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Has fiscal expansion inflated house prices in China? Evidence from an estimated DSGE model

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Abstract

A canonical DSGE model for housing, extended to embrace government spending and government investment, is estimated on Chinese data to evaluate the impact of fiscal policy on house prices. Government spending substitutes for housing; a rise in government spending lowers house prices, but its impact is weak. Government investment generates a wealth effect, causing housing demand, and therefore prices, to rise; its variation had a substantial impact on the boom-bust cycles of house prices in the past decade. Both government spending and government investment are effective instruments for manipulating output. However, their different impacts on house prices would recommend policies to count more on spending if fiscal expansion is not to sacrifice the stability of house prices.

Keywords: fiscal policy; housing price; China; DSGE model

JEL Classification: E62; R31

1 Introduction

In this paper we study the impact of fiscal policy on the dynamics of house prices in China. The research is motivated by the following observations: first, while the 'Great Housing Boom' (Chen and Wen, 2017) of China has prompted a growing literature on what made it happen, existing studies have revealed little about the role of fiscal policy – a device frequently used by the Chinese government to intervene in the economy; second, the 'Tiebout hypothesis' (Tiebout, 1956) suggests house prices can be affected by government spending if the latter is 'capitalised' into the former in the form of public goods and services that improve the quality of living; while this is supported by some early empirical work (Oates, 1969, 1973; Afonso and Sousa, 2009; Aye, et al., 2014; Khan and Reza, 2016), it has never been clear how this could (and whether it will) happen in a structural model[1]; last but not least, that local governments in China are the main investors in major infrastructural projects and to some land sales proceeds are key to local budget – known as 'land financing' – gives the perception that 'government investment inflated house prices, as house developers pass

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[1] Indeed, there is also evidence against Tiebout; e.g., Brasington (2002), Hilber and Mayer (2009) and Hilber (2011) find the degree of capitalisation depends on the scarcity of lands/houses; Ruiz and Vargas-Silva (2016) find house prices respond little to government spending.

on the cost of land to prices of homes'; however this is never tested, nor its transmission mechanism is ever explained explicitly (e.g., about how land costs would have risen in the first place). We argue that the existing literature is lacking a theory that carefully addresses how these important fiscal instruments could have affected the housing boom in China, which we investigate here.

The state-of-the-art approach to structural analysis of the housing market has been, since Iacoviello (2005) and Iacoviello and Neri (2010), based on a New Keynesian model with (heterogeneous) households, entrepreneurs, retailers, and a central bank governing monetary policy. Fiscal policy (usually represented by government spending) is in most cases either omitted or, if not, condensed to an exogenous AR(1) process which by construction would only affect the market aggregate but not the ways market interactions happen. The intuition behind this is that in major free economies fiscal policy was far less manipulated, at least before the 'Zero Lower Bound' problem loomed large. When this type of model is applied to the Chinese market, such a convention is followed. Thus, Minetti and Peng (2015), Ng (2015) and Wen and He (2015) have all omitted the public sector, so government spending is not given a role. On the other hand, since all these works have made no distinction between private investment and government investment, the role of the latter, embraced by 'total investment', is well accounted for, but it is never distinct from the former. Liu and Ou (2018) in a more recent work pick up government spending, but they only let it follow an AR(1) process as just mentioned. Zhou and Jariyapan (2013) and Guo, et al. (2015) both model government investment explicitly; but they both force government investment to be driven by land sales proceeds which is a misconception of land financing, since the proceeds – being parts of the government revenue supporting the policy – are not themselves objectives guiding the policy.

Our account of the role of fiscal policy is innovative in two aspects: first, we allow for non-separability between housing and government spending in the utility function of households. The idea follows the literature on the non-separability between private consumption and government spending (e.g., Cardia, et al., 2003; Bouakez and Rebei, 2007; Marattin and Palestini, 2013; Feve and Sahuc, 2015), though here the former is replaced by housing for the Tiebout hypothesis to be allowed for. However we do not impose the existence of it. Instead, we let the data speak, to decide whether according to our estimation government spending promotes, or depresses, housing, or the two variables just have no intrinsic relations. Second, on accounting for government investment and its relation to land financing, we let the former be guided by a feedback rule in the spirit of Leeper, et al. (2010) where the fiscal instrument is driven by the policy's targets, not the solution of the government budget equation[2]. Land sales proceeds in our case only finance, but not direct, government investment. However they are also collateralised for government borrowing as is the case for land financing in China. Nevertheless, since government investment is governed by the feedback rule, such borrowing – like the proceeds themselves – would have no direct impact on the investment. Both these revenues would just affect the tax to be levied which we assume to be a lump-sum tax below.

Our model, estimated using the Bayesian method with data between 2004 and 2016, finds: a) government spending is a substitute, instead of a complement, for housing. In contrary to 'crowding in' housing consumption as the Tiebout hypothesis would predict, it 'crowds out' housing, causing house prices to fall on impact. However in practice such an impact is hardly significant, as shocks to the spending are small; b) government investment inflates house prices. After housing demand, it is the second most important determinant of the housing price dynamics in shorter horizons, and it becomes leading in the long run. Historically, the investment revitalised the lacklustre market after the global crisis. However this did not come from land financing directly. As per the working of our model, it was the wealth effect as output responded to fiscal

[2] See also Bhattarai and Trzeciakiewicz (2017).

stimulus positively. The rise in output shifted (up) the housing demand curve, causing house prices to rise; c) the fiscal multipliers of government spending and government investment both exceed unity. The latter is triple the size of the former; but government investment also carries a multiplier effect on house prices, while government spending does not. Thus, fiscal expansion aiming at stimulating output should take into account its impact on house prices on choosing the relevant instruments.

This paper – being the first to examine the Tiebout hypothesis in a structural model, and the first to address the role of fiscal expansion in the housing boom of China taking land financing seriously – uncovers the importance of government investment that existing studies have never documented. While we still echo the widely-accepted conclusion that housing demand shock dominates the determination of house prices, we point out that these studies overstated its role. Stabilisation of the housing market requires Chinese officials to be more cautious about the side effect of fiscal stimulus on house prices.

The rest of this paper is organised as follows: Section 2 constructs the DSGE model; Section 3 estimates the model using the Bayesian method; Section 4 investigates the roles of government spending and government investment in the determination of house prices; Section 5 concludes.

2 Model

Our model is a variant of the canonical Iacoviello (2005) model, modified to allow for capitalisation of government spending (the Tiebout hypothesis), a government investment fiscal rule, and the unique features of land financing in China. There are two types of households, one 'Ricardian' and one 'non-Ricardian', both consume, buy houses, and work in both the goods and housing sectors. Entrepreneurs produce intermediate goods and houses using labour, capital and land. Retailers convert intermediate goods to final products sold to households. Monetary policy is governed by a Taylor rule. Government spending follows an AR(1) process, but under the assumption of non-separability between housing and government spending it enters the household utility functions. Government investment is governed by a fiscal feedback rule; like private investment, it is converted to 'public capital' which we assume will improve the efficiency of production in the goods sector. Government is the sole provider of land. The whole government expenditure is financed by a lump-sum tax, land sales proceeds, and borrowing backed by such proceeds expected in the future. The working of the model is detailed below.

2.1 Ricardian households

Ricardian households are labelled 'R'. They consume (c_t^R), buy houses (h_t^R) and work ($n_{c,t}^R$ and $n_{h,t}^R$) for both goods and housing productions, and have lifetime utility:

$$U_0^R = E_0 \sum_{t=0}^{\infty} (\beta^R)^t j_t \left\{ \begin{array}{c} \Gamma^R \ln\left(c_t^R - \vartheta c_{t-1}^R\right) + \phi_t \ln\left(h_t^R + \mu \frac{g_{s,t}}{q_{h,t}}\right) \\ -\frac{\psi_t}{1+\eta^R}\left[(n_{c,t}^R)^{1+\xi^R} + (n_{h,t}^R)^{1+\xi^R}\right]^{\frac{1+\eta^R}{1+\xi^R}} \end{array} \right\} \quad (1)$$

where β^R is the discount factor, Γ^R is a scaling factor[3], ϑ is the degree of consumption habit persistence, η^R is the inverse of wage elasticity, ξ^R is the substitutability between labour in different sectors, and j_t, ϕ_t and ψ_t are shocks to time preference, housing demand and labour supply, respectively.

[3] $\Gamma^R \equiv \frac{1-\vartheta}{1-\vartheta\beta^R}$. This is to ensure the marginal utility of consumption is equal $\frac{1}{c^R}$ in the steady state (See e.g., Iacoviello and Neri, 2010).

Equation (1) distinguishes itself from a 'standard' utility function in that housing is non-separable from government spending ($g_{s,t}$) normalised by the real housing price ($q_{h,t}$). This is to allow for the Tiebout hypothesis (Tiebout, 1956) which suggests that government spending, e.g., on municipal facilities, health and security services, education and environment, can improve the quality of living, such that – if it crowds in consumption on housing – it will be 'capitalised' into house prices. The Tiebout hypothesis requires complementarity between government spending and housing. This happens when $\mu \in [-1, 1] < 0$. When $\mu > 0$, government spending and housing are substitutes. When $\mu = 0$, the marginal utility of housing is independent of government spending, which is the standard case of separable utility of housing.

Ricardian households are house owners who also rent houses to non-Ricardian households. They also buy private capital, rent it to entrepreneurs, and resell the undepreciated capital back to capital producers at the end of each period. The Ricardian household budget constraint is:

$$\begin{aligned} & c_t^R + q_{h,t}\left[h_t^R - (1-\delta_h)\,h_{t-1}^R\right] + q_{h,t}\left[h_t^{NR} - (1-\delta_h)\,h_{t-1}^{NR}\right] + q_{kc,t}k_{c,t} + q_{kh,t}k_{h,t} + s_t + t_t \qquad (2) \\ = \; & w_{c,t}^R n_{c,t}^R + w_{h,t}^R n_{h,t}^R + r_{h,t}h_t^{NR} + r_{kc,t}k_{c,t-1} + r_{kh,t}k_{h,t-1} + q_{kc,t}\left(1-\delta_{kc}\right)k_{c,t-1} + q_{kh,t}\left(1-\delta_{kh}\right)k_{h,t-1} \\ & +(1+r_{t-1})s_{t-1} + \Pi_t^K + \Pi_t^{Gds} \end{aligned}$$

where h_t^{NR} is the rental housing and $r_{h,t}$ is the rental rate; $k_{c,t}$ and $k_{h,t}$ are capitals in the goods and housing sectors, priced at $q_{kc,t}$ and $q_{kh,t}$, and rented at $r_{kc,t}$ and $r_{kh,t}$, respectively; $w_{c,t}^R$ and $w_{h,t}^R$ are real wages; s_t and r_{t-1} are household savings and the saving rate; δ_h, δ_{kc} and δ_{kh} are depreciation rates of houses and the two capitals; Π_t^K and Π_t^{Gds} are lump-sum profits transferred from capital producers and retailers modelled below; t_t is a lump-sum tax levied by the fiscal authority.

The Ricardian household problem is to maximise (1) by choosing c_t^R, h_t^R, h_t^{NR}, $n_{c,t}^R$, $n_{h,t}^R$, $k_{c,t}$, $k_{h,t}$ and s_t, subject to (2). The first order conditions (which we detail in Appendix A) determine their demand for goods, houses and private capitals, and their supply of labour.

2.2 Non-Ricardian households

Non-Ricardian households are labelled 'NR'. Their utility function is similar to that of Ricardian households, except that: a) because non-Ricardian households have no access to the financial market, they are unable to optimise intertemporally but can just allocate resources *within* each period by rule of thumb; b) because non-Ricardian households do not 'keep up with the Joneses' (Galí, 1994), their consumption exhibits no habit persistence.

