



Government Land Regulations and Housing Supply Elasticity in Urban China

Wenbin Huang*

Abstract

This paper studies the effects of government land regulations (GLR) on housing supply elasticity in urban China. We first extend the theoretical framework of Saiz (2010), then use land transaction microdata, satellite-generated data, and the construction of instrumental variables to analyze the marginal effect of GLR, and finally calculate the housing supply elasticity caused by GLR. Our analysis finds that GLR is an important reason for the overall inelasticity of housing supply in 272 Chinese cities, which reduces housing supply elasticity from 1.457 (elastic) to 0.872 (inelastic). Housing supply elasticity caused by GLR has declined the most in first-tier cities and the eastern regions. The marginal effect of land use regulation is greater than that of land allocation and supply regulations. The initial development level and natural geographic constraint of each city also matter in China's housing supply market.

Keywords: China, housing supply elasticity, land allocation regulation, land supply regulation, land use regulation

JEL codes: C24, R31, R38

I. Introduction

The determinants of housing supply elasticity are crucial for explaining the current global trend of rising house prices (Glaeser et al., 2006). A considerable body of literature focuses on the effect of government regulations (e.g., land use regulation) on housing supply and housing prices in various countries (Gyourko and Molloy, 2015; Molloy, 2020; Osman, 2020). In many countries around the world, the use of regulations on housing supply is a common government behavior, which is usually driven by common political incentives, such as protecting the interests of local residents and rising government “fiscal profit” (Bhavnani and Lacina, 2017; Glaeser et al., 2017; Liang et al., 2020).

*Wenbin Huang, Post-doctoral Researcher, Lingnan College, Sun Yat-sen University, China. E-mail: huangwb58@mail.sysu.edu.cn.

There are differences in regulations on housing supply in different countries. Many countries only have land use regulations, like the US (Saiz, 2010; Hsieh and Moretti, 2019), and some countries include land use, allocation, and supply regulations, like China (Huang and Wang, 2021). First, the Chinese central government unevenly distributes the national land supply quotas to provinces every year (i.e., land supply regulation). Second, local governments allocate land quotas to residential, industrial, commercial, and other uses (i.e., land allocation regulation). Lastly, local governments also impose restrictions on each piece of residential land use (i.e., land use regulation). This leads to several questions. Which kind of government land regulation (GLR) has a greater marginal effect on housing price and housing supply elasticity? To what extent do the three kinds of GLR reduce housing supply elasticity in urban China?

To answer the above questions, we construct a single-center city model by extending the framework of Saiz (2010), which includes land use, allocation, and supply regulations. In the theoretical model, housing supply elasticity is estimated by the identification of exogenous demand shocks. In the empirical design, we use satellite-generated data and land-transaction microdata to measure three kinds of GLR and natural geographic constraints in 272 Chinese cities. We also set up econometric models and construct several instrumental variables (IVs) to solve endogeneity problems. Based on the estimated results, we measure the housing supply elasticity of 272 cities and analyze the change in housing supply elasticity caused by GLR.

Our research yields the following key findings. First, GLR has a positive effect on housing prices and a negative effect on housing supply elasticity. The marginal effect of land use regulation is greater than that of land supply and allocation regulations. Second, after controlling GLR, the overall level of housing supply elasticity in 272 cities decreases from 1.457 (elastic) to 0.872 (inelastic), a decrease of more than 40 percent. Third, housing supply elasticity caused by GLR has declined the most in first-tier cities and the eastern region. Finally, the initial development level and natural geographic constraints of the city also matter in China's housing supply market.

In the existing literature, Saiz (2010) used American urban samples and Liu et al. (2019) used Chinese urban samples to investigate the effect of land use regulation and natural geographic constraints on housing supply. This paper is different from the above two kinds of literature in the following aspects. First, based on empirical facts about China, we depict a complete GLR system from the central government to local governments by simultaneously considering land supply, allocation, and use regulations. Existing studies only focus on land use regulation. Second, we put three kinds of GLR into a unified theoretical framework and compare the marginal effect of each kind of GLR on housing price after solving the endogenous problems. This is also different

from the earlier literature. Except for land use regulation, the existing literature also examines the effects of land supply regulation (Liang et al., 2016; Han and Lu, 2017; Su and Qian, 2020) and land allocation regulation (Cheng, 2020; Fan et al., 2020) on urban housing supply market in China. However, no literature has been found to analyze three kinds of GLR simultaneously. This paper therefore contributes to the literature on GLR and housing-supply elasticity.

The rest of the paper is structured as follows. Section II discusses the institutional background of GLR in China. Section III models the effect of land supply, allocation, and use regulations on housing supply elasticity. Section IV and Section V introduce empirical design and analysis of the estimation results, respectively. Section VI concludes.

II. Background

Since 1994, China has carried out the tax-sharing reform, which mainly divides all the taxes into central tax, local tax, and shared tax. Shared tax is the most important source of tax revenue. In this reform, the tax-sharing ratio between the central government and local governments is about 60 percent to 40 percent, resulting in an increasing strain on local fiscal revenues. In China, urban land is owned by the state, and other urban land rights are owned by local governments. Land revenue is owned entirely by local governments and it does not need to be turned over to the central government, so local governments have strong incentive to sell land.

However, large-scale urban land sales by local governments have affected domestic food supply security. The reason is that agricultural land is owned by villages collectively, and agricultural land ownership must be transferred to the state through land expropriation before it can be used for urban construction. To ensure the domestic food supply, the central government has set a strict red line for farmland and has formulated general and annual plans for land use to control the scale of land sales. In order to balance regional economic development, the central government began to increase inland land supply quotas in 2003, while reducing land supply quotas in the coastal area (Han and Lu, 2017; Fang and Huang, 2020). However, the coastal area is the area with net population inflow, and its demand for land supply quotas is greater than the inland area (Fang et al., 2021). As a result, the national land supply quota has a serious problem of spatial misallocation (Liang et al., 2016).

After the central government implements land supply regulation, local governments need to allocate these land quotas for residential, industrial, commercial, and other use, forming land allocation regulation. Residential land and industrial land are the most

important land uses. Corporate tax is an important fiscal revenue and China's official promotion tournaments encourage local governments to compete for enterprise resources (Li and Zhou, 2005; Yao and Zhang, 2015; Chen and Kung, 2016). Local governments tend to use low-price industrial land to attract enterprises. As a result, a land allocation pattern forms that is biased towards industrial land. On the one hand, local governments tend to increase the industrial land quota and sell it to enterprises at a relatively low price. On the other hand, local governments reduce the residential land quota to raise the sale price, increasing the revenue from land sales (Zheng and Shi, 2018).

After land allocation regulation, local governments also impose several restrictions on each piece of residential land, such as floor-area-ratio (FAR) regulation, building height limits, and so on. Land use regulation is multi-dimensional and is difficult to be measured directly. As FAR regulation is the most important one among the regulations in China, it is often used to measure the intensity of land use regulation (Cai et al., 2017; Tan et al., 2020). The FAR is the ratio of the total construction area of each piece of land to residential lot size, and FAR regulation is the restriction of FAR by local governments.

Furthermore, FAR regulation affects the housing supply through the quantity, cost, and progress of housing development. First, FAR regulation determines the building area available for development per unit of land, thus affecting housing supply. Second, stronger FAR regulation will lead to a smaller developable floor area per unit of land and higher housing construction cost, reducing housing supply. Third, local governments not only need to set legal FAR for each piece of land before land development and construction but also need to check whether the new buildings meet legal FAR, thus affecting the progress of housing development.

III. Theoretical framework

We introduce land supply, allocation, and use regulations into the framework described by Saiz (2010) to study the effects of GLR on housing supply elasticity. In this theoretical model, we assume that consumers are homogeneous, and developers face a perfectly competitive land market and acquire land from local governments (Jiang et al., 2009).

1. Consumer

We assume that all jobs in city i are concentrated in the central business district (CBD), and the total consumption by residents (C_i) is composed of city amenities (A_i) and personal consumption. Personal consumption is equal to wage (w_i) minus rent (r_i) and

commuting costs. For simplicity of analysis, we assume that each resident lives in a separate house, which makes the urban population (pop_i) equal to the amount of housing supply (H_i). The consumer utility function in city i can therefore be expressed as:

$$U(C_i) = (A_i + w_i - r_i - t \times d_i)^\rho, \quad (1)$$

where ρ is the consumption elasticity, t is the commuting cost of per unit distance, and d_i is the straight-line distance between the consumer's residence and the CBD in city i . Referring to Gaigné et al. (2012), we normalize the lot size of house building as 1 so that the shared homestead area of each house is $1/\bar{f}_i$, where $\bar{f}_i$ is the upper limit of legal FAR in city i , which represents the highest floor that can be reached in a house building. According to the Alonso-Muth-Mills models, each consumer attains utility via competition in the land market under conditions of non-arbitrage (Brueckner, 1987). The CBD therefore has the highest rent $r_i(0)$ and each consumer has to pay rent $r_i(d) = r_i(0) - t \times d_i$.

