frac{b_s}{d}\hat{b}_{S,t}$$

$$\delta\frac{k_S}{yS}\hat{b}_{S,t} = \frac{q_k k_S}{y_S}\hat{k}_{S,t} - (1-\delta)\frac{q_k k_S}{y_S}\hat{k}_{S,t-1} + \frac{\delta q_k k_S}{y_S}\hat{q}_{k,t} + \frac{q_L LS}{y_S}\hat{L}_{S,t} - \frac{q_L LS}{y_S}\hat{L}_{S,t-1}$$

$$0 = \frac{L_H}{L}\hat{L}_{H,t} + \frac{L_E}{L}\hat{L}_{E,t} + \frac{L_S}{L}\hat{L}_{S,t}$$

$$\hat{N}_t = \frac{N_E}{N}\hat{N}_{E,t} + \frac{N_S}{N}\hat{N}_{S,t}$$

$$-\hat{q}_{k,t} = -\gamma_I(\hat{\chi}_{I,t} + \hat{I}_t - \hat{I}_{t-1}) + \gamma_I\beta_H E_t(\hat{\chi}_{I,t+1} + \hat{I}_{t+1} - \hat{I}_t)$$

$$\delta\frac{k_S}{yS}\hat{b}_{S,t} = \frac{q_k k_S}{y_S}\hat{k}_{S,t} - (1-\delta)\frac{q_k k_S}{y_S}\hat{k}_{S,t-1} + \frac{\delta q_k k_S}{y_S}\hat{q}_{k,t} + \frac{q_L LS}{y_S}\hat{L}_{S,t} - \frac{q_L LS}{y_S}\hat{L}_{S,t-1}$$

$$\frac{k_E}{Y}\hat{k}_{E,t} + \frac{k_S}{Y}\hat{k}_{S,t} - (1-\delta)\left(\frac{k_E}{Y}\hat{k}_{E,t-1} + \frac{k_S}{Y}\hat{k}_{S,t-1}\right) = \frac{I}{Y}\hat{I}_t$$

$$\hat{Y}_t = \frac{C_H}{Y}\hat{C}_{H,t} + \frac{C_E}{Y}\hat{C}_{E,t} + \frac{I}{Y}\hat{I}_t$$

$$\hat{y}_{E,t} = -\xi(\hat{x}_{E,t} - \hat{x}_t) + \hat{y}_t$$

$$\hat{y}_{S,t} = -\xi(\hat{x}_{S,t} - \hat{x}_t) + \hat{y}_t$$

$$\hat{y}_t = \hat{Y}_t - \frac{\rho\theta}{1-\theta}\hat{\pi}_t$$

$$\hat{i}_t = \hat{r}_t + E_t\hat{\pi}_{t+1}$$

$$\hat{i}_t = \gamma_i\hat{i}_{t-1} + \gamma_{\Delta\pi}(E_t\hat{\pi}_{t+1} - \hat{\pi}_t) + \gamma_\pi E_t\hat{\pi}_{t+1} + \gamma_Y\hat{Y}_t + \epsilon_{i,t}$$

$$\hat{A}_{E,t} = \gamma_{A_E}\hat{A}_{E,t-1} + \epsilon_{A_E,t}$$

$$\hat{A}_{S,t} = \gamma_{A_S}\hat{A}_{S,t-1} + \epsilon_{A_S,t}$$

$$\hat{\chi}_{N,t} = \gamma_{\chi_N}\hat{\chi}_{N,t-1} + \epsilon_{\chi_N,t}$$

$$\hat{\chi}_{L,t} = \gamma_{\chi_L}\hat{\chi}_{L,t-1} + \epsilon_{\chi_L,t}$$

$$\hat{\chi}_{I,t} = \gamma_{\chi_I}\hat{\chi}_{I,t-1} + \epsilon_{\chi_I,t}$$

$$\hat{m}_t = \gamma_m\hat{m}_{t-1} + \epsilon_{m,t}$$

Appendix B. Calibration and estimation

See Tables 1 and 2.

Table 1
Parameter calibration.

Parameter	Value	Parameter	Value
β_H	0.993	ρ	4.61
β_E	0.985	γ_E	0.6
δ	0.03	θ	0.84
υ	0.5	m	0.6
ϕ	0.25	γ_I	1.8
η	6.16	$\frac{AE}{AS}$	1.03
ξ	4.61		

Table 2
Bayesian estimation.