Non-Ricardian households are modelled as house renters. In each period they maximise:

$$U_t^{NR} = \ln c_t^{NR} + \phi_t \ln\left(h_t^{NR} + \mu\frac{g_{s,t}}{q_{h,t}}\right) - \frac{\psi_t}{1+\eta^{NR}}\left[(n_{c,t}^{NR})^{1+\xi^{NR}} + (n_{h,t}^{NR})^{1+\xi^{NR}}\right]^{\frac{1+\eta^{NR}}{1+\xi^{NR}}} \qquad (3)$$

by choosing c_t^{NR}, h_t^{NR}, $n_{c,t}^{NR}$ and $n_{h,t}^{NR}$, subject to:

$$c_t^{NR} + r_{h,t}h_t^{NR} = w_{c,t}^{NR}n_{c,t}^{NR} + w_{h,t}^{NR}n_{h,t}^{NR} \qquad (4)$$

where parameters/variables have their usual meanings. The first order conditions determine the non-Ricardian household demand for goods and houses, and their supply of labour[4].

[4] Mankiw (2000), Galí, et al. (2007), Straub and Coenen (2004) and Marto (2013) are earlier examples. For a setup more similar to ours, see Alpanda and Zubairy (2016).

2.3 Entrepreneurs

Entrepreneurs are labelled 'E'. They are producers of intermediate goods (y_t) and houses (ih_t), with technologies:

$$y_t = \left[Z_{c,t}(n_{c,t}^R)^{\alpha}(n_{c,t}^{NR})^{1-\alpha}\right]^{1-u_c} (k_{c,t-1})^{u_c} (k_{g,t-1})^{\varsigma} \tag{5}$$

and

$$ih_t = \left[Z_{h,t}(n_{h,t}^R)^{\alpha}(n_{h,t}^{NR})^{1-\alpha}\right]^{1-u_h-v_h} (k_{h,t-1})^{u_h} (l_{t-1})^{v_h} \tag{6}$$

where $Z_{c,t}$ and $Z_{h,t}$ are sectoral productivities; α, u_c, u_h, ς and v_h are input shares. Goods production is assumed to be determined partially by public capital ($k_{g,t-1}$), converted from government investment which we model later in the public sector problem. This to reflect the substantial investment in infrastructures by the Chinese government, which is believed to have a profound impact on China's production over the past decades[5]. House production also involves the use of land (l_{t-1}).

Entrepreneurs have lifetime utility:

$$U_0^E = E_0 \sum_{t=0}^{\infty} (\beta^E)^t j_t \Gamma^E \ln(c_t^E - \vartheta c_{t-1}^E) \tag{7}$$

where parameters/variables have the usual meanings (however, $\beta^E < \beta^R$; $\Gamma^E \equiv \frac{1-\vartheta}{1-\vartheta\beta^E}$). Their budget constraint is:

$$\begin{aligned} & c_t^E + r_{kc,t}k_{c,t-1} + r_{kh,t}k_{h,t-1} + q_{l,t}l_t + (1+r_{t-1})b_{t-1}^E \\ & +w_{c,t}^R n_{c,t}^R + w_{h,t}^R n_{h,t}^R + w_{c,t}^{NR} n_{c,t}^{NR} + w_{h,t}^{NR} n_{h,t}^{NR} \\ = & \ \frac{y_t}{x_t} + q_{h,t} ih_t + b_t^E \end{aligned} \tag{8}$$

of which $q_{l,t}$ and $1/x_t$ are real prices of land and intermediate goods, and borrowing (b_t^E) is constrained by the discounted value of asset – put as collateral – at maturity:

$$b_t^E \leq \varpi^E \frac{E_t(q_{l,t+1} l_t)}{1+r_t} \tag{9}$$

where ϖ^E is the loan-to-value ratio.

Entrepreneurs maximise (7) by choosing c_t^E, $n_{c,t}^R$, $n_{h,t}^R$, $n_{c,t}^{NR}$, $n_{h,t}^{NR}$, $k_{c,t-1}$, $k_{h,t-1}$, l_t and b_t^E, subject to (5), (6), (8) and (9). The first order conditions determine their demand for goods, labour, rental (private) capitals and land. The collateral condition pins down the demand for loans. The production functions determine the supply of intermediate goods and houses at the optimum.

2.4 Capital producers

Private capital is produced by capital producers. In each period, they buy old undepreciated capital from Ricardian households and recast it with new investments $i_{c,t}$ and $i_{h,t}$. The accumulation process follows:

$$k_{c,t} - k_{c,t-1} = \varepsilon_t(i_{c,t} - adj_{i_c,t}) - \delta_{kc}k_{c,t-1} \tag{10}$$

[5] See also Guo, et al. (2015) and Wang and Wen (2017). A good example of this would be the rapid expansion of the highway and high-speed rail networks over the past 10-15 years.

and

$$k_{h,t} - k_{h,t-1} = \varepsilon_t (i_{h,t} - adj_{i_h,t}) - \delta_{kh} k_{h,t-1} \tag{11}$$

where the costs are:

$$adj_{i_c,t} = \frac{\zeta_{i_c}}{2} \left(\frac{i_{c,t}}{i_{c,t-1}} - 1 \right)^2 i_{c,t} \tag{12}$$

and

$$adj_{i_h,t} = \frac{\zeta_{i_h}}{2} \left(\frac{i_{h,t}}{i_{h,t-1}} - 1 \right)^2 i_{h,t} \tag{13}$$

ζ_{i_c} and ζ_{i_h} govern the marginal costs; ε_t is the shock to investment efficiency.

New capital produced is sold to Ricardian households (who thereupon rent it to entrepreneurs). Capital producers have lifetime profit:

$$E_0 \sum_{t=0}^{\infty} (\beta^R)^t V_{0,t} \Pi_t^K \tag{14}$$

where profit in each period is[6]:

$$\Pi_t^K = q_{kc,t} k_{c,t} + q_{kh,t} k_{h,t} - q_{kc,t} \left(1 - \delta_{kc}\right) k_{c,t-1} - q_{kh,t} \left(1 - \delta_{kh}\right) k_{h,t-1} - i_{c,t} - i_{h,t} \tag{15}$$

The optimisation problem is to find $i_{c,t}$ and $i_{h,t}$, subject to (10) – (13), such that (14) is maximised. The first order conditions determine the two investments, hence, the supply of private capitals.

2.5 Retailers

Retailers convert intermediate goods to differentiated final products sold to households. Differentiation in products creates market power whereby we assume retailers are able to set prices in the spirit of Calvo (1983) here. We follow Smets and Wouters (2003) to let the fraction who are able to reoptimise be $1 - \omega$, while the rest update prices following an indexation rule. Under the standard setup[7], the optimal pricing strategy of retailers implies the New Keynesian Phillips curve:

$$\pi_t = \frac{\beta^R}{1 + \beta^R \epsilon} E_t \pi_{t+1} + \frac{\epsilon}{1 + \beta^R \epsilon} \pi_{t-1} + \frac{(1-\omega)(1-\omega\beta^R)}{\omega(1+\beta^R\epsilon)} (-\hat{x}_t) + \hat{\varepsilon}_{\pi,t} \tag{16}$$

which relates inflation (π_t) to change in real marginal cost of production ($\hat{x}_t$), given expected future and past inflations. $\hat{\varepsilon}_{\pi,t}$ is the inflation shock.

Normalising the general price level to 1, the retailer profit in each period equals:

$$\Pi_t^{Gds} = (1 - \frac{1}{x_t}) y_t \tag{17}$$

[6] This is assumed to be owned by and fully transferred in the end of each period to Ricardian households. $V_{0,t} \equiv \lambda_t^R / \lambda_0^R$ in (14) is the marginal rate of substitution between incomes received in periods 0 and t.

[7] That is, the retailer lifetime profit $E_0 \sum_{t=0}^{\infty} \left(\omega\beta^R\right)^t V_{0,t} \left[\left(\frac{p_t(j)}{p_t}\right) - \frac{1}{x_t} \right] y_t(j)$, the indexation rule $p_{t+i}(j) = p_t(j) \left(\frac{p_{t+i-1}}{p_{t-1}}\right)^{\epsilon}$ (Christiano, et al., 2005), the demand aggregator $y_t(j) = \left[\frac{p_t(j)}{p_t}\right]^{-\theta} y_t$ (Dixit-Stiglitz, 1977), and the general price aggregator $p_t = \left[\int_0^1 p_t(j)^{1-\theta} dj\right]^{\frac{1}{1-\theta}}$. j is the index for individual firms; ϵ is the degree of inflation indexation; θ is the price elasticity.

We let this be transferred as a lump-sum to Ricardian households.

2.6 The public sector

2.6.1 Monetary policy

Monetary policy follows a Taylor rule[8]:

$$1 + R_t = (1 + R_{t-1})^{\rho_R} (1 + \pi_t)^{(1-\rho_R)\varphi_\pi} \left(\frac{gdp_t}{\overline{gdp}}\right)^{(1-\rho_R)\varphi_x} (1 + \bar{r})^{(1-\rho_R)} \varepsilon_{MP,t} \tag{18}$$

where nominal interest rate (R_t) responds to inflation and GDP (φ_π and φ_x), and is 'smoothed' by ρ_R. $\bar{r}$ is the steady-state value of real interest rate. $\varepsilon_{MP,t}$ is the monetary policy shock.

2.6.2 Fiscal policy

Fiscal policy is a combination of government spending ($g_{s,t}$) and government investment ($g_{i,t}$). The former is non-productive but it affects the marginal utility of housing as assumed in (1) and (3). The latter can be converted to public capital which enters (5); hence it affects the efficiency of goods production.

Government spending is determined exogenously, following:

$$g_{s,t} = \varepsilon_{gs,t} \bar{g}_s \tag{19}$$

where $\bar{g}_s$ is the steady-state value of $g_{s,t}$, and $\varepsilon_{gs,t}$ is the government spending shock.

Government investment stabilises GDP and public debt in the form of Leeper, et al. (2010), though here feedback goes to investment, rather than spending, as in Bhattarai and Trzeciakiewicz (2017):

$$g_{i,t} = \varepsilon_{gi,t} \bar{g}_i (\frac{gdp_t}{\overline{gdp}})^{\gamma_x} (\frac{b^G_{t-1}}{\overline{b^G}})^{\gamma_b} \tag{20}$$

where γ_x, $\gamma_b < 0$, and $\bar{g}_i$ and $\varepsilon_{gi,t}$ are the steady-state value of $g_{i,t}$ and the government investment shock, respectively.

The accumulation of public capital follows:

$$k_{g,t} - k_{g,t-1} = \varepsilon_t g_{i,t} - \delta_{kg} k_{g,t-1} \tag{21}$$

where capital depreciates at δ_{kg}. For simplicity we assume there is no cost; and the investment shock confronted by government is the same as that confronted by capital producers.

The whole government expenditure is financed by a lump-sum tax, land sales proceeds, and borrowing:

$$g_{s,t} + g_{i,t} + b^G_{t-1}(1 + r_{t-1}) = t_t + q_{l,t} l_t + b^G_t \tag{22}$$

of which the last is backed by expected land sales proceeds by the time the borrowing is due (subject to

[8] We use a Taylor rule here for the sake of circumventing the well-known difficulties in measuring monetary aggregates due to financial deregulation and innovation (A good example for China would be the recent boom in electronic payment methods such as Alipay and Wechat Pay). A money supply rule may well be used, though it would not alter the way the main variables in our model respond to a 'monetary policy shock'. The Taylor rule here can be interpreted as an implicit interest rate target the PBoC aims to achieve – by whatever means, whether using money supply, guidance, or other policy instruments.

ϖ^G):

$$b_t^G = \varpi^G \frac{E_t(q_{l,t+1} l_{t+1})}{1 + r_t} \tag{23}$$

$q_{l,t} l_t$ and b_t^G in (22) reflect the broad features of land financing in China we introduced at the beginning.