Because amenities and wages are important factors affecting population mobility, we write them as a function of the urban population $A_i = \bar{A}_i - \alpha\sqrt{pop_i}$ and $w_i = \bar{w}_i - \omega\sqrt{pop_i}$, where $\bar{A}_i$ and $\bar{w}_i$ are exogenous amenity and wage, $\alpha \geq 0$ is the parameter to adjust marginal congestion costs, $\omega \geq 0$ is the elasticity of wage to the change of urban population. In the asset market steady-state equilibrium, housing price will equal the discounted value of rent: $P_i(d) = r_i(d)/I$, where I is the discounted rate. Assuming that the utility of the equilibrium (U) is normalized to zero, and then according to $pop_i = H_i$, we can obtain the housing demand function of consumers living in CBD:

$$\sqrt{H_i} = \frac{\bar{A}_i + \bar{w}_i}{\alpha + \omega} - \frac{I}{\alpha + \omega} \times P_i(0), \quad (2)$$

where $P_i(0)$ is the housing price in CBD. Equation (2) reflects that the external demand shock (such as amenities and wages) causes the demand curve in the local equilibrium model to shift. We can therefore estimate housing supply elasticity based on Equation (2). The housing supply not only is limited by the undevelopable land area (such as areas affected by natural geographical constraints and protected farmland areas) but also is affected by a variety of GLRs. The GLRs include land supply, allocation, and use regulations. If the housing demand factors are fixed, a higher proportion of developable land (θ_i), a larger land supply quota allocated by the central government (δ_i), a greater residential land quota allocated by local governments (τ_i), and higher legal FAR ($\bar{f}_i$) can increase housing supply (H_i). If we regard the city as a circle with the CBD as its core and R_i as its radius, π is the pi ($= 3.14$), then we can obtain the city radius:

$$R_i = \sqrt{\frac{H_i}{\pi\theta_i\tau_i\delta_i\bar{f}_i}}. \quad (3)$$

2. Developer

Suppose the developer buys land at a unit price $LC(d)$, and spends the construction cost of per unit land $CC(f)$ to build the amount of housing $N(f)$, then sells to consumers at a price $P(d)$, where f is the real FAR of the developer and can not exceed legal FAR. $N(f)$ is the concave function satisfying $N'(f) > 0$ and $N''(f) < 0$, and $CC(f)$ is the convex function satisfying $CC'(f) > 0$ and $CC''(f) > 0$. The developer therefore obtains profit per unit of land: $P(d) \times N(f) - CC(f) - LC(d)$. The developer's profit in a competitive market is zero, so we obtain the optimal FAR (mark as f^*) of the developer in equilibrium, and then calculate the optimal housing price of developer: $P^*(d) = CC(f^*)/N(f^*) + LC(d)/N(f^*)$. However, house building is constrained by legal FAR, so the unit housing price needs to be adjusted to $P(d) = CC(\bar{f})/N(\bar{f}) + LC(d)/N(\bar{f})$. Furthermore, according to Saiz (2010), the average housing price level ($\bar{P}_i$) is equal to the housing price within a radius of two-thirds of the CBD. We can therefore obtain the housing supply function of the developers:

$$\bar{P}_i = \frac{CC(\bar{f}_i)}{N(\bar{f}_i)} + \frac{t}{3I} \times \sqrt{\frac{H_i}{\pi\theta_i\tau_i\delta_i\bar{f}_i}}. \quad (4)$$

3. Equilibrium

According to Equations (2) and (4), the housing supply in city i under the equilibrium state is:

$$H_i = \left[\frac{\bar{A}_i + \bar{w}_i - I \times CC(\bar{f}_i)}{(\alpha + \omega) + t \times \sqrt{1/(\pi\theta_i\tau_i\delta_i\bar{f}_i)}} \right]^2. \quad (5)$$

Based on Equations (4) and (5), the land supply quota (δ_i), residential land quota (τ_i), and legal FAR cause the change in the housing supply elasticity through the housing supply and housing price. Among them, land supply and allocate regulations affect housing supply through the through urban residential land quota, while FAR regulation affects the amount of housing that can be built per unit of land.

First, we analyze the effect of FAR regulation on housing supply elasticity. According to Brueckner and Singh (2020), the intensity of FAR regulation is the ratio of the developer's optimal FAR to legal FAR, $\kappa_i = f_i^*/\bar{f}_i$. A larger κ_i means a larger gap between f_i^* and $\bar{f}_i$ and stronger FAR regulation. For the simplification derivation, we set $N(f) = f^\gamma$ and $CC(f) = f^\lambda$, where $0 < \gamma < 1$ and $\lambda > 1$. $\beta_i = \partial \ln P_i / \partial \ln H_i$ is the inverse elasticity of housing supply. It reflects the percentage change in housing price caused by 1 percent change in housing supply. We can therefore obtain the relationship between FAR regulation and housing supply elasticity:

$$\frac{\partial \beta_i}{\partial \kappa_i} = \frac{(2\lambda - 2\gamma + 1)\kappa_i^{\gamma-\lambda-1/2} \times (f_i^*)^{\lambda-\gamma} \times t \sqrt{H_i/(\pi\theta_i\tau_i\delta_i\bar{f}_i)}}{12I(\bar{P}_i)^2} > 0. \quad (6)$$

Equation (6) shows that the FAR regulation (κ_i) is proportional to β_i and inversely proportional to the housing supply elasticity ($1/\beta_i$). Suppose land supply and allocation regulations are fixed. In that case, stronger FAR regulation will lead to a smaller amount of houses that can be built per unit of land, thus reducing the housing supply elasticity. We therefore propose the first hypothesis.

Hypothesis 1: Greater FAR regulation (i.e., the stronger land use regulation) leads to the smaller housing supply elasticity.

Then, we analyze the effects of land supply and allocate regulations on housing supply elasticity. According to Equation (5), the relationship between land supply quota (δ_i), residential land quota (τ_i) and housing supply elasticity can be obtained as follows:

$$\frac{\partial \beta_i}{\partial \delta_i} = -\frac{CC(\bar{f}_i) \times t \sqrt{H_i / (\pi \theta_i \tau_i \delta_i^3 \bar{f}_i)}}{12I(\bar{P}_i)^2 \times N(\bar{f}_i)} < 0, \quad (7)$$

$$\frac{\partial \beta_i}{\partial \tau_i} = -\frac{CC(\bar{f}_i) \times t \sqrt{H_i / (\pi \theta_i \tau_i^3 \delta_i \bar{f}_i)}}{12I(\bar{P}_i)^2 \times N(\bar{f}_i)} < 0. \quad (8)$$

Equations (7) and (8) show that δ_i and τ_i are inversely proportional to β_i , and proportional to housing supply elasticity ($1/\beta_i$). Suppose land allocation and use regulations are fixed. In that case, the more land supply quotas are allocated by the central government, the larger area of urban residential land will be, which increases housing supply elasticity. If land supply and use regulations are fixed, and if more residential land quotas is allocated by local governments, this also increases housing supply elasticity. We therefore propose the second hypothesis.

Hypothesis 2: More land supply quotas and residential land quotas (i.e., relax land supply and allocate regulations) lead to greater housing supply elasticity.

IV. Empirical design

1. Model specification

To measure how much GLR reduces housing supply elasticity in urban China, we calculate and compare housing supply elasticity without and with GLR. In the absence of GLR, we consider the effects of housing supply, natural geographic constraint, and farmland protection on housing supply elasticity. Based on this, we introduce land use, allocation, and supply regulations to calculate the housing supply elasticity with GLR. China's per capita arable land is less than half of the world average, so the strict protection of farmland

is important to ensure domestic food security, and it is a rigid and stable constraint faced by local governments.¹ We therefore do not regard farmland protection as GLR in this paper.

