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Article

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ORIGINAL ARTICLE

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Low-rise buildings in big cities: Theory and evidence from China

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Abstract

This article explores the determinants of floor area ratio (FAR) limit, a major form of construction density regulation, in China. I develop a spatial equilibrium framework to study local governments' optimal FAR design and investigate over 400,000 residential land transactions between 2007 and 2019 to perform the empirical analysis. Exploiting the exogenous variations generated by administrative adjustments and applying a propensity score matching approach, I find that a one standard deviation increase in local budgetary revenue decreases FAR limits by 0.29. Further counterfactual analysis suggests that the land finance model contributes to housing affordability issues and spatial inequality in China.

KEYWORDS

floor area ratio, housing affordability, housing supply, land use regulation, political economy in China

1 | INTRODUCTION

Land use regulation has been a long-time focus of economic research. It is implemented around the world in a variety of forms such as the zoning policy in the United States and the green belt policy in the United Kingdom. The literature suggests that land use regulation has a wide range of impacts on housing markets, labor supply, local environment, and productivity (e.g., Cheshire et al., 2015; Glaeser & Kahn, 2004; Gyourko & Krimmel, 2021; Gyourko & Molloy, 2015; Hilber & Vermeulen, 2016; Hsieh & Moretti, 2019; Mayer & Somerville, 2000; Mills, 2005; Saks, 2008). As

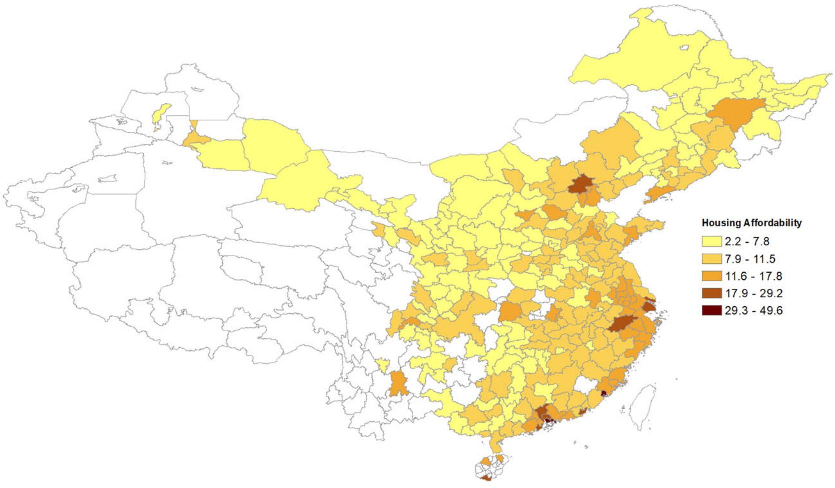

FIGURE 1 Prefecture-level housing affordability in China.
[Color figure can be viewed at wileyonlinelibrary.com]
Note: The housing affordability measure corresponds to how many years it takes to purchase a 100 m^2 property with the average annual income in the prefecture in 2018.

land use regulation is of primary importance to local economic development and urban environment, there is another strand of literature exploring its determinants. Previous studies find that restrictive land use regulations are implemented in order to protect home value, reduce local disamenities, prevent low-income households from moving in, and maintain local fiscal advantages (e.g., Bates & Santerre, 1994; Been et al., 2014; Fischel, 1987; Glaeser & Ward, 2009; Hilber & Robert-Nicoud, 2013; Pogodzinski & Sass, 1994). However, the literature to date contains few attempts to explore land use regulations in the context of developing countries. This is largely due to a vague understanding of local politics and a lack of high-quality data in emerging economies.

This article sets out to understand the determinants of land use regulation in China, a developing country that has experienced a rapid process of urbanization during the past decades.[1] I investigate the designation process of floor area ratio (FAR) limit, a major form of land use regulation that specifies construction density. FAR restriction regulates the maximum ratio of the floor area within the proposed property relative to the size of the land parcel. It has a crucial impact on land value and housing supply, as it determines the number of housing units to be constructed by developers. Besides, FAR design will affect neighborhood environment and local amenities, as high construction and population densities are usually associated with negative externalities such as less sunshine, more congestion, and more pollution (Borck & Schrauth, 2021; Carozzi & Roth, 2023; Duranton & Turner, 2018). Therefore, understanding the determinants of FAR limits can provide insights into both local housing price dynamics and urban environment.