2.7 Market clearing

Let land supply of government be fixed at its steady-state level ($\bar{l}$), subject to a land supply shock ($\varepsilon_{l,t}$)[9]:

$$l_t = \varepsilon_{l,t} \bar{l} \tag{24}$$

GDP is defined to be:

$$gdp_t = y_t + \bar{q}_h ih_t \tag{25}$$

where $\bar{q}_h$ is the steady-state value of housing price.

Nominal and real interest rates are linked by the Fisher Equation:

$$R_t = r_t + E_t \pi_{t+1} \tag{26}$$

General equilibrium is reached when the following conditions are satisfied:

(Goods market clearing):

$$c_t + i_t + g_{s,t} = y_t \tag{27}$$

where $c_t = c_t^R + c_t^{NR} + c_t^E$, $i_t = i_{c,t} + i_{h,t} + g_{i,t}$.

(Housing market clearing):

$$h_t^R - (1 - \delta_h) h_{t-1}^R + h_t^{NR} - (1 - \delta_h) h_{t-1}^{NR} = ih_t \tag{28}$$

(Financial market clearing):

$$s_t = b_t^E + b_t^G \tag{29}$$

All shocks in the model are let follow an $AR(1)$ process.

3 Estimation

The model is estimated using the Bayesian method. Parameters known to be hard to identify or sensitive to model specification in the DSGE literature are calibrated for key features of the data to be met. Other parameters are estimated based on their prior distributions. The posteriors are found by the Monte Carlo optimisation routine (random-walk Metropolis), with a total of 1,000,000 draws from two independent Markov Chains, discarding for each of these the first 50% as burn-in. Convergence of the Markov Chains is diagnosed with the standard trace plots which confirm the chains are well mixed and there is no trend in the sampled values.

[9] Here, we let the land supply shock be partially affected by innovations to government investment. This is to reflect that, under land financing, government may finance unexpected expenditure on investment projects by selling more lands temporarily.

3.1 Calibration

We calibrate the discount factors, input shares, depreciation rates, loan-to-value ratios, and two steady-state values ($\bar{\phi}$ and $\bar{x}$).

We set the Ricardian household discount factor (β^R) to 0.974 to match the observed (mean) annual interest rate of 2.65%. The entrepreneur discount factor (β^E) is set to 0.97 which is just below β^R[10]. The share of private capital for goods production (u_c) is set to 0.53, which echoes Bai and Qian (2010). The share of public capital (ς) is set to 0.22 to follow Guo, et al. (2015), which is consistent with Wang and Wen (2017). Unfortunately, there is no direct evidence for shares in the housing sector. Here we set the capital share (u_h) to 0.2 and the land share (v_h) to 0.1[11]. The former is based on the assumption that house production is generally more labour intensive so capital share in this sector is low; the latter follows Davis and Heathcote (2005), by assuming land shares for house production are similar in modern economies. The depreciation rate of houses (δ_h) is set to 0.015, and the steady-state preference to housing ($\bar{\phi}$) is set to 0.16. The combination implies a steady-state residential investment ratio ($\frac{\bar{q}_h \overline{ih}}{\overline{gdp}}$) of 7.48%, which replicates the data of 7.49%. The depreciation rates of capital for goods production (both δ_{kc} and δ_{kg}) are set to 0.1 following Wang and Wen, while that for house production (δ_{kh}) is set to 0.12 – somewhat higher, to reflect the shorter service life of construction machinery (Iacoviello and Neri, 2010). The loan-to-value ratio of entrepreneurs (ϖ^E) is set to 0.6 to match the average liability ratio of industrial enterprises over the sample period (around 0.58). The same value is assigned to the LTV of government (ϖ^G), assuming that the public sector is at least as capable in accessing to loans. The steady-state price markup to intermediate products ($\bar{x}$) is set to 1.1 as estimated by Liu and Ma (2015). Table 1 summarises the calibrated parameters.

In Table 2 we compare the key steady-state features of our model to those of the data. We find the calibrations replicate the macro-evidence reasonably well.

Table 1: Calibrations

Parameter	Value	Parameter	Value
β^R	0.974	δ_{kc}	0.1
β^E	0.97	δ_{kh}	0.12
u_c	0.53	δ_{kg}	0.1
ς	0.22	$\bar{\phi}$	0.16
u_h	0.2	ϖ^E	0.6
v_h	0.1	ϖ^G	0.6
δ_h	0.015	$\bar{x}$	1.1

Table 2: Steady-state features

Features	$4\bar{R}-1$	$\bar{c}/\overline{gdp}$	$\bar{\imath}/\overline{gdp}$	$\bar{q}_h\overline{ih}/\overline{gdp}$	$\bar{g}_s/\overline{gdp}$
Model	2.67%	40.6%	37.6%	7.48%	14.3%
Data[a]	2.67%	40.1%	38.0%	7.49%	14.4%
a: Period between 2004 – 2016.					

[10] This is to motivate borrowing and ensure (9) in the steady state is binding.
[11] These imply a labour share of 70%, which mimics Bai and Qian (2010).

3.2 Priors

The estimated parameters are those about preferences, labour share and substitutabilities, elasticities, nominal rigidity, policies and shock processes. Since existing studies on the Chinese economy have yet to form consensus on priors of most of them, we refer to those established in the DSGE literature[12]. It turns out that our choices are sufficiently diffuse for the Chinese data[13].

The habit in consumption (ϑ) follows a beta distribution with a mean of 0.5. μ follows a uniform distribution (within [-5; 5]) to reflect our agnostic view on whether government spending and housing are complements, substitutes, or separated. The share of Ricardian household labour (α) follows a beta distribution with a mean of 0.65 (Alpanda and Zubairy, 2016). The substitutabilities between labour skills (ξ^R and ξ^{NR}) follow a normal distribution around 0.5. The wage elasticities (η^R and η^{NR}) and investment costs (ζ_c and ζ_h) all follow a gamma distribution with means of 0.5, 0.5, 10 and 10, respectively. Inflation indexation (ϵ) and the Calvo parameter (ω) follow a beta distribution with means of 0.5 and 0.67. The interest rate responses to inflation (φ_π) and GDP (φ_x) are normally distributed around 1.5 and 0.15, while the smoothness of policy (ρ_R) follows a beta distribution with a mean of 0.75. The responses of government investment to GDP (γ_x) and debt (γ_b) are normally distributed around -0.07 and -0.4 (Leeper, et al., 2010). These are summarised in Table 3.

Table 4 lists the priors of the shock parameters which are standard in the literature.

Table 3: Priors and posteriors – structural parameters

	Prior			Posterior			
Parameter	Distribution	Mean	Std. Err.	Mode	Mean	2.5%	97.5%
ϑ	Beta	0.5	0.08	0.63	0.62	0.50	0.74
μ	Uniform	0	2.89	1.18	1.10	0.89	1.25
α	Beta	0.65	0.05	0.85	0.86	0.82	0.90
ξ^R	Normal	0.5	0.1	0.56	0.56	0.38	0.75
ξ^{NR}	Normal	0.5	0.1	0.51	0.52	0.32	0.71
η^R	Gamma	0.5	0.1	0.33	0.34	0.21	0.48
η^{NR}	Gamma	0.5	0.1	0.48	0.49	0.31	0.69
ζ_c	Gamma	10	2.5	3.76	4.01	2.71	5.31
ζ_h	Gamma	10	2.5	9.39	10.1	5.45	15.13
ϵ	Beta	0.5	0.2	0.48	0.64	0.26	0.97
ω	Beta	0.67	0.05	0.92	0.92	0.90	0.94
ρ_R	Beta	0.75	0.1	0.96	0.96	0.95	0.98
φ_π	Normal	1.5	0.1	1.60	1.60	1.42	1.78
φ_x	Normal	0.15	0.1	0.12	0.12	0.08	0.16
γ_x	Uniform	-0.07	0.05	-0.07	-0.08	-0.15	-0.00
γ_b	Uniform	-0.4	0.2	-0.01	-0.06	-0.14	-0.00

[12] Most are based on Smets and Wouters (2007) and Iacoviello and Neri (2010).

[13] Figure A.1 in Appendix compares the priors and posteriors. It is clear that the data have reshaped the distributions of most parameters quite substantially. Hence, there is no clear sign that our estimation was dominated by the priors in a major way.

Table 4: Priors and posteriors – shock processes

Parameter	Prior			Posterior			
	Distribution	Mean	Std. Err.	Mode	Mean	2.5%	97.5%
ρ_{Zc}	Beta	0.5	0.2	0.70	0.69	0.61	0.76
ρ_{Zh}	Beta	0.5	0.2	0.91	0.89	0.81	0.96
ρ_j	Beta	0.5	0.2	0.70	0.68	0.54	0.81
ρ_ϕ	Beta	0.5	0.2	0.94	0.89	0.77	0.99
ρ_ψ	Beta	0.5	0.2	0.50	0.51	0.14	0.88
ρ_ε	Beta	0.5	0.2	0.18	0.18	0.03	0.35
ρ_π	Beta	0.5	0.2	0.22	0.24	0.03	0.46
ρ_{MP}	Beta	0.5	0.2	0.50	0.51	0.29	0.74
ρ_{gs}	Beta	0.5	0.2	0.70	0.69	0.51	0.87
ρ_{gi}	Beta	0.5	0.2	0.99	0.99	0.99	0.99
ρ_l	Beta	0.5	0.2	0.36	0.33	0.16	0.49
ρ_{lg}	Beta	0.5	0.2	0.50	0.49	0.13	0.85
$100\sigma_{Zc}$	Inv. gamma	0.1	2	7.29	7.75	6.06	9.53
$100\sigma_{Zh}$	Inv. gamma	0.1	2	12.3	12.7	10.2	15.4
$100\sigma_j$	Inv. gamma	0.1	2	1.72	1.78	1.29	2.3
$100\sigma_\phi$	Inv. gamma	0.1	2	3.10	6.72	1.56	12.7
$100\sigma_\psi$	Inv. gamma	0.1	2	0.05	0.09	0.02	0.26
$100\sigma_\varepsilon$	Inv. gamma	0.1	2	19.0	20.3	14.5	26.6
$100\sigma_\pi$	Inv. gamma	0.1	2	0.32	0.32	0.22	0.44
$100\sigma_{MP}$	Inv. gamma	0.1	2	0.05	0.05	0.04	0.06
$100\sigma_{gs}$	Inv. gamma	0.1	2	3.11	3.21	2.61	3.85
$100\sigma_{gi}$	Inv. gamma	0.1	2	2.99	3.08	2.53	3.68
$100\sigma_l$	Inv. gamma	0.1	2	12.1	12.8	10.3	15.4