According to Equation (5), housing supply is also affected by construction cost $CC(f)$. However, the data on construction cost are not available. We therefore regard construction cost as a time-invariant variable and eliminate it by difference. Based on the above analysis, the econometric model without GLR can be set as follows:

$$\Delta \ln P_i = \alpha + \bar{\beta} \times \Delta \ln H_i + \beta^g \times geography_i \times \Delta \ln H_i + \beta^p \times protect_i \times \Delta \ln H_i + region_i + \varepsilon_i, \quad (9)$$

where $\Delta \ln P_i = \ln(P_{2013}) - \ln(P_{2004})$ is the logarithmic difference of urban housing price between 2004 and 2013; $\Delta \ln H_i = \ln(H_{2013}) - \ln(H_{2004})$ is the logarithmic difference in the urban housing stock between 2004 and 2013; $geography_i$ is the proportion of natural geographical constraint in the municipal district; $protect_i$ is the proportion of farmland area in the municipal district; $region_i$ is a region dummy variable, for which west region = 1, central region = 2, and eastern region = 3; $\bar{\beta}$, β^g , and β^p are the estimated coefficients, α and ε_i are the constant term and error term, respectively. $\Delta \ln H_i \times geography_i$ and $\Delta \ln H_i \times protect_i$ capture $geography_i$ and $protect_i$'s potential impact on housing price through housing supply change. The inverse elasticity of the housing supply without GLR can therefore be expressed as: $\hat{\beta}_i = \bar{\beta} + \beta^g \times geography_i + \beta^p \times protect_i$.

We introduce use_p , $allocate_p$, and $supply_i$ into Equation (9), and the econometric model needs to be adjusted to:

$$\begin{aligned} \Delta \ln P_i = & \alpha + \bar{\beta} \times \Delta \ln H_i + \beta^g \times \Delta \ln H_i \times geography_i + \beta^p \times \Delta \ln H_i \times protect_i \\ & + \beta^u \times \Delta \ln H_i \times use_i + \beta^a \times \Delta \ln H_i \times allocate_i + \beta^s \times \Delta \ln H_i \times supply_i \\ & + region_i + \varepsilon_i, \end{aligned} \quad (10)$$

where β^u , β^a , and β^s are the estimated coefficients of GLR. $\Delta \ln H_i \times use_i$, $\Delta \ln H_i \times allocate_i$, and $\Delta \ln H_i \times supply_i$ capture use_i , $allocate_i$, and $supply_i$'s potential impact on housing price through housing supply change. The inverse elasticity of housing supply with GLR can therefore be expressed as: $\hat{\beta}_i = \bar{\beta} + \beta^g \times geography_i + \beta^p \times protect_i + \beta^u \times use_i + \beta^a \times allocate_i + \beta^s \times supply_i$.

2. Variable measurement

(1) Measure housing price ($\Delta \ln P$)

Housing price is the ratio of residential housing sales to sales area in a city, with data from NBS (2004a, 2013a). Because this yearbook was not released after 2013, we select

¹Available from: <http://www.fao.org/3/AC623E/ac623e0d.htm> (online; cited June 2022).

residential housing prices from 2004 to 2013.² The yearbook also published residential land sales and sales areas since 2005, and we calculate residential housing price in 2004 according to the following equation: (residential housing price in 2004)/(housing price including both residential and commercial real estate in 2004) = (residential housing price in 2005)/(housing price including both residential and commercial real estate in 2005). The housing price includes residential and commercial real estate in 2004 and 2005, and residential housing prices in 2005 are available directly from NBS (2005).

(2) Measure housing supply ($\Delta \ln H$)

As the housing stock in each city is not available directly in China, we refer to Liu et al. (2019) and use the product of per capita housing floor area and urban population to measure housing stock. The per capita housing floor area is from the CASS (2004, 2013), and the urban population is from NBS (2004b, 2013b). Although this method has some measurement errors, it reflects the housing stock in a city to a large extent. We use logarithmic differential processing to eliminate the time-invariant measurement error.

(3) Measure land use regulation (use)

With reference to Cai et al. (2017), we use FAR regulation to reflect land use regulation. According to Brueckner and Singh (2020), we use $\kappa_i = f_i^*/\bar{f}_i$ to measure FAR regulation. A larger κ_i means a larger deviation between developer's optimal FAR and legal FAR, it also reflects a stronger FAR regulation. However, the developer's optimal FAR is not observed. We cannot measure κ_i directly. As the coefficient of the land transaction price on legal FAR is positively correlated with κ_i (Brueckner et al., 2017), we use the microdata of land transactions in each city from 2004 to 2013 to obtain this coefficient. The land transaction data are from the China Index Academy, and the total land sample in this paper is 83,032 pieces of land.³

$$\ln R_{jdt} = \alpha_{idt} + \bar{\gamma} \times \ln \bar{f}_{jdt} + \gamma_i \times \ln \bar{f}_{jdt} \times D_i + D_i + D_t + \varepsilon_{jdt}, \quad (11)$$

where $\ln R_{jdt}$ and $\ln \bar{f}_{jdt}$ are the logarithm values of land transaction price and legal FAR, respectively; subplots j , i , d , and t represent land parcel, city, district, and year, respectively; γ_i is the estimated coefficient of $\ln \bar{f}_{jdt} \times D_i$ in city i ; $\bar{\gamma}$ is the estimated

²The reason for choosing 2004 is that the central government began to implement land supply regulation in favor of inland areas after 2003 (Liang et al., 2016; Fang et al., 2021). We also obtained residential housing prices in 2019 from Macroeconomic and Real Estate Database of State Information Center (<http://www.crei.cn>), and investigated the effect of GLR on housing supply elasticity from 2004 to 2019. We found that the three kinds of GLR still have significant positive (negative) effects on housing price (housing supply elasticity), and the marginal effect of land use regulation is greater than that of land allocation and supply regulations.

³Data are available from <http://www.chinaindexacademy.com/> (online; cited April 2022).

coefficient of legal FAR; D_i and D_t are dummy variables controlling the fixed effect of city and year, respectively. Based on the estimated results of Equation (11), we calculate $\hat{\kappa}_{ji} = (\gamma_i - \bar{\gamma}) / \ln \bar{f}_{ji}$. The $\hat{\kappa}_{ji}$ represents the deviation of the developer's optimal FAR and legal FAR of land parcel j in the city i , and $\kappa_i = \sum_{j=1}^J \hat{\kappa}_{ji} / J$, where J is the number of total land parcel. The mean level and standard deviation of $\hat{\kappa}_{ji}$ are 1.016 and 0.641, respectively.

(4) Measure land allocation regulation (allocate)

Residential and industrial land are the main uses for which land is allocated; the ratio of urban industrial, and residential land supply can reflect the intensity of land allocation regulation. The city-level data on residential and industrial land is from NBS (2004c, 2013c). Under the official promotion tournament and the fiscal decentralization system in China, local governments tend to increase industrial land and reduce the industrial land price to attract enterprises and complete the task of attracting investment. Correspondingly, residential land will be reduced to increase the residential land price, which can make up the total land sale revenue (Huang and Du, 2017; Zheng and Shi, 2018). A higher ratio of industrial and residential land supply therefore means stronger land allocation regulation.

(5) Measure land supply regulation (supply)

Because the central government began to form a land supply pattern in favor of the central and western regions after 2003, we refer to Han and Lu (2017) and use the following formula to measure land supply regulation in each city:

$$supply_i = \frac{\sum_{t=2001}^{2003} landsupply_{it}}{\sum_{t=2001}^{2003} landsupply_t} - \frac{\sum_{t=2004}^{2013} landsupply_{it}}{\sum_{t=2004}^{2013} landsupply_t}, \quad (12)$$

where $supply_i$ is land supply regulation of city i , $landsupply_{it}$ is the land supply quota of city i in year t and $landsupply_t$ is the national land supply quota in year t , with data from Ministry of Land and Resources (2001–2014). $supply_i \leq 0$ means land supply regulation has been relaxed after 2004; $supply_i > 0$ means land supply regulation has been strengthened after 2004. A larger value of $supply_i$ represents stronger land supply regulation.

(6) Measure natural geographic constraints (geography)

The natural geographic constraint is measured as the ratio of undevelopable land area in the municipal district. The stronger the natural geographic constraint is, the less land area can be developed in the city, which will reduce housing supply elasticity. Referring to Saiz (2010) and Wang et al. (2012), *geography* can be measured by summing up

the area of slopes over 15 degrees and the water area in a municipal district. The water size of area includes rivers, lakes, wetlands, and others. Based on 90m resolution digital elevation model data in 2009, we use ArcGIS technology to calculate the area of undevelopable land in each city accurately.