Investigating FAR design also has important policy implications in China. As shown in Figure 1, many Chinese cities along the southeast coast are faced with housing affordability issues. On average, it takes approximately 9.4 years' annual salary to buy a 100 m^2 property in 2018, and in the most unaffordable city, Shenzhen, it takes approximately 50 years. A lack of housing supply is one reason for the severe affordability issues in some cities. Between 2007 and 2019, the mean

[1] According to the National Bureau of Statistics, the share of the urbanized population in China rises from 26.4% in 1990 to 63.9% in 2020.

value of the FAR upper limit for residential use is much lower in superstar cities such as Shanghai (1.9) and Beijing (2.3) compared with the national mean level (2.8) in China.[2] The relatively low construction density reduces the number of housing units produced by developers despite the high demand in these superstar cities. Conversely, cities in the less developed middle and western regions tend to set relatively high FAR upper limits for residential projects. However, these cities are not experiencing economic prosperity like Beijing and Shanghai. High-rise buildings are constructed there but sometimes left vacant, which is covered by the media as the "ghost town" or "over-building" phenomenon.

To understand the determinants of FAR design in China, this article first develops a spatial equilibrium framework with households, developers, and local governments. In the model, households can migrate across cities with no cost to achieve the highest utility level. Developers bid for land plots based on the market housing price, the construction cost, and the FAR limit. Local governments design the optimal FAR limit to maximize endogenous population size. The model implies that under a spatial equilibrium, the optimal FAR design is the outcome of local governments trading off between the benefits (more housing supply, land revenue, and public good provision) and the costs (more negative externalities) of higher construction density. Local governments with sufficient budgetary revenue are less financially reliant on land sales and will opt to set relatively low FAR limits to reduce the negative externalities caused by high density. Conversely, cities with less budgetary revenue are more financially dependent on land sales and will design higher FAR limits to generate more fiscal income. The theoretical framework also shows that the Chinese land finance model contributes to the spatial differences in FAR design and the housing affordability issues in major cities.

To empirically test the main proposition from the theoretical framework, I exploit a dataset of over 400,000 residential land transactions in China between 2007 and 2019 and combine it with prefecture- and county-level information. I first match land transactions with the corresponding residential projects and find that developers usually build sites with FARs close to the upper limits set by the government. I then use the rich dataset of land transactions to study the impact of local budgetary revenue on FAR design. To mitigate the endogeneity concerns of local confounding characteristics and reverse causality, I first create $0.02° \times 0.02°$ (approximately 2.2 km $\times$ 2.2 km) spatial grids across the country and compare land parcels within a small geographic unit. I then exploit the exogenous variation generated by a central government administrative adjustment policy to develop an instrumental variable (IV) identification strategy. This administrative adjustment policy turns self-governed rural counties into prefecture-governed municipal districts, which breaks administrative barriers, leads to infrastructure improvement, and boosts local agglomeration economy and budgetary revenue. To further mitigate the concern of potential selection bias, I utilize a propensity score matching (PSM) approach to select economically similar cities before the administrative adjustments, and estimate the PSM sample using the adjustment policy as an instrument. In line with the theoretical framework's prediction, this article's most credible PSM-IV estimate suggests that a one standard deviation increase in local budgetary revenue will decrease FAR limit by 0.29, which is around 18% of the standard deviation of the FAR limit in the baseline sample. Based on the IV estimates, this article conducts a quantitative analysis and shows that the land finance model contributes to housing affordability issues and spatial inequality in China. This article also provides additional evidence on the negative externalities caused by high construction density and on the FAR design for commercial

[2] The average FAR upper limit is computed based on this paper's land transaction dataset. See Section 3.1 for details about the data.

and special uses. Finally, I subject the main empirical findings to a long list of robustness checks by considering household sorting, different grid sizes, superstar cities, local government debt, and so on, and find results consistent with the baseline estimates.