3.3 Data

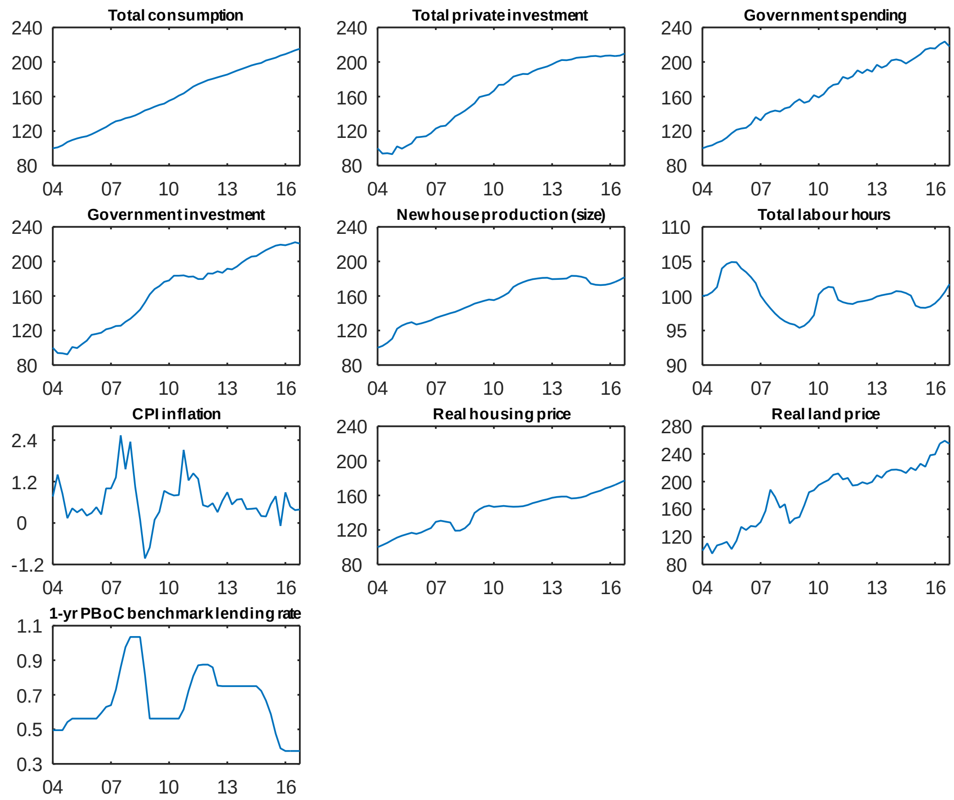
There are ten observable variables: total consumption, total private investment, government spending, government investment, new house production, total labour hours, inflation, real housing price, real land price, and nominal interest rate. The data are observed between 2004Q1 and 2016Q4. The sources include the Center for Quantitative Economic Research (Chang, et al., 2016), the National Bureau of Statistics of China, *China Statistical Yearbook of Labour*, and Oxford Economics[14]. Real variables are measured in per capita terms. All variables, except inflation and nominal interest rate, are in natural logarithm. The adjusted data are plotted in Figure 1. The measurement equations connecting the data to the log-linearised model are:

[14] The choices of the raw time series and the associated adjustments are detailed in Appendix B.

$$
\begin{bmatrix} \Delta\ln(c_t^{Obs}) \\ \Delta\ln(i_t^{Obs}) \\ \Delta\ln(g_{s,t}^{Obs}) \\ \Delta\ln(g_{i,t}^{Obs}) \\ \Delta\ln(ih_t^{Obs}) \\ \ln(n_t^{Obs}) \\ \pi_t^{Obs} \\ \Delta\ln(q_{h,t}^{Obs}) \\ \Delta\ln(q_{l,t}^{Obs}) \\ R_t^{Obs} \end{bmatrix} = \begin{bmatrix} \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{g}_{s,t} - \hat{g}_{s,t-1} \\ \hat{g}_{i,t} - \hat{g}_{i,t-1} \\ \widehat{ih}_t - \widehat{ih}_{t-1} \\ \hat{n}_t \\ \pi_t \\ \hat{q}_{h,t} - \hat{q}_{h,t-1} \\ \hat{q}_{l,t} - \hat{q}_{l,t-1} \\ \tilde{R}_t \end{bmatrix} \tag{30}
$$

where 'Obs' denotes the observables, '$\wedge$' and '$\sim$' are percentage and level deviations of a variable from its steady-state value, respectively.

Figure 1: Data used by measurement equations



3.4 Posteriors

Posteriors of the estimated parameters are compared to the priors in Tables 3 and 4. The data are proven quite informative, as for most parameters there is a clear shift in their distributions. The most obvious changes are from the labour parameters of Ricardian households, where the data suggest a clear dominance of their input share (α), and a higher wage elasticity ($1/\eta^R$). The cost of investing in the goods sector (ζ_c)

is much lower, while nominal contracts have even longer lives (ω). Monetary policy is rather smoothed (ρ_R), while government investment hardly responds to debt (γ_b). The data also identify a substituting relationship between government spending and housing (a positive estimate of μ). The shocks are mostly quite persistent (the $\rho' s$); but as their sizes (the $\sigma' s$) are considered, they are very different.

Table 5 compares the sample moments of the observable variables to those of the model calculated at the mode of the posteriors. Our research question would focus on the two fiscal instruments and house prices, and how these variables interact. It turns out that the model accounts very well the correlations of government spending and government investment between house prices. The persistence and volatility of the instruments are also well embraced by the 95% boundaries, though the persistence of house prices is slightly above the upper bound. Most other moments perform equally well. In the next section, we use the model at its mode to establish our evidence.

Table 5: Comparison between data and model moments

	$\Delta\hat{c}_t$	$\hat{\imath}_t$	$\Delta\hat{g}_{s,t}$	$\Delta\hat{g}_{i,t}$	$\Delta\widehat{ih}_t$	$\hat{n}_t$	π_t	$\Delta\hat{q}_{h,t}$	$\Delta\hat{q}_{l,t}$	$\tilde{R}_t$
Cross-correlation with $\Delta\hat{q}_{h,t}$										
Data	0.16	-0.06	0.07	0.19	0.11	-0.12	-0.64	1.00	0.13	-0.37
Model	0.23	0.07	0.00	0.06	0.03	0.06	-0.06	1.00	0.43	-0.04
2.5%	-0.05	-0.19	-0.31	-0.28	-0.26	-0.19	-0.32	1.00	0.16	-0.29
97.5%	0.50	0.34	0.25	0.42	0.31	0.31	0.22	1.00	0.66	0.20
Autocorrelation (Order=1)										
Data	0.33	0.04	-0.33	0.20	0.56	0.93	0.60	0.44	-0.08	0.89
Model	-0.03	0.28	-0.15	-0.01	-0.18	0.69	0.79	-0.04	-0.31	0.94
2.5%	-0.29	0.01	-0.39	-0.29	-0.42	0.47	0.61	-0.29	-0.53	0.86
97.5%	0.24	0.53	0.10	0.26	0.08	0.83	0.90	0.22	-0.06	0.98
Standard deviation (%)										
Data	0.73	2.66	3.47	3.08	2.46	2.36	0.64	2.75	10.1	0.17
Model	2.38	3.72	3.37	3.07	10.3	15.4	1.15	5.15	14.0	0.51
2.5%	1.93	2.63	2.73	2.43	8.15	10.6	0.74	2.95	10.5	0.19
97.5%	2.85	4.97	4.03	3.75	12.7	21.7	1.71	7.41	18.0	1.06

Note: model moments are calculated with 10,000 simulations of the same length as the data, generated by bootstrapping the shocks identified over the sample period, using the posterior mode of the estimated parameters.

4 Fiscal policy and house prices

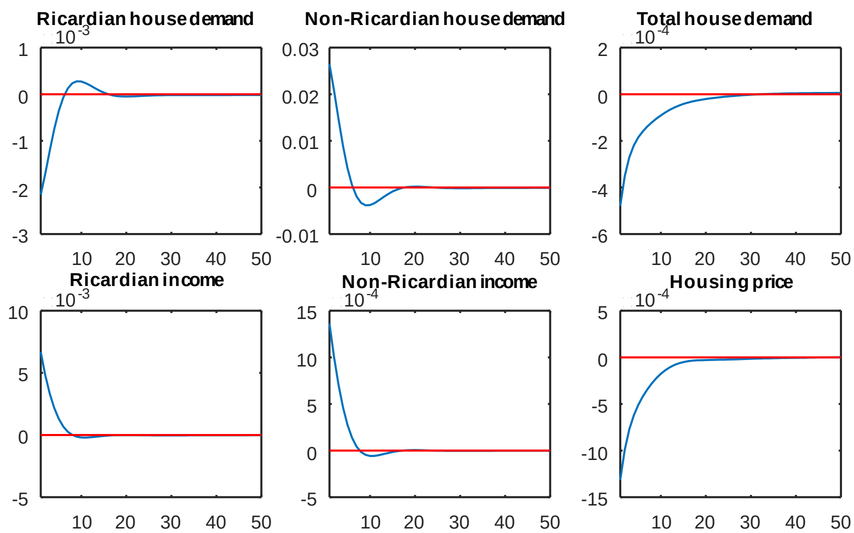
4.1 Is government spending capitalised into house prices?

As reviewed at the beginning of this paper, one possible way government spending could have affected house prices is via the ‘capitalisation effect’, whereby expansion of spending on public goods and services result in better living conditions capitalised into the value of houses. Such a ‘Tiebout hypothesis’ has implicitly assumed complementarity between government spending and housing. The subtext is that government spending could encourage purchase of houses, as households maximise utility by taking more housing when the marginal utility of it is boosted by the spending. The capitalisation effect is reflected by a positive response of house prices to a government spending shock.

While the literature has yet to establish a structural model for such a complementing relationship to be tested, our allowance for non-separability between government spending and housing in (1) and (3) nests the Tiebout hypothesis, for the first time ever, as a special case of $\mu < 0$. Interestingly, what we discover (as Table 3 has already reported) is that μ is well above zero, with a posterior mode of 1.18 and a 95% lower bound of 0.89. This suggests government spending and housing, instead of being complements, are substitutes to each other. While we believe this is the first evidence about the Tiebout hypothesis established with a full DSGE model, our finding with the Chinese data undermines its basis, and hence, its corollary of house price capitalisation.

Such a substituting relationship could mean that households are willing to trade living space with higher living quality provided by better public goods and services. In terms of impulse responses this would imply (on impact) a fall in the demand for houses should a positive government spending shock happen. This is precisely what we find with Ricardian households here, as Figure 2 illustrates. The demand of non-Ricardian households is affected in a similar way, but on this occasion it is dominated and reversed by a wealth effect from the rise in household income[15]. Nevertheless with the relevant steady-state ratios total demand falls, and so do house prices. Hence, government spending is not capitalised into house prices.

Figure 2: Impulse responses to a government spending shock



4.2 The effect of government investment

Government investment is the most frequently used fiscal instrument in China. The best known stimulus packages in the past decades include those proposed after the global crisis which many, given the background of land financing, believe to have catalysed the housing boom. The general perception is that the need for land sales proceeds implies that high land costs are passed on to home buyers as inflated house prices. However, few has been able to provide an explanation on how this might be happening in the context of a structural model.

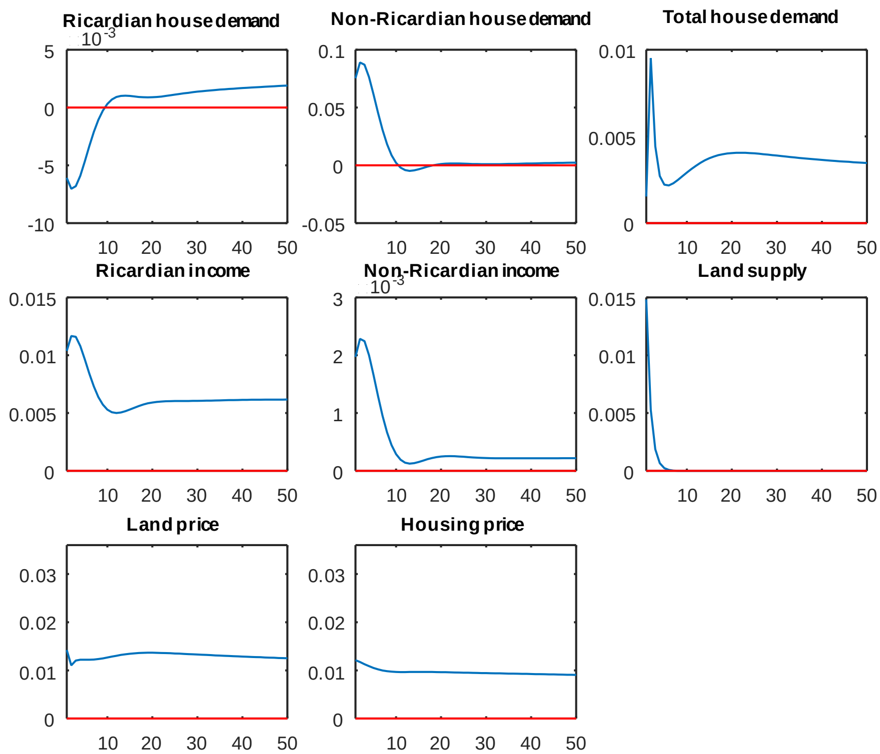
In our setting, government investment is transmitted to house prices via two channels. The first is by the wealth effect on housing demand as just mentioned but in this case it arises as government investment is converted to public capital that boosts output (Equations 21 and 5). The other is by a feedback to land

[15] The same wealth effect happens to Ricardian households. But as the impulse response shows it does not dominate the crowding-out effect of government spending there.

supply, which we assume here that an unexpected rise in the investment will lure the government into selling more land in the following period (Equations 24, and A.65 in Appendix A). The former has a tendency of raising house prices, while the latter tends to lower them. The net effect is clearly a joint outcome depending on the demand/supply elasticities in both the housing and land markets.