(7) Measure farmland protection (protect)

The constraint of farmland protection is the ratio of farmland area in the municipal district. The higher ratio of farmland area is, the stronger constraint of farmland protection will be, leading to weaker housing supply elasticity. Based on the remote sensing monitoring data of China's land use status of 1 km × 1 km grid in 2005, we use ArcGIS technology to calculate the farmland area of each city accurately. The remote sensing monitoring data are from the Resource and Environmental Science and Data Center of Chinese Academy of Sciences.⁴

Descriptive statistics of the above variables are shown in Table 1. First-tier cities show the biggest increase in housing prices from 2004 to 2013, followed by second-tier cities, third-tier cities, and fourth-tier cities. With regard to GLR, land use, allocation, and supply regulations in first-tier cities are strongest, followed by second-tier, third-tier, and fourth-tier cities. Thus, there is a close connection between the three kinds of GLR in each city.

Table 1. Descriptive statistics

Variables	All cities		First-tier cities		Second-tier cities		Third-tier cities		Fourth-tier cities	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
$\Delta \ln P$	1.189	0.272	1.230	0.205	1.212	0.289	1.193	0.288	1.118	0.207
$\Delta \ln H$	0.711	0.261	0.913	0.347	0.746	0.239	0.714	0.26	0.679	0.269
<i>use</i>	0.874	0.517	2.284	0.456	0.997	0.616	0.805	0.373	0.806	0.479
<i>allocate</i>	0.792	0.325	0.915	0.127	0.891	0.297	0.842	0.317	0.684	0.326
<i>supply</i>	-0.015	0.375	1.176	0.869	0.065	0.542	-0.062	0.219	-0.067	0.232
<i>geography</i>	0.196	0.160	0.281	0.098	0.188	0.185	0.166	0.13	0.214	0.149
<i>protect</i>	0.401	0.139	0.318	0.139	0.421	0.122	0.434	0.129	0.361	0.147

Source: The above variables are obtained from NBS (2004a, 2013a), NBS (2004b, 2013b), NBS (2004c, 2013c), CASS (2004, 2013), MFC (2004a, 2004b), land transaction microdata and satellite-generated data.

Notes: Because the Chinese government does not release an official list of city grading, we refer to Zhang et al. (2019) and categorize cities according to their urban population in 2013. We divide the urban population in 2013 into four levels: less than 0.5 million, 0.5 million to 1 million, 1 million to 10 million, and over 10 million, corresponding to the population of fourth-tier to first-tier cities, respectively. The first-tier includes four cities, the second-tier includes 66 cities, the third-tier includes 97 cities, and the fourth-tier includes 105 cities. The definitions of the variables are explained in Section IV. 2.

⁴Data are available from: <https://www.resdc.cn/> (online; cited April 2022).

3. Endogeneity and instrumental variables

We analyze endogeneity problems in Equation (10). There are three endogeneity problems in this paper: endogeneities of $\Delta \ln H$, *use*, and *allocate*. We think *supply* is exogenous to housing prices. The reason is that only the central government has the right to distribute the national land supply quota in China. Local governments cannot exploit more land than is allocated by the central government. It is therefore difficult for local governments to adjust their land supply quota in the short term, making *supply* exogenous to housing prices (Dong, 2016; Han and Lu, 2017).

First, we analyze the endogeneity between housing supply and housing price. Increasing housing supply can slow the rise in housing price, whereas rising housing price reduces consumer demand for housing, thus affecting housing supply. To solve this endogeneity problem, we construct the Bartik index for each city by referring to Saks (2008) and Brueckner et al. (2017) with data from the NBS (2004a, 2013a). The Bartik index is used as a proxy for labor demand shock, the predicted change (growth) in labor demand. It is a weighted average of national industry growth rates, and the weights are the share of an industry's employment (relative to total city employment). The Bartik index is based on the industrial structure of each city to predict labor demand, so it has a strong correlation with housing supply change. At the same time, the Bartik index reflects the growth rate of industrial employment in other cities, which does not directly affect the local housing price and has good exogeneity.

Second, we analyze the endogeneity between *use* (i.e., FAR regulation) and housing price. In the case of $f^* > \bar{f}$, appropriately increasing legal FAR can increase both land financial revenue and housing supply, then slow the rise of housing prices. However, increasing housing prices will raise the urban wage and attract labor inflow (Glaeser and Mare, 2001). The large labor inflow increases the management pressure (e.g., traffic congestion) of local governments, which leads to the motivation to lowering legal FAR to control the urban population (Saiz, 2010).

To solve this endogeneity problem, we refer to Liu et al. (2019) and select the longitude and latitude data for each city as the IV of FAR regulation. The urban longitude and latitude determine the solar height and midday shadow length on the winter solstice and major cold days, affecting the residential area's sunshine duration. The solar altitude angles of northern cities in winter are smaller than those of southern cities. To ensure the sunshine spacing required by the minimum sunshine standard for residential areas, northern cities need to adopt more strict legal FAR standards to limit building heights. Because the urban longitude and latitude are extrinsic to housing price and have a strong correlation with FAR regulation, the urban longitude and latitude can be used as an IV for *use*.

Lastly, we analyze the endogeneity between *allocate* and housing price. Under the official promotion tournament mode and the fiscal decentralization system in China, local governments reduce residential land supply and push up housing price. However, the rapid increase in housing price is not conducive to the healthy development of the urban economy, which in turn affects land allocate regulation. In view of this endogeneity problem, we choose the value-added tax (VAT) sharing ratio of each province and the central government as the IV. Since 1994, the reform of the tax sharing system has strained local finances and gradually formed a land allocation pattern in favor of industrial land, which then affected the housing supply. The VAT sharing ratio therefore meets the requirements of relevance and exogeneity of IV. The VAT sharing ratio is equal to the ratio of the VAT revenue of provincial city and county to the total VAT revenue organized by the provincial tax authorities. The VAT revenue data are from Ministry of Finance of China (2004a, b).

V. Empirical analysis

1. The effect of government land regulations on housing price

We use the ordinary least square (OLS) model to carry out baseline regression for Equations (9) and (10), and then use the two-stage least-square model to solve the endogenous problems of $\Delta \ln H$, *use*, and *allocate*. The dependent variable is housing price, and we analyze the effect of GLR on housing supply elasticity according to the estimated results of GLR on housing price.

(1) Baseline regression

Table 2 reports the OLS estimated results without considering endogeneity problems. In column (1), $\Delta \ln H$ has a significant positive effect on $\Delta \ln P$ when we do not introduce control variables. To study how the natural geographic constraint and farmland protection affect housing price through housing supply, we introduce $(\Delta \ln H \times \textit{geography})$ and $(\Delta \ln H \times \textit{protect})$ into the basic model. In column (2), the positive effects of $(\Delta \ln H \times \textit{geography})$ and $(\Delta \ln H \times \textit{protect})$ are significant at the 1 percent statistical level. This estimated result indicates that stronger *geography* and *protect* leads to higher housing prices and smaller supply elasticity.

With reference to Saiz (2010), we introduce $\Delta \ln H \times \textit{geography} \times \ln \textit{population}_{2000}$ and $\Delta \ln H \times \textit{coastal}$ to control the initial economic development level and ocean effect, respectively. In columns (3) and (4), both $\Delta \ln H \times \textit{geography} \times \ln \textit{population}_{2000}$ and $\Delta \ln H \times \textit{coastal}$ have a positive effect on housing price, but it is not significant. Furthermore, we introduce $\Delta \ln H \times \textit{use}$, $\Delta \ln H \times \textit{allocate}$ and $\Delta \ln H \times \textit{supply}$ to study

how GLR affects housing price through housing supply, and then analyze the effect of GLR on housing supply elasticity. In column (5), the interaction terms of the three types of land regulation are positive, and the estimated results of $\Delta \ln H \times use$ and $\Delta \ln H \times supply$ are significant. It shows that stronger GLR leads to higher housing prices and smaller housing supply elasticity.