Param.	Prior			Posterior		
	Density	Mean	St.dev.	Mean	Lower (90%)	Upper (90%)
γ_i	β	0.75	0.10	0.16	0.12	0.20
$\gamma_{\Delta\pi}$	β	0.65	0.10	0.63	0.47	0.77
γ_Y	β	0.15	0.10	0.07	0.05	0.08
γ_π	β	0.10	0.10	0.04	0.01	0.08
γ_{A_E}	β	0.50	0.10	0.59	0.50	0.69
γ_{A_S}	β	0.50	0.10	0.70	0.62	0.79
γ_{χ_N}	β	0.50	0.10	0.59	0.49	0.70
γ_{χ_L}	β	0.50	0.10	0.953	0.951	0.954
γ_{χ_I}	β	0.50	0.10	0.60	0.49	0.72
γ_m	β	0.50	0.10	0.90	0.82	0.95
σ_i	*Inv. Gamma2*	0.01	inf	0.08	0.07	0.10
σ_{A_E}	*Inv. Gamma2*	0.01	inf	0.04	0.03	0.05
σ_{A_S}	*Inv. Gamma2*	0.01	inf	0.05	0.04	0.06
σ_{χ_N}	*Inv. Gamma2*	0.01	inf	0.15	0.12	0.18
σ_{χ_L}	*Inv. Gamma2*	0.01	inf	0.30	0.24	0.37
σ_{χ_I}	*Inv. Gamma2*	0.01	inf	0.08	0.06	0.10
σ_m	*Inv. Gamma2*	0.01	inf	0.15	0.12	0.18

Appendix C. Variance decomposition and impulse response

See Figs. 1–4.

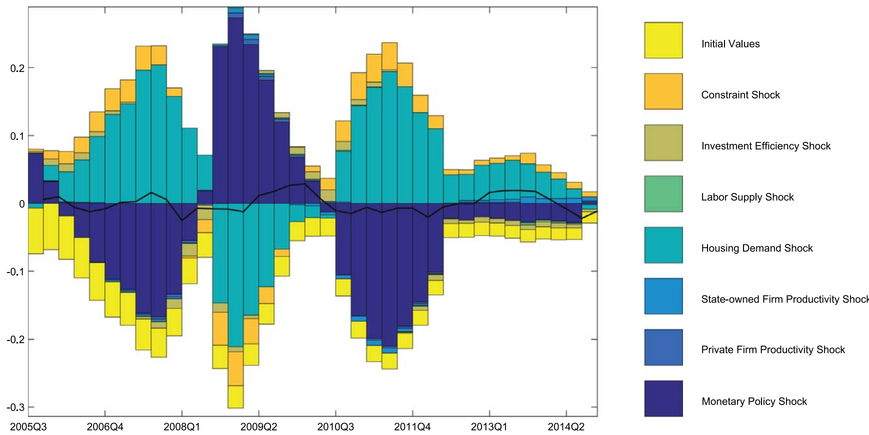

Fig. 1. Land price variance decomposition.

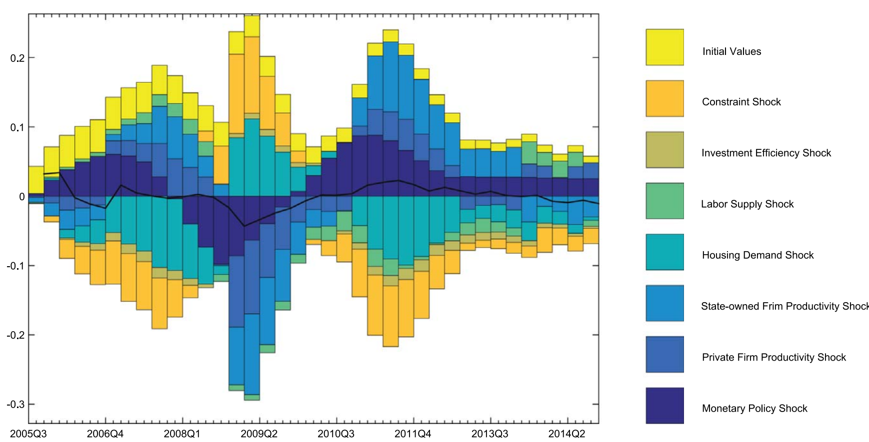

Fig. 2. Output variance decomposition.