What we find here is that a government investment shock first raises both households' incomes and hence their demand for houses[16]; land supply rises on the other hand, but with a short-lived effect. The rise in housing demand causes to a rise in land demand; the rise in land supply increases production of houses. The overall effect in the housing market is a rise in house prices (as the wealth effect dominates the offsetting effect of land supply). The overall effect in the land market is similar so that land price also rises. The impact is illustrated by the impulse responses in Figure 3. Clearly, a positive government investment shock has a lasting, positive impact on house prices. The persistence is partially from the shock itself as already reported for the posteriors.

Figure 3: Impulse responses to a government investment shock



It is worth pointing that, while the above *happens to be* consistent with the perception that 'government investment leads land price to rise', the rise in land price is indeed *not the reason* why house prices have risen. As the last two paragraphs implied, the upward pressure on land price comes from the demand side as more land is needed when housing demand rises in response to a positive government investment shock. Apart from this the only other way government investment could have affected the land market would be via land supply, whose rise is a downward pressure on prices. Thus, government investment does *not* first lead to a rise in land price, which is then transmitted to house prices to reflect higher construction costs. Rather,

[16] The demand of Ricardian households rises with lags, presumably due to temporary substitution of consumption demand.

it reaches the housing market causing a rise in housing demand and *in consequence* a rise in land demand; and housing price and land price both rise to clear the markets. Since government investment is governed by the fiscal policy rule but not the government budget constraint, the above correlations hold regardless of the way such investment is financed, whether or not by land sales proceeds (provided that it does not affect the relative price of houses as we briefly remark in the conclusion). Thus, reduced form evidence built on correlations among these variables could have been statistical artefacts which misinterpret the wealth effect as a cost pass-through.

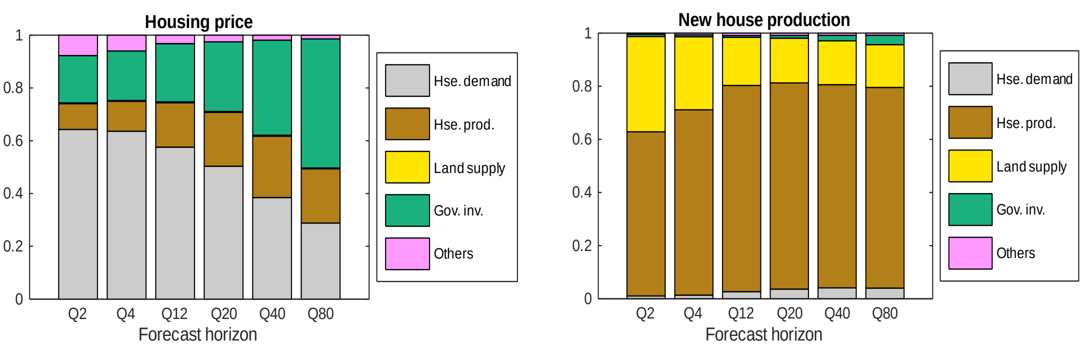
4.3 How much do the instruments count?

We now turn to evaluate the empirical importance of the fiscal instruments. Two assessments are conducted. The first is forecast error variance decomposition (FEVD), which predicts how each shock in the model contributes to the volatility of a variable over a chosen forecast horizon. The second is historical decomposition (HD), where we first calculate the shocks that actually occurred, and then use them to reproduce how each of them has contributed in shaping the sample data. We focus on housing price and house production as per the aim of this paper.

4.3.1 Forecast error variance decomposition

Figure 4 decomposes the forecast error variance of housing price and house production over a selection of time horizons covering the short run (less than 1 year ahead), the medium run (3 to 5 years ahead) and the long run (10 years and longer).

Figure 4: Forecast error variance decompositions



We find that housing price is dominated by the housing demand shock (in grey), which accounts for up to 65% of its variations, in the short run, in contrast to the second and third most important determinants – government investment (green) and housing productivity (brown), which account for some 20% and 10%, respectively. While section 4.1 has identified an impact of government spending, empirically it affects little for the shock is small; here, it is embraced by the remaining others (pink) which are mainly private investment, preference and goods-sector productivity. However as it moves towards the long run, government investment and housing productivity both become more influential. The former overtakes the housing demand shock and becomes dominating, accounting for up to 50% in the end. The housing demand shock remains important (ranked 2^{nd}), but its impact has fallen to under 30%. The remaining is picked up by housing productivity.

On the other hand, house production is always governed by housing productivity. The shock dominates less overwhelmingly in the short run (yet, still over 60%), and more (up to 75%) in the medium and long runs. The land supply shock (yellow) contributes to a substantial portion (over 35% on average) within one year and then levels off at near 20% thereafter. Neither housing demand nor government investment affects substantially, despite their negligible 'long-run effects' caused by the persistence of the shocks. Government spending and the remaining others are not affecting, either, due to the small shock sizes.

These findings are important advances on understanding what determines house prices in China with evidence from a DSGE model. As for what has become consensus in existing studies, we confirm that housing demand shocks are the main driver, whether they are assisted by monetary policy (e.g., Ng, 2015) or not (e.g., Wen and He, 2015; Liu and Ou, 2018). Yet, by allowing for non-separability between government spending and housing, and government investment linked to goods production and land supply, we uncover that fiscal policy – here, found to affect via government investment – is another key determinant suppressed in previous studies built on regular monetary models designed for developed economies. Nevertheless, we do find that this only affects the house prices, but not the house production.

4.3.2 Historical decomposition

We now decompose the sample data of housing price and house production into shocks which affected them to understand how cycles in the housing market were determined. The historical shocks we calculate are plotted in Figure 5. In Figure 6 we decompose the timelines of housing price and house production.

Figure 5: Historical shocks

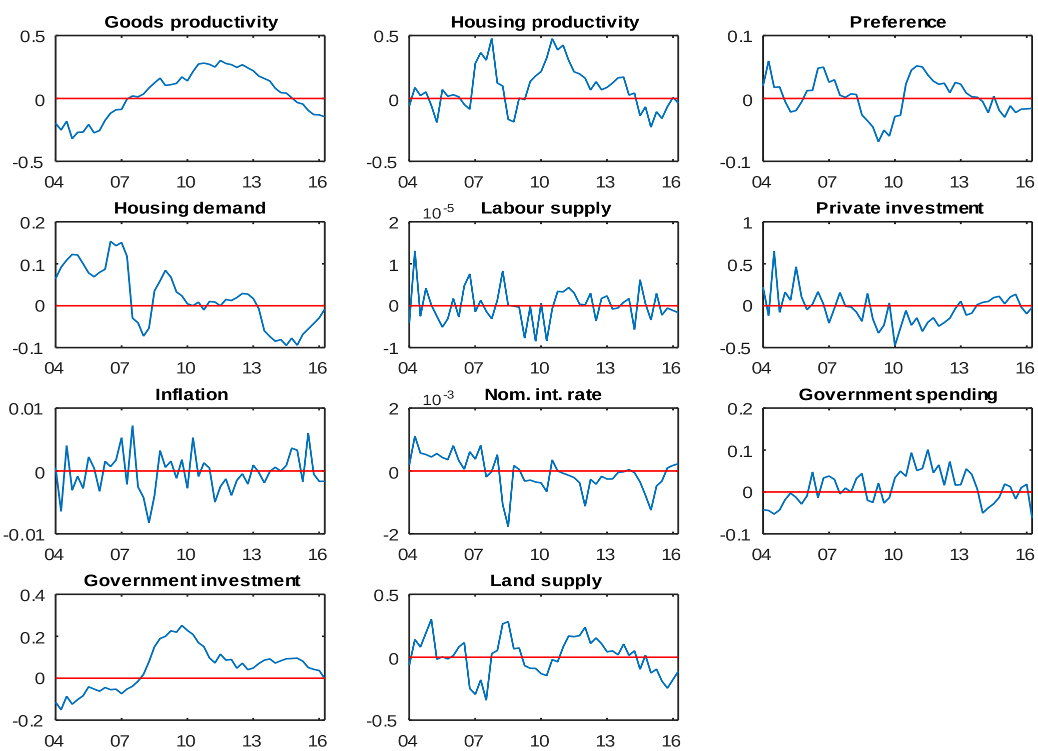
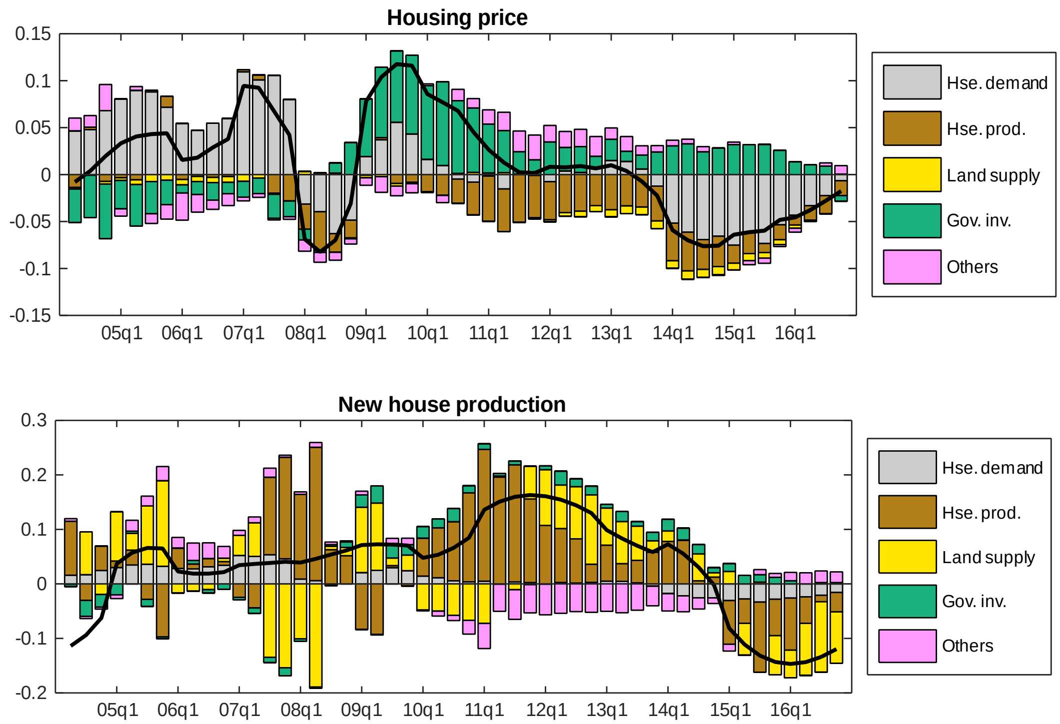


Figure 6: Historical decompositions



While there are two major episodes of boom and bust of house prices, we find the upswing between 2004 and 2007 was literally a boom in housing demand, which dominated the negative impact of contraction of government investment (See also Figure 5 for the shocks' evolution). The global crisis then reversed such demands, causing a deep (but short-lived) slowdown, deepened by improved productivity in housing, in 2008. The prices then rebounded very quickly and reached the peak of a new cycle in mid-2009, as government investment surged in response to the crisis (known as the '4 Trillion Stimulus Packages'), and demand was recovering. Since 2010, a series of property purchase restrictions came into force, which greatly suppressed demand; as government investment was stabilised gradually and housing productivity improved again, housing price levelled off at just above the steady-state level between 2011 and 2013. However, as housing demand was further impaired by tighter property purchase policies (known as the 'Five New Rules of the State Council')[17], prices fell again and found a trough (almost as deep as that during the crisis) in 2014. However, lacking strong supports from government investment (due to accumulated debt problems) on this occasion, a fast rebound did not happen. Instead, as the impact of the new policies was digested only very slowly, prices were corrected very slowly.