Table 2. The effect of government land regulation on housing prices: Ordinary least square model

Variables	(1)	(2)	(3)	(4)	(5)
$\Delta \ln H$	0.359*** (0.092)	0.331*** (0.081)	0.264** (0.126)	0.322*** (0.082)	0.209*** (0.069)
$\Delta \ln H \times geography$		1.364*** (0.154)	1.120*** (0.383)	1.362*** (0.154)	0.541*** (0.150)
$\Delta \ln H \times protect$		0.464*** (0.173)	0.444** (0.175)	0.462*** (0.173)	0.050 (0.150)
$\Delta \ln H \times geography \times \ln population_{2000}$			0.021 (0.031)		
$\Delta \ln H \times coastal$				0.078 (0.088)	
$\Delta \ln H \times use$					0.398*** (0.046)
$\Delta \ln H \times allocate$					0.083 (0.055)
$\Delta \ln H \times supply$					0.110** (0.056)
Center (base group: West)	-0.092 (0.066)	0.009 (0.059)	0.008 (0.059)	0.010 (0.059)	-0.028 (0.050)
East (base group: West)	0.343*** (0.066)	0.345*** (0.058)	0.341*** (0.058)	0.324*** (0.062)	0.201*** (0.051)
R^2	0.228	0.410	0.411	0.412	0.590
F -value	26.463	37.008	30.862	30.935	47.341
Observations	272	272	272	272	272

Source: See Table 1.

Notes: *** and ** represent significance at the 1 and 5 percent levels, respectively. Robust standard errors are in parentheses. *Coastal* is a dummy variable: the coastal cities are marked with 1 and other cities with 0. The coastal cities include 49 cities, such as Tianjin and Shanghai.

Using the estimated results in column (5), we calculate the housing supply elasticities of 272 cities and find that the overall level of housing supply elasticity (1.489) is greater than 1. This result means that the overall housing supply in China is elastic if we do not solve the endogeneity problems. However, this result is inconsistent with the fact that housing prices in China have risen rapidly since 2004 (Liang et al., 2016), which means

the overall housing supply in China is inelastic. The endogeneity problems therefore cannot be ignored, otherwise, they will affect the accuracy of the estimated results in this paper.

(2) Solve the endogenous problems

Table 3 reports the estimated results for solving the endogenous problem of housing supply. According to Table 3, the F -values of the first-stage of weak IV tests are basically higher than the rule of thumb (F -value is 10), which means that the Bartik index can solve the endogenous problem of $\Delta \ln H$ very well. $\Delta \ln H$ still has a significant positive effect on $\Delta \ln P$, and the estimated coefficient of $\Delta \ln H$ is much higher than that in Table 2. This result indicates that the result of $\Delta \ln H$ will be underestimated if we do not solve the endogeneity problem.

Table 3. The effect of government land regulation on housing prices:
Endogeneity of housing supply

Variables	Solve endogeneity of $\Delta \ln H$				
	(1)	(2)	(3)	(4)	(5)
$\Delta \ln H$	2.811*** (0.655)	2.306*** (0.554)	2.444*** (0.795)	2.332*** (0.575)	1.432*** (0.400)
$\Delta \ln H \times \text{geography}$		1.187*** (0.280)	1.885** (0.940)	1.193*** (0.284)	0.673*** (0.231)
$\Delta \ln H \times \text{protect}$		0.211 (0.307)	0.959** (0.488)	0.216 (0.308)	0.013 (0.213)
$\Delta \ln H \times \text{geography} \times \ln \text{population}_{2000}$			0.755** (0.353)		
$\Delta \ln H \times \text{coastal}$				0.196* (0.102)	
$\Delta \ln H \times \text{use}$					0.293*** (0.077)
$\Delta \ln H \times \text{allocate}$					0.164** (0.082)
$\Delta \ln H \times \text{supply}$					0.050 (0.075)
Center (base group: West)	0.003 (0.134)	0.071 (0.112)	0.117 (0.135)	0.071 (0.113)	0.014 (0.072)
East (base group: West)	0.579*** (0.145)	0.534*** (0.119)	0.648*** (0.165)	0.587*** (0.140)	0.343*** (0.082)
Instrumental variable	Bartik index	Bartik index	Bartik index	Bartik index	Bartik index
F -value of first stage	19.997	18.135	8.451	17.317	14.581
Observations	272	272	272	272	272

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. Robust standard errors are in parentheses. The definitions of the variables are explained in Section IV. 2.

According to columns (3) and (4), the estimated results of $\Delta \ln H \times \text{geography} \times \ln \text{population}_{2000}$ and $\Delta \ln H \times \text{coastal}$ are positive and significant. This result shows that the cities with a larger population are more constrained by natural geography in their housing supply, and $\Delta \ln P$ of eastern coastal cities have a greater sensitivity to $\Delta \ln H$ than that in inland cities. The initial economic development level (e.g., urban population) and geographical location of each city therefore matter in China's housing supply market, which is consistent with Saiz (2010).

In column (5), both $\Delta \ln H \times \text{use}$ and $\Delta \ln H \times \text{allocate}$ have a significantly positive effect on $\Delta \ln P$, and the estimated result of $\Delta \ln H \times \text{supply}$ is insignificant. However, the estimated coefficient of $\Delta \ln H \times \text{geography}$ in column (5) is higher than that of *use*, *allocate*, and *supply*, which means that *geography* is also an important factor in China's housing supply market. As for the region dummy, $\Delta \ln P$ in the eastern and central regions is higher than the western region, and for the eastern region region this is highly significant at the 1 percent level.

Table 4 reports the estimated results for solving the endogenous problems of GLR and housing supply.⁵ In column (1), using urban longitude and latitude as the IV for *use*, the *F*-value of the first stage is 24.428, and the overidentification and underidentification tests are passed. $\Delta \ln H \times \text{use}$ has a significantly positive effect on $\Delta \ln P$, indicating that stronger land use regulation will push up housing prices by reducing housing supply, thus reducing housing supply elasticity and verifying hypothesis 1. After we solve the endogeneity of *use*, the estimated coefficient of $\Delta \ln H \times \text{use}$ increases from 0.293 to 0.454. Regarding *allocate* and *supply*, both $\Delta \ln H \times \text{allocate}$ and $\Delta \ln H \times \text{supply}$ have a positive effect on $\Delta \ln P$, but only the former is significant at the 10 percent statistical level. Although $\Delta \ln H$ still has a significantly positive effect on $\Delta \ln P$, the estimated coefficient (0.198) is very close to the estimated result in column (5) of Table 2, and much lower than the estimated result in column (5) of Table 3. The reason is that we have not solved the endogeneity of $\Delta \ln H$ in column (1) of Table 4.

In column (2), we only solve the endogeneity of *allocate*. The VAT sharing ratio can solve this endogeneity very well, and the *F*-value of the first stage is 18.842, which is higher than the rule of thumb (the *F*-value is 10). However, only $\Delta \ln H \times \text{allocate}$

⁵We have tried to introduce three IVs into the model simultaneously, but the estimated results are poor. The *F*-value of first stage is only 1.135, and the estimated results of each GLR are not significant. Both housing stock and GLR maybe endogenous, so we have tried to construct the instrument for the interacted terms (i.e., Bartik index interacts with urban longitude, urban latitude and VAT sharing ratio, respectively); each GLR still has positive effect on $\Delta \ln(P)$. As the urban population may have a regulatory effect on housing supply elasticity through GLR, we also introduce $\Delta \ln(H) \times \text{geography} \times \ln \text{population}_{2000}$ and $\Delta \ln(H) \times \text{protect} \times \ln \text{population}_{2000}$ into Table 4, and find that both of them have small but significant effects on housing prices.

have a significant positive effect on $\Delta \ln P$; the estimated results of $\Delta \ln H \times use$ and $\Delta \ln H \times supply$ are insignificant.

Table 4. The effect of government land regulation on housing prices:
Endogeneity of government land regulation and housing supply

Variables	Solve endogeneity of <i>use</i>	Solve endogeneity of <i>allocate</i>	Solve endogeneity of <i>use</i> and <i>allocate</i>	Solve endogeneity of $\Delta \ln H$ and <i>use</i>
	(1)	(2)	(3)	(4)
$\Delta \ln H$	0.198** (0.078)	0.121 (0.095)	0.200** (0.093)	0.921*** (0.351)
$\Delta \ln H \times geography$	0.462* (0.240)	0.117 (0.410)	0.463 (0.401)	0.456 (0.302)
$\Delta \ln H \times protect$	0.013 (0.183)	0.081 (0.272)	0.153 (0.289)	0.064 (0.208)
$\Delta \ln H \times use$	0.454*** (0.140)	0.027 (0.148)	0.246 (0.298)	0.452*** (0.168)
$\Delta \ln H \times allocate$	0.085* (0.049)	0.161*** (0.049)	0.126*** (0.041)	0.135** (0.065)
$\Delta \ln H \times supply$	0.082 (0.075)	0.150 (0.152)	0.297* (0.169)	0.160* (0.082)
Center (base group: West)	0.032 (0.046)	0.246*** (0.096)	0.234** (0.100)	0.011 (0.060)
East (base group: West)	0.189*** (0.050)	0.276*** (0.063)	0.327*** (0.081)	0.261*** (0.082)
Instrumental variables	Urban longitude Urban latitude	VAT sharing ratio	VAT sharing ratio Urban longitude Urban latitude	Bartik index Urban longitude Urban latitude
<i>F</i> -value of first-stage	24.428	18.842	4.360	5.621
Underidentification test (<i>p</i> -value)	34.624 (0.000)	16.079 (0.000)	14.783 (0.001)	10.690 (0.005)
Overidentification test (<i>p</i> -value)	1.161 (0.069)	Exactly identified	2.372 (0.124)	5.947 (0.015)
Joint significance test (<i>p</i> -value)	63.08 (0.000)	13.93 (0.003)	29.15 (0.000)	28.03 (0.000)
Observations	272	272	272	272

Source: See Table 1.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. Robust standard errors in parentheses. The 15 percent maximal instrumental variable size of two endogenous problems is 5.450. The estimated result is poor when we solve the endogeneity of $\Delta \ln H$ and *allocate* simultaneously. The null hypothesis of the joint significance test is that three kinds of GLR have no effect on $\Delta \ln P$, which is significantly rejected in this paper. The definitions of the variables are explained in Section IV. 2.