This article relates to the literature that explores the economics of housing supply and land use regulations, including the welfare analysis of land use regulations (Cheshire & Sheppard, 2002; Turner et al., 2014), the micro geography of housing supply (Baum-Snow & Han, 2022), the determinants of housing supply restrictions (Been et al.,2014; Glaeser & Ward, 2009; Hankinson & Magazinnik, 2023; Hilber & Robert-Nicoud, 2013; Saiz, 2010), and the consequences (Gyourko & Molloy, 2015; Hilber & Vermeulen, 2016; Kulka et al., 2022; Mayer & Somerville, 2000). Most previous studies discuss land use regulations in the context of developed countries and find that homeowners (or "not in my backyard residents") tend to oppose local new developments and vote for politicians who can introduce restrictive land use regulations to protect their home value. The literature also discusses the fiscal incentive (Bates & Santerre, 1994; Rolleston, 1987) and the exclusion incentive (Pogodzinski & Sass, 1994) of restrictive land use regulations. This article contributes to the literature by documenting the determinants of land use regulation in the context of a rapidly urbanizing and developing country. Theoretically, this article links the Rosen–Roback spatial equilibrium framework with the politician tournament theory in China (Li & Zhou, 2005) and discusses how local officials' incentives and the Chinese land finance model influence land use design. Empirically, most previous studies measure land use regulations that are aggregated at some geographical levels (e.g., The Wharton Residential Land Use Regulatory Index from Gyourko et al., 2008). This article uses a unique and comprehensive dataset of land transactions in China to measure time-varying regulatory restrictiveness at the plot level with detailed land parcel information. The granular dataset allows me to employ a rigorous identification strategy and to test for the robustness of the main results.

This article also relates to the literature on the economics of construction density in the contexts of both developed countries (Ahlfeldt & McMillen, 2018; Barr, 2013) and developing countries (Fu & Somerville, 2001). Cai et al. (2017) estimate a dataset of land parcels matched with residential projects and find that developers tend to violate FAR restrictions in more desirable locations in China. Brueckner et al. (2017) show that the elasticity of land price with respect to the FAR limit can be used to measure local regulation stringency. However, the literature to date contains few attempts on understanding the determinants of density control regulations. This article aims to fill the gap.

This article also refers to the discussion on urban density, agglomeration, and negative externalities. Although higher density leads to higher productivity (Duranton & Puga, 2014), it also causes more air pollution (Borck & Schrauth, 2021; Carozzi & Roth, 2023) and congestion (Duranton & Turner, 2018). This article contributes to this strand of literature by estimating the negative externalities generated by high-density new developments, and by studying how local governments trade-off between the benefits and the costs of high construction density to achieve a desirable outcome.

This article focuses on a local public finance perspective to investigate the across-county variation rather than the within-county variation in housing supply restrictions.[3] This is because FAR

[3] In terms of within-local-authority variation, for instance, in the context of the United States, because at-large systems are more likely to underrepresent minority voters, unwanted housing is more likely to be concentrated in minority neighborhoods, all else equal (Hankinson & Magazinnik, 2023). To mitigate the potential endogeneity concerns caused by the within-county variation in FAR limits, this article controls for a wide range of parcel-level characteristics and grid fixed effects in the main specification.

limits are set at the local government level in China. When making planning decisions, local governments will take into account not only the within-county specifics (e.g., geographical obstacles or the density of the preexisting informal housing) but also the local fiscal conditions. The latter consideration has arguably more important policy implications, given the essential role of the land finance model in China. By proposing an original political economy story about the determinants of land use regulations in China, this article contributes to the literature on fiscal policies and fiscal decentralization in China (Han & Kung, 2015; Jin et al., 2005), and the conditions and risks of Chinese housing markets (Wu et al., 2012, 2016).

The rest of this article is structured as follows. Section 2 describes the local fiscal system and land use regulation design in China and provides a theoretical framework to guide the empirical analysis. Section 3 contains the data sources, descriptive analysis, identification strategy, and the main empirical results. Section 4 presents robustness checks for these findings and additional results. Section 5 concludes.

2 | BACKGROUND AND THEORETICAL FRAMEWORK

2.1 | Institutional background

2.1.1 | Local fiscal system and land finance model in China

During the last decades, China has experienced several waves of reforms with the aim of fiscal decentralization. Fiscal decentralization was first accomplished in the early 1980s through a fiscal contract system. Under this system, local governments could keep almost all extra revenues generated beyond their preset contract responsibilities. Following a major tax reform in 1994, which weakened the budgetary revenue for local governments, and a major housing reform in 1998, city leaders learned that selling land leases was an effective way to generate fiscal revenue. Local governments can take advantage of their monopolistic positions in local urban land supply and collect extrabudgetary revenue from selling land parcels to developers (Cao et al., 2008). The land finance model has since then become a key feature of local public finance in China, as land sale revenue is classified as "extrabudgetary revenue" and local governments are not required to share it with the central government. Over the last decades, local governments have increasingly relied on selling land parcels as a major source of fiscal revenue to finance local public goods and infrastructure investments. Figure 2 shows that between 2007 and 2017, land sale revenue equals 36%–68% of local governments' budgetary revenue, which is a common measure for local governments' fiscal capacity. Local budgetary revenue includes local taxes, administration fees, and the revenue from state-owned resources, but it does not include the proceeds from land sales.