Turning to the cycles of production, we find booms and busts alternated much less frequently. Thus, production had been growing continuously since 2004 until a peak was reached in the end of 2011. The main contributing factor had been the rise in housing productivity, assisted a little by higher demand for houses, but offset in many occasions by a reduction in land supply. Production then started to decline as productivity reduced from 2012. However as land supply remained high the pace was modest. Nevertheless, as productivity and land supply both continued to fall and reversed in 2014 (and negative housing demand was pushing), a bust happened finally.

[17] Principles published on February 20^{th}, 2013, with details refined on March 1^{st}.

Thus, fiscal policy affected the house price cycle with investment but its role and influence were quite varied in different episodes: when government investment was below the steady-state level before the global crisis, it was a stabilising factor that prevented house prices from rising 'too immoderately' despite the boom caused by the huge demands; when it responded strongly to the crisis in 2009, it dominated the other factors and became the key destabiliser that led to the bigger boom that followed; since 2011, it had been maintained at just above the steady-state level – this time, it was the only factor corrected the market in the face of the pressure brought by tighter property purchase policies.

4.4 The fiscal multipliers

It would be helpful to know how effective these fiscal instruments are should policy-makers be confronted with targets these instruments could help to achieve. Since output is usually the variable of most concern for fiscal policy, and what this paper studies is how the latter affects housing price, we focus on the fiscal multipliers for these variables here.

We follow the recent literature (e.g., Mountford and Uhlig, 2009; Leeper et al., 2010; Zubairy, 2014) to account for the cumulative effects by calculating the present value multiplier, defined as the ratio of the sum of discounted values of change in one variable over T periods, to that of another over the same time horizon[18]. The calculation is reported in Table 6[19].

Both government spending and investment are very effective stimulus for output. The spending multiplier is greater than 1 at all horizons, which is clearly higher than those found by Mountford and Uhlig, and Leeper et al. (ranging from a negative value to no greater than 0.7 for the US). Few in the literature has studied the investment multiplier as it is rarely used in developed economies. But we find this instrument very powerful in China, being more than triple that of the spending multiplier, with the maximum effect being six times the initial investment happening one year after. By contrast, these instruments are much less effective in manipulating house prices: the spending multiplier is hardly significant at all horizons; the investment multiplier is positive and greater than 1, but its efficacy is weaker at longer horizons.

Table 6: Present value multipliers for output and house prices

	Q1	Q4	Q12	Q20	Inf.
	Government spending multiplier				
$\frac{PV(\Delta y)}{PV(\Delta g_s)}$	1.38	1.45	1.40	1.32	1.28
$\frac{PV(\Delta q_h)}{PV(\Delta g_s)}$	-0.06	-0.07	-0.08	-0.09	-0.09
	Government investment multiplier				
$\frac{PV(\Delta y)}{PV(\Delta g_i)}$	4.70	6.34	5.45	4.87	4.53
$\frac{PV(\Delta q_h)}{PV(\Delta g_i)}$	1.78	1.72	1.57	1.53	1.46

Since government spending and investment both affect output positively but their impacts on housing price are opposite, there is a combination of them which allows policy-makers to deliver a desired output

[18] The formula we use is: $\frac{PV(\Delta Y)}{PV(\Delta X)} = \frac{E_t \sum_{i=0}^{T}(1+r^{ss})^{-i}(Y_{t+i}-\bar{Y})}{E_t \sum_{i=0}^{T}(1+r^{ss})^{-i}(X_{t+i}-\bar{X})} \approx \frac{E_t \sum_{i=0}^{T}(1+r^{ss})^{-i}\hat{Y}_{t+i}}{E_t \sum_{i=0}^{T}(1+r^{ss})^{-i}\hat{X}_{t+i}} \frac{\bar{Y}}{\bar{X}}$. The calculation in Table 6 has used the sample mean of output-spending ratio and output-investment ratio as proxies for the corresponding steady-state ratios.

[19] We also calculated the impact multipliers, which give similar numbers.

without disturbing house prices, at least theoretically. Thus, any expansionary/contractionary fiscal policies need not result in unintended turbulence of house prices. Of course, how such instruments should be combined would depend on the specific targets, considering both the end objectives and time efficiency. Yet from what we calculate here, it seems that if fiscal expansion is not to destabilise the housing market, it should count more on government spending.

5 Conclusion

In this paper we investigated the role of fiscal policy in the determination of the Great Housing Boom of China. We considered both government spending and government investment – both of which are frequently used in practice, but widely muted in existing work in this area. Our paper fills this gap.

Thus, by estimating a canonical DSGE model which we extend to embrace non-separability between housing and government spending and a fiscal rule governing government investment, we find: a) government spending crowds out housing consumption but empirically it hardly affects housing price; b) government investment (second to housing demand) is a key determinant of house prices in the short-to-medium run, and it becomes dominating in the long run. Historically, this was also what caused the rebound of house prices when demand for houses was muted after the global crisis; c) both government spending and government investment are effective instruments for manipulating output, but the two have opposite impacts on house prices. Unless policy is to deliver a drastic improvement on output, stabilisation of the housing market would recommend a fiscal expansion with spending.

This is, to the best of our knowledge, the first time the role of fiscal policy is carefully accounted for in studies of China's housing price dynamics based on a DSGE model. That we find government investment is a key determinant establishes entirely new evidence that previous studies – by suppressing its role – have never discovered. Our finding seems consistent with the intuition that land financing has a direct impact on house prices as government investment is partially financed by land sales proceeds (as we model in the government budget constraint). However it is worth pointing that what really matters here is government investment itself, *not the way in which it is financed*. Government investment under our setting affects house prices via a wealth effect through its impact on output. Although land sales proceeds (and borrowing backed by them) form part of the government revenue, the government budget constraint only determines how much tax is needed when such proceeds are given. *Unless the collection of tax implies a change in the relative price of houses* – e.g., via an *ad valorem* house property tax, it hardly matters whether such investment is financed by land sales or others. Although a house property tax has not been levied nation-wide yet so our data do not carry information of its effect[20], it would be interesting to study how it would affect the role of fiscal policy should it come into play in the (likely near) future. We leave this topic for future research.

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Appendices

A Model

A.1 Ricardian households

Ricardian households maximise lifetime utility:

$$U_0^R = E_0 \sum_{t=0}^{\infty} (\beta^R)^t j_t \left\{ \begin{array}{c} \Gamma^R \ln\left(c_t^R - \vartheta c_{t-1}^R\right) + \phi_t \ln\left(h_t^R + \mu \frac{g_{s,t}}{q_{h,t}}\right) \\ -\frac{\psi_t}{1+\eta^R}\left[(n_{c,t}^R)^{1+\xi^R} + (n_{h,t}^R)^{1+\xi^R}\right]^{\frac{1+\eta^R}{1+\xi^R}} \end{array} \right\} \tag{A.1}$$

by choosing c_t^R, h_t^R, h_t^{NR}, $n_{c,t}^R$, $n_{h,t}^R$, $k_{c,t}$, $k_{h,t}$ and s_t, subject to budget constraint:

$$\begin{aligned} & c_t^R + q_{h,t}\left[h_t^R - (1-\delta_h) h_{t-1}^R\right] + q_{h,t}\left[h_t^{NR} - (1-\delta_h) h_{t-1}^{NR}\right] + q_{kc,t}k_{c,t} + q_{kh,t}k_{h,t} + s_t + t_t \qquad \text{(A.2)} \\ = \; & w_{c,t}^R n_{c,t}^R + w_{h,t}^R n_{h,t}^R + r_{h,t}h_t^{NR} + r_{kc,t}k_{c,t-1} + r_{kh,t}k_{h,t-1} + q_{kc,t}(1-\delta_{kc})k_{c,t-1} + q_{kh,t}(1-\delta_{kh})k_{h,t-1} \\ & +(1+r_{t-1})s_{t-1} + \Pi_t^K + \Pi_t^{Gds} \end{aligned}$$

The first order conditions are:

$$\frac{\partial L_t^R}{\partial c_t^R} : \Gamma^R j_t \frac{1}{c_t^R - \vartheta c_{t-1}^R} - \beta^R \Gamma^R \vartheta E_t\left[j_{t+1}\frac{1}{c_{t+1}^R - \vartheta c_t^R}\right] = \lambda_t^R j_t \tag{A.3}$$

$$\frac{\partial L_t^R}{\partial h_t^R} : j_t \frac{\phi_t}{h_t^R + \mu\frac{g_{s,t}}{q_{h,t}}} = j_t \lambda_t^R q_{h,t} - \beta^R (1-\delta_h) E_t j_{t+1} \lambda_{t+1}^R q_{h,t+1} \tag{A.4}$$

$$\frac{\partial L_t^R}{\partial h_t^{NR}} : 0 = j_t \lambda_t^{NR}\left[q_{h,t} - r_{h,t}\right] - \beta^R (1-\delta_h) E_t j_{t+1} \lambda_{t+1}^{NR} q_{h,t+1} \tag{A.5}$$

$$\frac{\partial L_t^R}{\partial n_{c,t}^R} : \psi_t (n_{c,t}^{R\;1+\xi^R} + n_{h,t}^{R\;1+\xi^R})^{\frac{\eta^R - \xi^R}{1+\xi^R}} n_{c,t}^{R\;\xi^R} = \lambda_t^R w_{c,t}^R \tag{A.6}$$

$$\frac{\partial L_t^R}{\partial n_{h,t}^R} : \psi_t (n_{c,t}^{R\;1+\xi^R} + n_{h,t}^{R\;1+\xi^R})^{\frac{\eta^R - \xi^R}{1+\xi^R}} n_{h,t}^{R\;\xi^R} = \lambda_t^R w_{h,t}^R \tag{A.7}$$

$$\frac{\partial L_t^R}{\partial k_{c,t}} : j_t \lambda_t^R q_{kc,t} = \beta^R (1-\delta_{kc}) E_t j_{t+1} \lambda_{t+1}^R (q_{kc,t+1} + r_{kc,t+1}) \tag{A.8}$$

$$\frac{\partial L_t^R}{\partial k_{h,t}} : j_t \lambda_t^R q_{kh,t} = \beta^R (1-\delta_{kh}) E_t j_{t+1} \lambda_{t+1}^R (q_{kh,t+1} + r_{kh,t+1}) \tag{A.9}$$

$$\frac{\partial L_t^R}{\partial s_t} : \beta^R E_t j_{t+1} \lambda_{t+1}^R \left[1 + r_t\right] = j_t \lambda_t^R \tag{A.10}$$

$$\frac{\partial L_t^R}{\partial \lambda_t^R} : c_t^R + q_{h,t}\left[h_t^R - (1-\delta_h)\, h_{t-1}^R\right] + q_{h,t}\left[h_t^{NR} - (1-\delta_h)\, h_{t-1}^{NR}\right] + q_{kc,t}k_{c,t} + q_{kh,t}k_{h,t} \tag{A.11}$$
$$+s_t + t_t = w_{c,t}^R n_{c,t}^R + w_{h,t}^R n_{h,t}^R + r_{h,t}h_t^{NR} + r_{kc,t}k_{c,t-1} + r_{kh,t}k_{h,t-1}$$
$$+q_{kc,t}\,(1-\delta_{kc})\,k_{c,t-1} + q_{kh,t}\,(1-\delta_{kh})\,k_{h,t-1} + (1+r_{t-1})s_{t-1} + \Pi_t^{Gds} + \Pi_t^K$$