In column (3), we solve the endogenous problems of *use* and *allocate* simultaneously. The *F*-value of first-stage in weak identification test is 4.360, which is lower than the

15 percent maximal IV size of two endogenous problems 5.450. According to column (3), the estimated results of $\Delta \ln H \times allocate$ and $\Delta \ln H \times supply$ are significantly positive, which shows that relax *allocate* and *supply* will increase residential land supply, then decrease housing prices and increase housing supply elasticity. Therefore, hypothesis 2 is verified. Although we solve the endogenous problems of *use* and *allocate* simultaneously, the estimated result of $\Delta \ln H \times use$ is insignificant.

In column (4), we solve the endogenous problems of $\Delta \ln H$ and *use* simultaneously, and the *F*-value of the first stage is 5.621, which is higher than 5.450. The problem of weak IVs is therefore addressed in column (4), and the overidentification and underidentification tests is passed. From column (4), the estimated coefficient of $\Delta \ln H$ is 0.921, which is closer to the estimated result of Liu et al. (2019). By comparing the estimated results for columns (1) and (4), the estimated coefficient of $\Delta \ln H$ increases from 0.198 to 0.921. Three land regulations also have a good estimated result in column (4), and all of them are significantly positive. Although we do not solve the endogeneity of *allocate* in column (4), the estimated coefficient of $\ln(H) \times allocate$ is closer to that in columns (2) and (3) of Table 4.

Above all, three types of GLR have a positive effect on $\Delta \ln P$ and negative effect on housing supply elasticity. Regarding the estimated coefficients of GLR in column (4) of Table 4, *use* has the largest marginal effect on $\Delta \ln P$, followed by *supply*, and *allocate* is the least. The reason is that the three kinds of land regulation have different effects on real estate developers. Specifically, *use* directly affects the housing construction behavior of real estate developers through such channels as housing supply's quantity, cost, and development schedule (Liu et al., 2019). Specifically, (i) *use* determines the developable floor area of a unit of land, then influences the number of housing development; (ii) stronger *use* will increase housing construction cost per unit area, thus affect urban housing supply; (iii) *use* requires relevant government departments to review compliance strictly before and after housing development, which also affects housing development progress and urban housing supply. However, *allocate* and *supply* indirectly affect the land cost of real estate developers through the supply of urban developable residential land. As a result, urban housing supply is more sensitive to changes in *use*.

2. Robustness test

To test the robustness of the above estimated results, we adopt the following two approaches: we use an urban subsample and we change the measurement method of GLR. The urban subsample includes: first, deleting the sample with more than 50 percent changes in the urban administrative area from 2004 to 2013; second, deleting 5

percent of the samples at both ends of $\Delta \ln P$; third, deleting 5 percent of the samples at both ends of $\Delta \ln H$.

The adjusted measurement of GLR includes as follows. First, we extend the year of microdata of land transactions from 2014 to 2018 to remeasure *use*. Second, we use the ratio of residential and industrial land prices to remeasure *allocate*. The larger ratio reflects the stronger land allocation regulation (Yan and Feng, 2019). Third, we use $\widehat{supply}_i = \sum_{2001}^{2003} supplyratio_{it} / 3 - \sum_{2004}^{2013} supplyratio_{it} / 10$ to remeasure *supply*, where $supplyratio_{it}$ is the proportion of land quota of city *i* in year *t* to national land supply quota. The larger *supply* reflects stronger land supply regulation, which will push up housing prices and reduce housing supply elasticity. We also only consider the endogeneity of *use* in the robustness tests.

According to Table 5, the *F*-value of the first stage is greater than 10, and three types of GLR have a significantly positive effect on $\Delta \ln P$, which is consistent with the above estimated results. The marginal effect of *use* is also larger than that of *allocate* and *supply*, which is also consistent with the estimated results in column (4) of Table 4. Government land regulations therefore have a robust effect on housing price and housing supply elasticity.

Table 6 reports the estimated results obtained by the adjusted measurement of GLR. The positive effects of three types of GLR on housing price still exist but the significance of the estimated result is different. Compared with the estimated coefficients of GLR, the marginal effect of *use* is still greater than that of *allocate* and *supply*.

Table 5. Robustness test: Subsamples

Variables	Delete urban area change $\geq 50\%$	5% truncated of $\Delta \ln P$	5% truncated of $\Delta \ln H$
$\Delta \ln H \times use$	0.452* (0.259)	0.388** (0.186)	0.366** (0.183)
$\Delta \ln H \times allocate$	0.053** (0.024)	0.046*** (0.017)	0.033** (0.014)
$\Delta \ln H \times supply$	0.320** (0.145)	0.189** (0.094)	0.130 (0.082)
Control variables	Yes	Yes	Yes
<i>F</i> -value of first-stage	8.479	13.574	13.939
Observations	206	244	244

Source: See Table 1.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. The robustness tests are based on the solution of endogeneity of land use regulation. Robust standard error in parentheses.

Table 6. Robustness test: Measurement change

Variables	Adopt new use	Adopt new allocate	Adopt new supply
$\Delta \ln H \times use$	0.284* (0.163)	0.454*** (0.140)	0.371* (0.203)
$\Delta \ln H \times allocate$	0.030* (0.016)	0.085* (0.049)	0.034** (0.015)
$\Delta \ln H \times supply$	0.151* (0.082)	0.082 (0.075)	0.063 (0.078)
Control variables	Yes	Yes	Yes
F-value of first-stage	14.621	24.428	11.591
Observations	272	272	272

Source: See Table 1.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. The robustness tests are based on the solution of endogeneity of land use regulation. Robust standard error in parentheses.

3. Calculate housing supply elasticity

Considering the significance of GLR in Table 4, we select the estimated results in column (4) and use $\hat{\beta}_i = \bar{\beta} + \beta^g \times geography_i + \beta^p \times protect_i + \beta^u \times use_i + \beta^a \times allocate_i + \beta^s \times supply_i$ to calculate housing supply elasticities in 272 Chinese cities. The measured results are shown in Table 7.

Table 7. The heterogeneity of housing supply elasticity

	Housing supply elasticity			Observations
	Without considering GLR	Considering GLR	Degree of elasticity reduction (%)	
All cities	1.457	0.872	40.15	272
Classify by city tier				
First-tier cities	0.962	0.432	55.09	4
Second-tier cities	1.387	0.822	40.74	66
Third-tier cities	1.470	0.885	39.80	97
Fourth-tier cities	1.508	0.908	39.78	105
Classify by region				
Eastern region	1.486	0.817	45.02	112
Central region	1.487	0.910	38.80	107
Western region	1.334	0.848	36.43	53

Source: The author's calculation.

Notes: The elasticity without considering GLR is calculated as $1/(0.921 \times \Delta \ln H + 0.456 \times geography + 0.064 \times protect)$, the elasticity considering GLR is calculated as $1/(0.921 \times \Delta \ln H + 0.456 \times geography + 0.064 \times protect + 0.452 \times use + 0.135 \times allocate + 0.160 \times supply)$. The degree of elasticity reduction = (the elasticity without considering GLR – the elasticity considering GLR) / the elasticity without considering GLR $\times 100\%$. The reason why the elasticity of housing supply in the western region is lower than that in the eastern and central regions without considering GLR is that $\Delta \ln H$ and $geography$ in the western region are higher than those in the eastern and central regions. GLR, government land regulations.