By law, all urban lands in China are owned by the state. Since 1988, the prefecture land bureau has gotten the authority to allocate the use rights of vacant urban lands. The maximum terms of the land use rights are 70 years for residential use, 50 years for industrial use and mixed use, and 40 years for commercial use. In the 1990s, most land leases were allocated through negotiation between local governments and developers. In order to control the corruption that occurred during negotiations, the Ministry of Land and Resources banned negotiated residential and commercial land transfers after 31 August 2004 and banned negotiated industrial land transfers after 30 June 2007. Since then, most urban land leases for private development have been allocated through public auctions. Land auctions are held by local government's land bureau, and detailed information on land parcels is required to be available to the public. According to Cai et al. (2013),

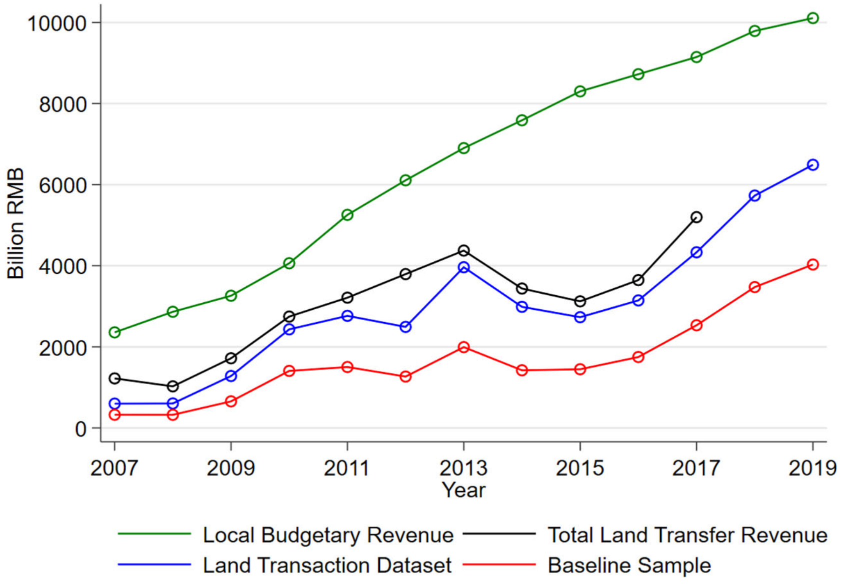

FIGURE 2 Fiscal revenue and land revenue in China.
[Color figure can be viewed at wileyonlinelibrary.com]

Notes: "Local Budgetary Revenue" corresponds to the total local budgetary revenue collected by local governments in China, and the data comes from the National Bureau of Statistics. "Total Land Transfer Revenue" corresponds to the total land transfer revenue in China, and the data comes from China Land and Resources Statistical Yearbooks. "Land Transaction Dataset" corresponds to the aggregated value of land transaction prices based on this article's land transaction dataset (including all land uses). "Baseline Sample" corresponds to the aggregated value of land transaction prices based on this article's baseline estimation sample (including the residential land use only).

more than 95% of land auctions were conducted via either English auctions or two-stage auctions. Local governments collect land revenue from these auctions and the land sale serves as an important source of local fiscal revenue besides taxes and administrative fees.

2.1.2 | FAR design and the objective of local officials

Local government's urban planning bureau designs land use regulations such as FAR limit and the share of green space for each land plot to be released. These plots will then be turned over to the land bureau for auction. In practice, based on local governments' documentation and my interviews with local officials and developers, the designation process of FAR limit is mainly through discussions and negotiations between county- and prefecture-level governments. County-level governments propose land use plans to the prefecture-level governments, and the decisions will be made by prefecture-level governments based on different environmental, economic, and urban planning criteria. This article uses the county-level budgetary revenue in the main empirical analysis because county-level governments, especially the more rural ones ("xian"), usually have a major influence on land use regulation design.[4]

[4] This article also applies the prefecture-level budgetary revenue in the empirical estimation as a robustness check, and the results are reported in the appendix.