A.2 Non-Ricardian households

Non-Ricardian households maximise utility in each period:

$$U_t^{NR} = \ln c_t^{NR} + \phi_t \ln\left(h_t^{NR} + \mu\frac{g_{s,t}}{q_{h,t}}\right) - \frac{\psi_t}{1+\eta^{NR}}\left[(n_{c,t}^{NR})^{1+\xi^{NR}} + (n_{h,t}^{NR})^{1+\xi^{NR}}\right]^{\frac{1+\eta^{NR}}{1+\xi^{NR}}} \tag{A.12}$$

by choosing c_t^{NR}, h_t^{NR}, $n_{c,t}^{NR}$ and $n_{h,t}^{NR}$, subject to budget constraint:

$$c_t^{NR} + r_{h,t}h_t^{NR} = w_{c,t}^{NR}n_{c,t}^{NR} + w_{h,t}^{NR}n_{h,t}^{NR} \tag{A.13}$$

The first order conditions are:

$$\frac{\partial L_t^{NR}}{\partial c_t^{NR}} : \frac{1}{c_t^{NR}} = \lambda_t^{NR} \tag{A.14}$$

$$\frac{\partial L_t^{NR}}{\partial h_t^{NR}} : \frac{\phi_t}{h_t^{NR} + \mu\frac{g_{s,t}}{q_{h,t}}} = \lambda_t^{NR} r_{h,t} \tag{A.15}$$

$$\frac{\partial L_t^{NR}}{\partial n_{c,t}^{NR}} : \psi_t\left(n_{c,t}^{NR\ 1+\xi^{NR}} + n_{h,t}^{NR\ 1+\xi^{NR}}\right)^{\frac{\eta^{NR}-\xi^{NR}}{1+\xi^{NR}}} n_{c,t}^{NR\ \xi^{NR}} = \lambda_t^{NR} w_{c,t}^{NR} \tag{A.16}$$

$$\frac{\partial L_t^{NR}}{\partial n_{h,t}^{NR}} : \psi_t\left(n_{c,t}^{NR\ 1+\xi^{NR}} + n_{h,t}^{NR\ 1+\xi^{NR}}\right)^{\frac{\eta^{NR}-\xi^{NR}}{1+\xi^{NR}}} n_{h,t}^{NR\ \xi^{NR}} = \lambda_t^{NR} w_{h,t}^{NR} \tag{A.17}$$

$$\frac{\partial L_t^{NR}}{\partial \lambda_t^{NR}} : c_t^{NR} + r_{h,t}h_t^{NR} = w_{c,t}^{NR}n_{c,t}^{NR} + w_{h,t}^{NR}n_{h,t}^{NR} \tag{A.18}$$

A.3 Entrepreneurs

Entrepreneurs maximise lifetime utility:

$$U_0^E = E_0\sum_{t=0}^{\infty}(\beta^E)^t j_t \Gamma^E \ln(c_t^E - \vartheta c_{t-1}^E) \tag{A.19}$$

by choosing c_t^E, $n_{c,t}^R$, $n_{h,t}^R$, $n_{c,t}^{NR}$, $n_{h,t}^{NR}$, $k_{c,t-1}$, $k_{h,t-1}$, l_t and b_t^E, subject to budget constraint, borrowing constraint, and technologies in the goods and housing sectors:

$$\begin{aligned} & c_t^E + r_{kc,t}k_{c,t-1} + r_{kh,t}k_{h,t-1} + q_{l,t}l_t \\ & +w_{c,t}n_{c,t}^R + w_{h,t}n_{h,t}^R + w_{c,t}n_{c,t}^{NR} + w_{h,t}n_{h,t}^{NR} + (1+r_{t-1})b_{t-1}^E \\ = \quad & \frac{y_t}{x_t} + q_{h,t}ih_t + b_t^E \end{aligned} \tag{A.20}$$

$$b_t^E \leq \varpi^E \frac{E_t(q_{l,t+1}l_t)}{1+r_t} \tag{A.21}$$

$$y_t = \left[Z_{c,t}(n_{c,t}^R)^{\alpha}(n_{c,t}^{NR})^{1-\alpha}\right]^{1-u_c}(k_{c,t-1})^{u_c}(k_{g,t-1})^{\varsigma} \tag{A.22}$$

$$ih_t = \left[Z_{h,t}(n_{h,t}^R)^{\alpha}(n_{h,t}^{NR})^{1-\alpha}\right]^{1-u_h-v_h}(k_{h,t-1})^{u_h}(l_{t-1})^{v_h} \tag{A.23}$$

The first order conditions are:

$$\frac{\partial L_t^E}{\partial c_t^E} : \Gamma^E j_t \frac{1}{c_t^E - \vartheta c_{t-1}^E} - \beta^E \Gamma^E \vartheta E_t \left[j_{t+1}\frac{1}{c_{t+1}^E - \vartheta c_t^E}\right] = \lambda_t^E j_t \tag{A.24}$$

$$\frac{\partial L_t^E}{\partial n_{c,t}^R} : \alpha(1-u_c)\frac{y_t}{x_t} = w_{c,t}^R n_{c,t}^R \tag{A.25}$$

$$\frac{\partial L_t^E}{\partial n_{c,t}^R} : (1-\alpha)(1-u_c)\frac{y_t}{x_t} = w_{c,t}^R n_{c,t}^R \tag{A.26}$$

$$\frac{\partial L_t^E}{\partial n_{h,t}^{NR}} : \alpha(1-u_h-v_h)q_{h,t}ih_t = w_{h,t}^{NR}n_{h,t}^{NR} \tag{A.27}$$

$$\frac{\partial L_t^E}{\partial n_{h,t}^{NR}} : (1-\alpha)\left(1-u_h-v_h\right)q_{h,t}ih_t = w_{h,t}^{NR}n_{h,t}^{NR} \tag{A.28}$$

$$\frac{\partial L_t^E}{\partial k_{c,t-1}} : u_c \frac{y_t}{x_t k_{c,t-1}} = r_{kc,t} \tag{A.29}$$

$$\frac{\partial L_t^E}{\partial k_{h,t-1}} : u_h \frac{q_{h,t}ih_t}{k_{h,t-1}} = r_{kh,t} \tag{A.30}$$

$$\frac{\partial L_t^E}{\partial l_t} : \beta^E E_t \left\{ j_{t+1}\lambda_{t+1}^E v_h \frac{q_{h,t+1}ih_{t+1}}{l_t} \right\} = j_t \lambda_t^E q_{l,t} - j_t \lambda_t^{Eb} \varpi \frac{E_t q_{l,t+1}}{1+r_t} \tag{A.31}$$

$$\frac{\partial L_t^E}{\partial b_t^E} : j_t\left(\lambda_t^E - \lambda_t^{Eb}\right) = \beta^E E_t\left[j_{t+1}\lambda_{t+1}^E(1+r_t)\right] \tag{A.32}$$

$$\begin{aligned} \frac{\partial L_t^E}{\partial \lambda_t^E} &: c_t^E + r_{kc,t}k_{c,t-1} + r_{kh,t}k_{h,t-1} + q_{l,t}l_t + w_{c,t}^R n_{c,t}^R + w_{h,t}^R n_{h,t}^R \\ & + w_{c,t}^{NR}n_{c,t}^{NR} + w_{h,t}^{NR}n_{h,t}^{NR} + (1+r_{t-1})b_{t-1}^E = \frac{y_t}{x_t} + q_{h,t}ih_t + b_t^E \end{aligned} \tag{A.33}$$

A.4 Capital producers

Capital producers maximise lifetime profit:

$$U_0^K = E_0 \sum_{t=0}^{\infty} (\beta^R)^t \frac{\lambda_t^R}{\lambda_0^R} \left[q_{kc,t} k_{c,t} + q_{kh,t} k_{h,t} - q_{kc,t} \left(1 - \delta_{kc}\right) k_{c,t-1} - q_{kh,t} \left(1 - \delta_{kh}\right) k_{kh,t-1} - i_{c,t} - i_{h,t} \right] \tag{A.34}$$

by choosing $i_{c,t}$ and $i_{h,t}$, subject to capital formation processes and costs of adjustments:

$$k_{c,t} - k_{c,t-1} = \varepsilon_t \left(i_{c,t} - adj_{_{c},t}\right) - \delta_{kc} k_{c,t-1} \tag{A.35}$$

$$k_{h,t} - k_{h,t-1} = \varepsilon_t \left(i_{h,t} - adj_{_{h},t}\right) - \delta_{kh} k_{h,t-1} \tag{A.36}$$

$$adj_{i_c,t} = \frac{\zeta_{_c}}{2} \left(\frac{i_{c,t}}{i_{c,t-1}^i} - 1 \right)^2 i_{c,t} \tag{A.37}$$

$$adj_{i_h,t} = \frac{\zeta_h}{2} \left(\frac{i_{h,t}}{i_{h,t-1}} - 1 \right)^2 i_{h,t} \tag{A.38}$$

The first order conditions are:

$$\begin{aligned} \frac{\partial L_t^K}{\partial i_{c,t}} \quad &: \quad q_{kc,t}\varepsilon_t \left[1 - \zeta_{_c} \left(\frac{i_{c,t}}{i_{c,t-1}} - 1 \right) \frac{i_{c,t}}{i_{c,t-1}} - \frac{\zeta_{_c}}{2} \left(\frac{i_{c,t}}{i_{c,t-1}} - 1 \right)^2 \right] \\ &= \quad 1 - \beta^R E_t \frac{\lambda_{t+1}^R}{\lambda_t^R} \left\{ q_{kc,t+1}\varepsilon_{t+1} \left[\zeta_{_c} \left(\frac{i_{c,t+1}}{i_{c,t}} - 1 \right) (\frac{i_{c,t+1}}{i_{c,t}})^2 \right] \right\} \end{aligned} \tag{A.39}$$

$$\begin{aligned} \frac{\partial L_t^K}{\partial i_{h,t}} \quad &: \quad q_{kh,t}\varepsilon_t \left[1 - \zeta_{_h} \left(\frac{i_{h,t}}{i_{h,t-1}} - 1 \right) \frac{i_{h,t}}{i_{h,t-1}} - \frac{\zeta_{_h}}{2} \left(\frac{i_{h,t}}{i_{h,t-1}} - 1 \right)^2 \right] \\ & 1 - \beta^R E_t \frac{\lambda_{t+1}^R}{\lambda_t^R} \left\{ q_{kh,t+1}\varepsilon_{t+1} \left[\zeta_{_h} \left(\frac{i_{h,t+1}}{i_{h,t}} - 1 \right) (\frac{i_{h,t+1}}{i_{h,t}})^2 \right] \right\} \end{aligned} \tag{A.40}$$