Table 7 shows that several findings were obtained. First, after considering GLR, the overall level of housing supply elasticities in 272 cities changes from elastic (1.457) to inelastic (0.872), and its reduction is more than 40 percent.⁶ Without considering GLR, housing supply elasticity ranges from 0.626 to 3.899, with a mean value of 1.457 and a standard deviation of 0.538. Considering GLR, housing supply elasticity ranges from 0.334 to 1.898, with a mean value of 0.872 and a standard deviation of 0.288. Government land regulation is therefore an important factor that causes the overall inelasticity of housing supply in China.

Second, from urban heterogeneity, GLR reduces housing supply elasticity in first-tier cities (55.09 percent) more than that in other cities. If we do not consider GLR, housing supply elasticity in Beijing, Shanghai, Guangzhou, and Shenzhen is 0.694, 0.768, 1.453, and 0.933, respectively. After considering GLR, housing supply elasticity in the above four cities dropped to 0.334, 0.338, 0.595, and 0.460, respectively, which are much lower than the national average level (0.872). In addition, the overall level of housing supply elasticity in fourth-tier cities becomes inelastic when we consider GLR. The reason is that, although the central government has allocated more land quotas to the central and western regions since 2004, land use regulation and land allocation patterns whereby local governments favor industrial land are common in all cities, leading to the decrease in housing supply elasticity in fourth-tier cities after considering GLR.

Third, from the perspective of regional heterogeneity, housing supply elasticity caused by GLR in the eastern region had the largest decline (45.02 percent), followed by the central region (38.80 percent), and finally the western region (36.43 percent). If we take GLR into account, the central region has the highest overall level of housing supply

⁶The method of measuring housing supply elasticity in this paper is similar to that of Liu et al. (2019). Based on controlling land use regulation, Liu et al. (2019) measured housing supply elasticity in 265 cities from 2005 to 2013, and the average housing supply elasticity was 0.805. In this paper, we measure the housing supply elasticity in 272 cities from 2004 to 2013 based on controlling for three kinds of GLR. However, the average housing supply elasticity measured in this paper was 0.872, which is higher than 0.805. We believe that there are two reasons why the housing supply elasticity measured in this paper is greater than that of Liu et al. (2019). One reason is the difference in time range between the two papers. Liu et al. (2019) selected 2005–2013 whereas this paper selected 2004–2013. Compared with 2004, GLR in 2005 was stronger (Figure 1 of Han and Lu (2018)), resulting in GLR in 2005–2013 being stronger than GLR in 2004–2013, and the average housing supply elasticity from 2005 to 2013 is smaller than that from 2004 to 2013. The other reason is that the two papers differ in the measurement methods of urban housing supply stock. Liu et al. (2019) uses the population of municipal districts to measure urban housing supply whereas this paper adopts the population of the whole city. To compare directly with the measured results of Liu et al. (2019), we selected urban samples from 2005 to 2013 and remeasured the urban housing supply by using the population of municipal districts, and the average housing supply elasticity becomes 0.783 (smaller than 0.805).

elasticity, followed by the western region, and finally the eastern region. The reduction in housing supply elasticity caused by GLR in the eastern region is greater than that in the central and western regions. This result is consistent with the land supply pattern in favor of central and western regions in China since 2004.

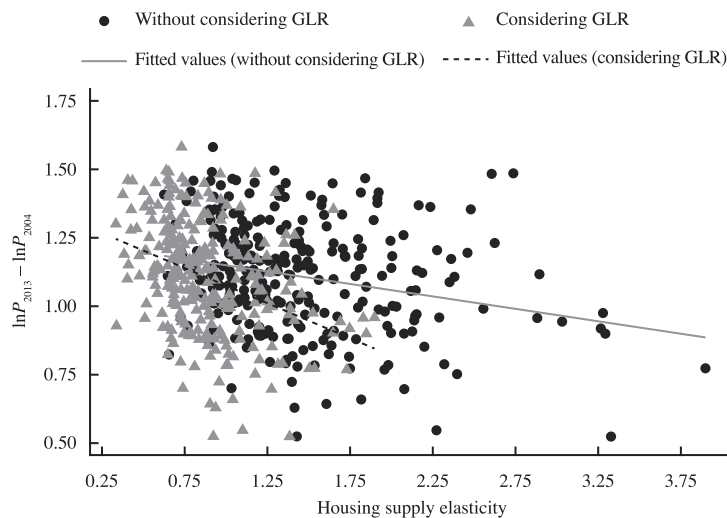
Based on the housing supply elasticities in 272 cities, we examine and plot the relationship between GLR and housing supply elasticity directly, as shown in Table 8 and Figure 1.

Table 8. The relationship between GLR and housing supply elasticity

GLR types	GLR $\geq$ GLR national average level		GLR < GLR national average level	
	Average elasticity	Observations	Average elasticity	Observations
Land use regulation	0.676	107	0.999	165
Land allocation regulation	0.788	40	0.886	232
Land supply regulation	0.737	69	0.918	203

Notes: The housing supply elasticities of 272 cities were calculated by the author. GLR, government land regulation.

Figure 1. Government land regulation and housing supply elasticity



Source: The author's calculation.

According to Table 8, the housing supply elasticity in the cities with stronger GLR is less than that in the cities with weaker GLR. The urban heterogeneity of land use regulation is most obvious, and the disparity in housing supply elasticity between the two subsamples is more than 0.3. According to Figure 1, the slope of the fitting curve between housing supply elasticity and housing price is significantly negative. However, compared with the fitting curve without considering GLR, the fitting curve considering GLR is steeper, which means that GLR makes housing prices more sensitive to housing supply elasticity.

VI. Conclusion

By extending the theoretical framework of Saiz (2010), this paper studied the effect of GLR on housing price and housing supply elasticity in China, which included land supply, allocation, and use regulations. Under the theoretical framework, we used satellite-generated data, land transaction micro-data, land allocation, and supply data at the city level to measure GLR and natural geographic constraints. We also constructed several instrumental variables to solve endogeneity problems and evaluate the marginal effect of GLR on housing price and housing supply elasticity between 2004 and 2013. Finally, we measured the housing supply elasticity of 272 cities and analyzed the change in housing supply elasticity considering and not considering GLR.

Empirically, GLR had a significant and robust positive effect on housing price, and negative effect on housing supply elasticity. After the introduction of GLR, the overall level of housing supply elasticity in 272 cities decreased from 1.457 (elastic) to 0.872 (inelastic), a reduction of more than 40 percent. Government land regulation significantly reduced (by more than 50 percent) housing supply elasticity in first-tier cities, followed by second-tier cities; third- and fourth-tier cities experienced the least impact. Similarly, the decline of housing supply elasticity in the eastern region caused by GLR was greater than in the central and western regions. We also found that the marginal effect of land use regulation on the housing price was greater than that of land allocation and supply regulations. The initial development level of the city and natural geographic constraints also matter in China's housing supply market.

The above conclusions have clear policy implications. Government land regulation reduces housing supply elasticity by about 40 percent, so relaxing GLR is an important method to slow down increasing housing prices, and especially to relax the intensity in first-tier cities and the eastern regions. From the perspective of land supply regulation,

the eastern region, as the net inflow of population, is subject to stricter land supply regulation, resulting in a spatial misallocation of land resources in China. The central government therefore needs to provide further support and improve the inter-provincial land index trading platform to improve the spatial allocation efficiency of land resources.

From the perspective of land allocation and use regulations, under the current financial system, local governments' dependence on "land finance" continues to deepen, forming a land-allocation pattern biased towards industry and urban heterogeneity of land use regulation. Land allocation and use regulations lead to the restriction of residential land supply and use, and drive increasing housing prices. Local governments therefore need to increase residential land supply moderately and improve the limits on the height of residential buildings, and then improve the efficiency of land allocation and use. While controlling housing prices from the demand side, the Chinese government also needs to pay more attention to the role of supply-side regulation. Through the organic links of land supply, allocation, and use regulations, the Chinese government can improve the allocation and utilization efficiency of land resources and promote the healthy development of the housing market.

By focusing on the effects of land use, allocation, and supply regulations on housing price and housing supply elasticity, this paper adopts a partial equilibrium analysis. A general analysis would need to consider how the central and local governments determine the intensity of GLR. In other words, a general analysis should introduce endogenous GLR into the theoretical framework. Furthermore, in the theoretical model of endogenous GLR, there should be an optimal GLR for each city. The study of optimal GLR is very important for the government's policymaking. We leave a full analysis of this topic to future research.