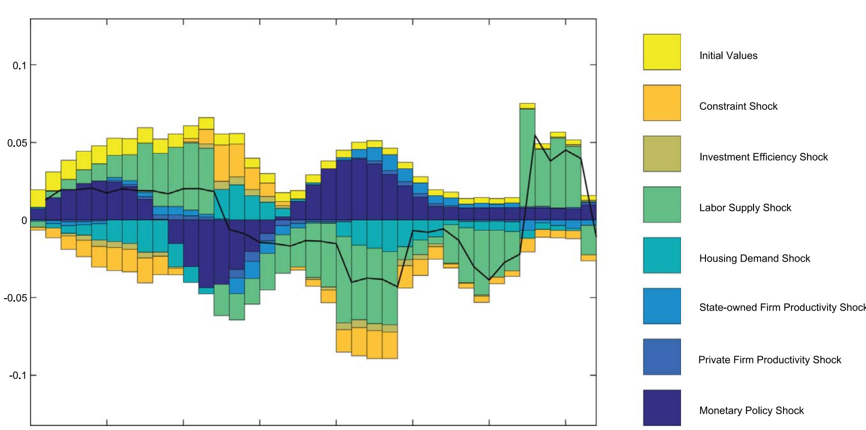

Fig. 3. Labor supply variance decomposition.

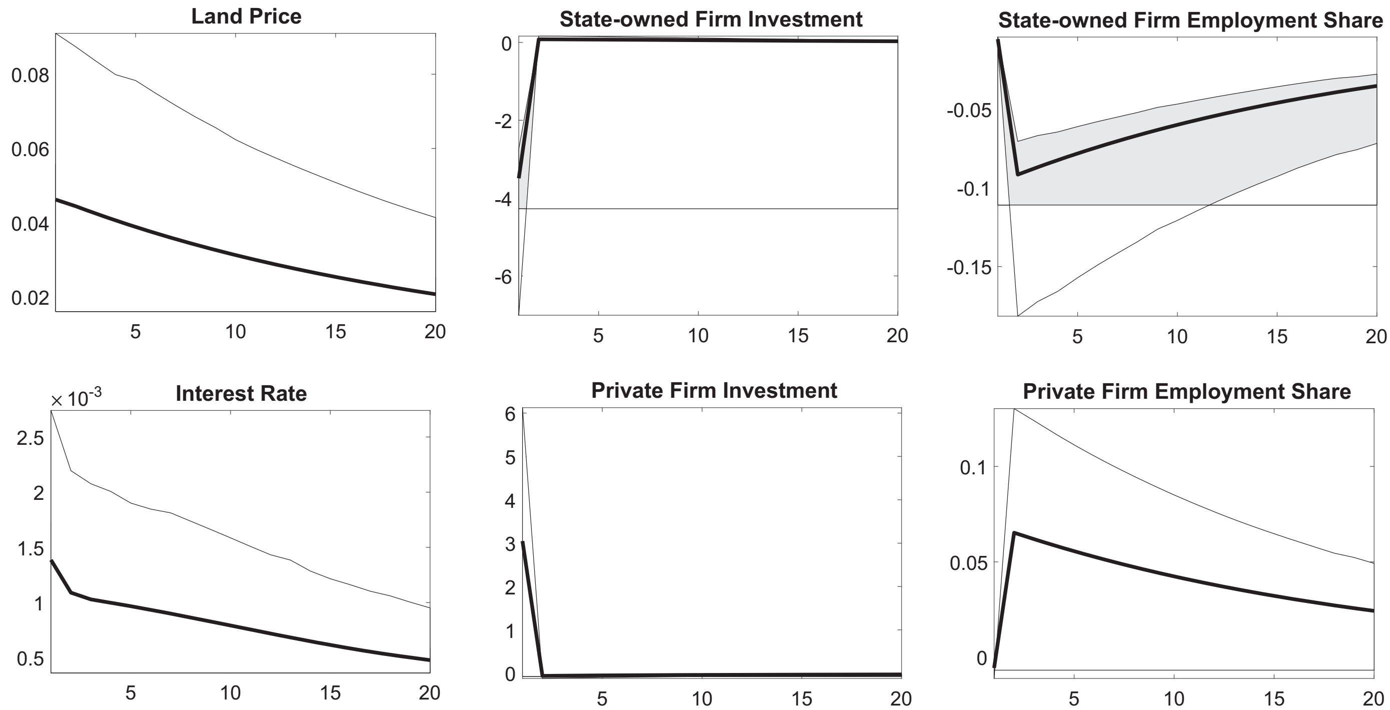

Fig. 4. Impulse response to a housing demand shock.

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