A.5 Retailers

Retailers convert intermediate goods to final goods by applying a constant markup to the real marginal cost. The standard Calvo pricing strategy, given the regular assumptions of price indexation rule $p_{t+i}(j) = p_t(j)(\frac{p_{t+i-1}}{p_{t-1}})^\epsilon$ (Christiano, et al., 2005), demand aggregator $y_t(j) = \left[\frac{p_t(j)}{p_t}\right]^{-\theta} y_t$ (Dixit-Stiglitz, 1977), and general price aggregator $p_t = \left[\int_0^1 p_t(j)^{1-\theta} dj\right]^{\frac{1}{1-\theta}}$, implies the New Keynesian Phillips curve:

$$\pi_t = \frac{\beta^R}{1+\beta^R\epsilon} E_t \pi_{t+1} + \frac{\epsilon}{1+\beta^R\epsilon} \pi_{t-1} + \frac{(1-\omega)(1-\omega\beta^R)}{\omega(1+\beta^R\epsilon)} (-\hat{x}_t) + \hat{\varepsilon}_{\pi,t} \tag{A.41}$$

The retailer profit is:

$$\Pi_t^{Ggds} = (1 - \frac{1}{x_t}) y_t \tag{A.42}$$

A.6 The public sector

The public sector implements a monetary policy in the form of a Taylor rule:

$$1+R_t = (1+R_{t-1})^{\rho_R}(1+\pi_t)^{(1-\rho_R)\varphi_\pi}\left(\frac{gdp_t}{\overline{gdp}}\right)^{(1-\rho_R)\varphi_x}(1+\bar{r})^{(1-\rho_R)}\varepsilon_{MP,t} \tag{A.43}$$

Government spending follows:

$$g_{s,t} = \varepsilon_{gs,t}\bar{g}_s \tag{A.44}$$

Government investment responds to GDP and debt:

$$g_{i,t} = \varepsilon_{gi,t}\bar{g}_i(\frac{gdp_t}{\overline{gdp}})^{\gamma_x}(\frac{b^G_{t-1}}{\overline{b^G}})^{\gamma_b} \tag{A.45}$$

where accumulation of public capital follows:

$$k_{g,t} - k_{g,t-1} = \varepsilon_t g_{i,t} - \delta_{kg}k_{g,t-1} \tag{A.46}$$

Total government expenditure is financed by a lump-sum tax, land sales proceeds, and borrowing:

$$g_{s,t} + g_{i,t} + b^G_{t-1}(1+r_{t-1}) = t_t + q_{l,t}l_t + b^G_t \tag{A.47}$$

of which the last is backed by expected land sales proceeds by the time the borrowing is due (subject to ϖ^G):

$$b^G_t = \varpi^G\frac{E_t(q_{l,t+1}l_{t+1})}{1+r_t} \tag{A.48}$$

A.7 Market clearing

Land is supplied by government and the level is fixed at the steady-state value ($\bar{l}$), subject to a land supply shock ($\varepsilon_{l,t}$):

$$l_t = \varepsilon_{l,t}\bar{l} \tag{A.49}$$

GDP is defined to be:

$$gdp_t = y_t + \bar{q}_h ih_t \tag{A.50}$$

where $\bar{q}_h$ is the steady-state value of housing price.

Nominal and real interest rates are linked by the Fisher Equation:

$$R_t = r_t + E_t\pi_{t+1} \tag{A.51}$$

General equilibrium is reached when the goods market, housing market and financial market are all cleared:

$$c^R_t + c^{NR}_t + c^E_t + i_{c,t} + i_{h,t} + g_{i,t} + g_{s,t} = y_t \tag{A.52}$$

$$h^R_t - (1-\delta_h)\,h^R_{t-1} + h^{NR}_t - (1-\delta_h)\,h^{NR}_{t-1} = ih_t \tag{A.53}$$

$$s_t = b_t^E + b_t^G \tag{A.54}$$

A.8 Shock processes:

The shock processes are:

Goods sector productivity:

$$\ln Z_{c,t} = \rho_{Zc} \ln Z_{c,t-1} + \ln u_{Zc,t} \tag{A.55}$$

Housing sector productivity:

$$\ln Z_{h,t} = \rho_{Zh} \ln Z_{h,t-1} + \ln u_{Zh,t} \tag{A.56}$$

Intertemporal preference:

$$\ln j_t = \rho_j \ln j_{t-1} + \ln u_{j,t} \tag{A.57}$$

Housing demand:

$$\ln \phi_t = (1 - \rho_\phi) \ln \bar{\phi} + \rho_\phi \ln \phi_{t-1} + \ln u_{\phi,t} \tag{A.58}$$

Labour supply:

$$\ln \psi_t = \rho_\psi \ln \psi_{t-1} + \ln u_{\psi,t} \tag{A.59}$$

Investment efficiency:

$$\ln \varepsilon_t = \rho_\varepsilon \ln \varepsilon_{t-1} + \ln u_{\varepsilon,t} \tag{A.60}$$

Inflation:

$$\ln \varepsilon_{\pi,t} = \rho_\pi \ln \varepsilon_{\pi,t-1} + \ln u_{\pi,t} \tag{A.61}$$

Monetary policy:

$$\ln \varepsilon_{MP,t} = \rho_{MP} \ln \varepsilon_{MP,t-1} + \ln u_{MP,t} \tag{A.62}$$

Government spending:

$$\ln \varepsilon_{gs,t} = \rho_{gs} \ln \varepsilon_{gs,t-1} + \ln u_{gs,t} \tag{A.63}$$

Government investment:

$$\ln \varepsilon_{gi,t} = \rho_{gi} \ln \varepsilon_{gi,t-1} + \ln u_{gi,t} \tag{A.64}$$

Land supply:

$$\ln \varepsilon_{l,t} = \rho_l \ln \varepsilon_{l,t-1} + \ln u_{l,t} + \rho_{lg} \ln u_{gi,t} \tag{A.65}$$

B Measurement, sources and adjustments of the raw data

The ten observable variables chosen are: total consumption, total private investment, government spending, government investment, new house production, total labour hours, inflation, real housing price, real land price, and nominal interest rate. The real variables are normalised by CPI and working-age population; inflation is defined as the quarter-on-quarter growth of CPI; real housing price and real land price are deflated by CPI; nominal interest rate is quoted as quarterly rate. All variables, except inflation and nominal interest rate, are in natural logarithm.

The data are observed between 2004Q1 and 2016Q4. Most are quarterly data collected directly from the Center for Quantitative Economic Research of the Federal Reserve Bank of Atlanta. Others are collected from the National Bureau of Statistics of China, *China Statistical Yearbook of Labour*, and Oxford Economics. For time series for which only annual data are available, we convert them to quarterly data using either the 'quadratic-match sum' or 'quadratic-match average' algorithms. Seasonal adjustment is applied to all time series except nominal interest rate. Table B.1 summarises the time series collected, their sources, and the relevant adjustments.

Table B.1: Measurement, sources & adjustments of the raw data

Observable variables	Time series collected	Source[c]	Divided by CPI?	Divided by pop.?	Seasonally adjusted ?
Total consumption	'NominalPrivC'	CQER	√	√	√
Total private investment	'NominalPrivGFCF'[a]	CQER	√	√	√
Government spending	'NominalGovtC'	CQER	√	√	√
Government investment	'NominalGovtGFCF'	CQER	√	√	√
New house production	'Completed Size of Comm. Resid. Houses'	NBSC	N.A.	√	√
Total labour hours	'Weekly Working Hours in Urban Area'[b]	CSYL	N.A.	√	√
Inflation	'CPI' (Quarter-on-quarter growth)	CQER	N.A.	N.A.	√
Real housing price	'Ave. Sales Price of Comm. Resid. Houses'	NBSC	√	N.A.	√
Real land price	'LandPrice'	CQER	√	N.A.	√
Nominal interest rate	'LendingRatePBC1year'	CQER	N.A.	N.A.	N.A.
	'Total Employment'	NBSC	N.A.	N.A.	√
	'Working-age Population'	OE	N.A.	N.A.	√

a: Net of residential investment.

b: Multiplied by 'Total Employment'.

c: CQER (Center for Quantitative Economic Research); NBSC (National Bureau of Statistics of China); CSYL (China Statistical Yearbook of Labour); OE (Oxford Economics).

C Comparison between priors and posteriors

Figure C.1: Priors (grey) and posteriors (black)

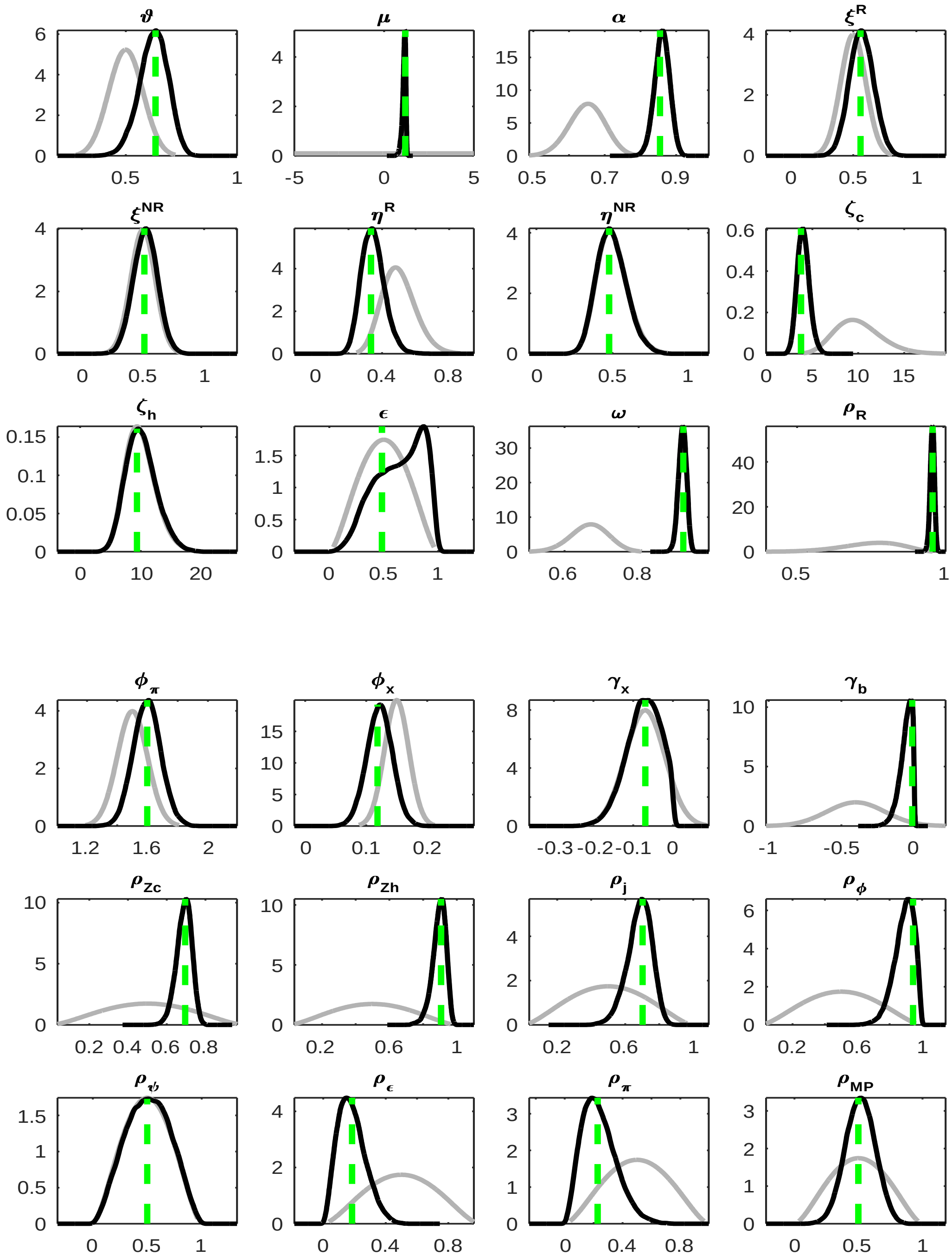

Figure C.1 (cont'd)