References

- Bhavnnani, R. R. and B. Lacina, 2017, "Fiscal federalism at work? Central responses to internal migration in India," *World Development*, Vol. 93, No. 3, pp. 236–48.
- Brueckner, J. K., 1987, "The structure of urban equilibria: A unified treatment of the Muth-Mills model," *Handbook of Regional and Urban Economics*, Vol. 2, pp. 821–45.
- Brueckner, J. K. and R. Singh, 2020, "Stringency of land use regulation: Building heights in US cities," *Journal of Urban Economics*, Vol. 116, Article No. 103239.
- Brueckner, J. K., S. Fu, Y. Gu and J. Zhang, 2017, "Measuring the stringency of land use

- regulation: The case of China's building height limits," *The Review of Economics and Statistics*, Vol. 99, No. 4, pp. 663–77.
- Cai, H., Z. Wang and Q. Zhang, 2017, "To build above the limit? Implementation of land use regulations in urban China," *Journal of Urban Economics*, Vol. 98, No. 4, pp. 223–33.
- CASS (Chinese Academy of Social Sciences), 2004, 2013, *Yearbook of China's Cities*, Beijing: Chinese City Yearbook Press (in Chinese).
- Chen, S. and J. K. Kung, 2016, "Of maize and men: The effect of a new world crop on population and economic growth in China," *Journal of Economic Growth*, Vol. 21, No. 1, pp. 71–99.
- Cheng, J., 2020, "Analyzing the factors influencing the choice of the government on leasing different types of land uses: Evidence from Shanghai of China," *Land Use Policy*, Vol. 90, Article No. 104303.
- Dong, Y., 2016, "A note on geographical constraints and housing markets in China," *Journal of Housing Economics*, Vol. 33, No. 1, pp. 15–21.
- Fan, X., S. Qiu and Y. Sun, 2020, "Land finance dependence and urban land marketization in China: The perspective of strategic choice of local governments on land transfer," *Land Use Policy*, Vol. 99, Article No. 105023.
- Fang, M., L. Han, Z. Huang, M. Lu and L. Zhang, 2021, "Regional convergence or just an illusion? Place-based land allocation policy and spatial misallocation," *SSRN Working Paper* No. 3846313 [online; cited September 2021]. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3846313.
- Fang, M. and Z. Huang, 2020, "Migration, housing constraints, and inequality: A quantitative analysis of China," *SSRN Working Paper* No. 3572838 [online; cited July 2021]. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3572838.
- Gaigné, C., J. Le Gallo, S. Larue and B. Schmitt, 2012, "Does regulation of manure land application work against agglomeration economies? Theory and evidence from the French hog sector," *American Journal of Agricultural Economics*, Vol. 94, No. 1, pp. 116–32.
- Glaeser, E. L., J. Gyourko and R. E. Saks, 2006, "Urban growth and housing supply," *Journal of Economic geography*, Vol. 6, No. 1, pp. 71–89.
- Glaeser, E. L. and D. C. Mare, 2001, "Cities and skills," *Journal of Labor Economics*, Vol. 19, No. 2, pp. 316–42.
- Glaeser, E. L., W. Huang, Y. Ma and A. Shleifer, 2017, "A real estate boom with Chinese characteristics," *Journal of Economic Perspectives*, Vol. 31, No. 1, pp. 93–116.
- Gyourko, J. and R. Molloy, 2015, "Regulation and housing supply," *Handbook of Regional and Urban Economics*, Vol. 5, No. 1, pp. 1289–337.
- Han, L. and M. Lu, 2017, "Housing prices and investment: An assessment of China's inland-favoring land supply policies," *Journal of the Asia Pacific Economy*, Vol. 22, No. 1, pp. 106–21.

- Han, L. and M. Lu, 2018, "Supply-demand mismatch: Solving the puzzle of China's housing price divergence," *Shijie Jingji (The Journal of World Economy)*, Vol. 41, No. 10, pp. 126–49.
- Hsieh, C. T. and E. Moretti, 2019, "Housing constraints and spatial misallocation," *American Economic Journal: Macroeconomics*, Vol. 11, No. 2, pp. 1–39.
- Huang, Z. and X. Du, 2017, "Government intervention and land misallocation: Evidence from China," *Cities*, Vol. 60, No. 3, pp. 323–32.
- Huang, W. and X. Wang, 2021, "Government land control, labor allocation efficiency among cities and economic growth," *Shijie Jingji (The Journal of World Economy)*, Vol. 44, No. 8, pp. 131–53.
- Li, H. and L. Zhou, 2005, "Political turnover and economic performance: The incentive role of personnel control in China," *Journal of Public Economics*, Vol. 89, No. 9–10, pp. 1743–62.
- Liang, W., M. Lu and H. Zhang, 2016, "Housing prices raise wages: Estimating the unexpected effects of land supply regulation in China," *Journal of Housing Economics*, Vol. 33, No. C, pp. 70–81.
- Liang, W., R. Song and C. Timmins, 2020, "Frictional sorting," *NBER Working Paper* No. 27643, National Bureau of Economic Research, Cambridge, MA.
- Liu, X., C. Du and S. Li, 2019, "Natural geographical constraints, land use regulations and China's housing supply elasticity," *Jingji Yanjiu (The Journal of Economic Research)*, Vol. 54, No. 4, pp. 99–105.
- Ministry of Finance of China, 2004a, *China Taxation Yearbook*, Beijing: China Taxation Press (in Chinese).
- Ministry of Finance of China, 2004b, *China Municipal and County Financial Statistics Data Collection*, Beijing: China Taxation Press (in Chinese).
- Ministry of Land and Resources, 2001–2014, *China Land and Resources Yearbook*, Beijing: Geological Press (in Chinese).
- Molloy, R., 2020, "The effect of housing supply regulation on housing affordability: A review," *Regional Science and Urban Economics*, Vol. 80, Article No. 103350.
- NBS (National Bureau of Statistics of China), 2004a, 2013a, *China City Statistical Yearbook*, Beijing: China Statistics Press (in Chinese).
- NBS (National Bureau of Statistics of China), 2004b, 2013b, *China Regional Economic Statistical Yearbook*, Beijing: China Statistics Press (in Chinese).
- NBS (National Bureau of Statistics of China), 2004c, 2013c, *China Urban Construction Statistical Yearbook*, Beijing: China Planning Press (in Chinese).
- Osman, T., 2020, "Restrictive land use regulations and economic performance," *International Regional Science Review*, Vol. 43, No. 4, pp. 291–315.
- Saiz, A., 2010, "The geographic determinants of housing supply," *The Quarterly Journal of*

Economics, Vol. 125, No. 3, pp. 1253–96.

- Saks, R. E., 2008, “Job creation and housing construction: Constraints on metropolitan area employment growth,” *Journal of Urban Economics*, Vol. 64, No. 1, pp. 178–95.
- Su, X. and Z. Qian, 2020, “State intervention in land supply and its impact on real estate investment in China: Evidence from prefecture-level cities,” *Sustainability*, Vol. 12, No. 3, pp. 1–15.
- Tan, Y., Z. Wang and Q. Zhang, 2020, “Land use regulation and the intensive margin of housing supply,” *Journal of Urban Economics*, Vol. 115, Article No. 103199.
- Wang, S., S. Chan and B. Xu, 2012, “The estimation and determinants of the price elasticity of housing supply: Evidence from China,” *Journal of Real Estate Research*, Vol. 34, No. 3, pp. 311–44.
- Xu, J., A. Yeh and F. Wu, 2009, “Land commodification: New land development and politics in China since the late 1990s,” *International Journal of Urban and Regional Research*, Vol. 33, No. 4, pp. 890–913.
- Yan, J. and L. Feng, 2019, “Land supply regulation, housing supply elasticity and housing price fluctuation,” *Zhongguo Tudi Kexue (China Land Science)*, Vol. 33, No. 3, pp. 16–24.
- Yao, Y. and M. Zhang, 2015, “Subnational leaders and economic growth: Evidence from Chinese cities,” *Journal of Economic Growth*, Vol. 20, No. 4, pp. 405–36.
- Zhang, J., R. Wang and C. Lu, 2019, “A quantitative analysis of Hukou reform in Chinese cities: 2000–2016,” *Growth and Change*, Vol. 50, No. 1, pp. 201–21.
- Zheng, D. and M. Shi, 2018, “Industrial land policy, firm heterogeneity and firm location choice: Evidence from China,” *Land Use Policy*, Vol. 76, No. 9, pp. 58–67.

(Edited by Shuyu Chang)