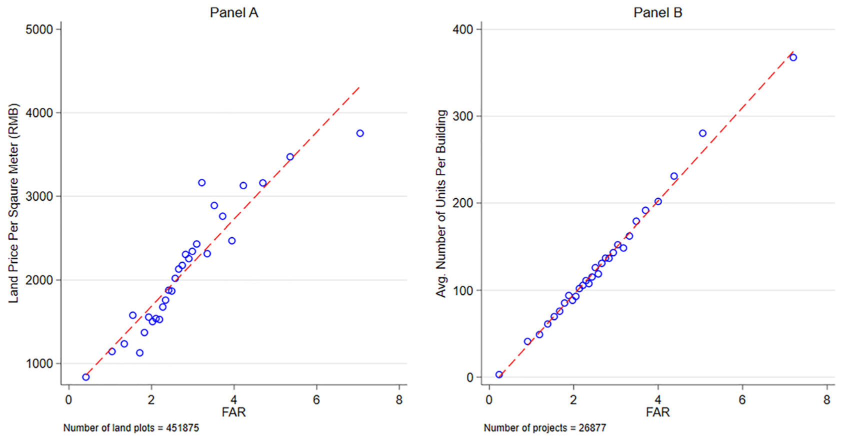

FIGURE 3 The benefits of high floor area ratio (FAR) design.
[Color figure can be viewed at wileyonlinelibrary.com]
Note: Prefecture fixed effects are controlled for in Panels A and B.

Local governments design both an upper bound and a lower bound for FAR limit. This article defines FAR restriction as the upper bound constraint, as the upper limit is always binding in practice and lower bound cases are very rare.[5] Developers follow the land use regulations set by local governments to complete the site construction. The completed residential projects with different FARs usually contain different types of buildings (Sohu, 2018): For instance, the FAR of projects with houses and low-rise buildings (below 6 stories) is usually below 1.2, the FAR of projects with medium-rise buildings (between 6 and 18 stories) is usually between 1.2 and 3, and the FAR of projects with high-rise buildings (over 18 stories) is usually above 3.

Local governments consider the benefits and costs of high construction density when designing FAR limits. The benefits of high FAR limits are mainly twofold: First, higher FAR limit can significantly increase the value of a land plot, as developers are allowed to build out more housing units. Panel A of Figure 3 plots a positive correlation between FAR upper limit and land price per square meter based on 451,875 residential land transactions in China. As land sale serves as a crucial source of fiscal revenue for many local governments, higher FAR design can enable them to collect more land revenue for public good provision and infrastructure investment. Second, higher construction density leads to more housing supply and better housing affordability. Based on 26,877 residential projects in China, Panel B of Figure 3 shows that there is a positive correlation between FAR design and the number of housing units per building. Meanwhile, there are some costs associated with high construction density. For instance, high-rise buildings will accommodate dense populations, causing more congestion and pollution in the neighborhood. Panel A of Figure 4 presents a positive correlation between construction density and local PM2.5 using 42,880 residential projects information. Besides, high FAR limits might generate negative externalities to local amenities. Panel B of Figure 4 shows that residential projects with higher construction densities are more likely to have lower green ratios (i.e., the proportion of green space such as parks and lawns within a residential project). Higher FAR design is also associated with worse views and less sunshine.

[5] Figure 7 and Cai et al. (2017) provide supporting evidence on the bindingness of FAR upper limits in China.

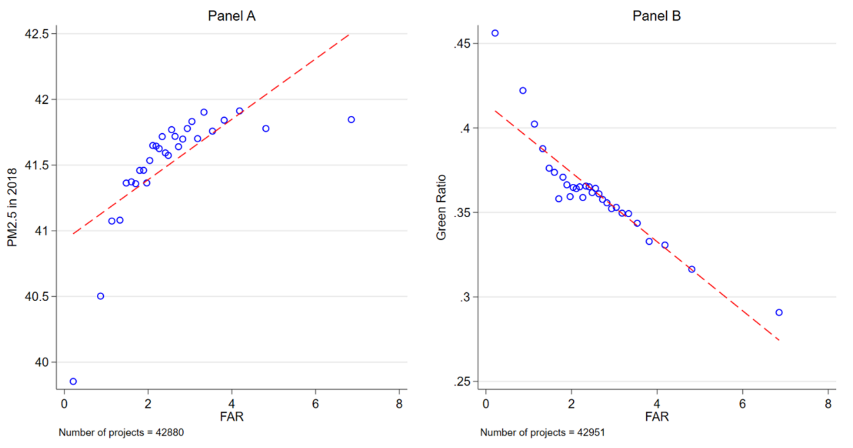

FIGURE 4 The costs of high floor area ratio (FAR) design.
[Color figure can be viewed at wileyonlinelibrary.com]
Notes: In Panel A, each residential project's PM2.5 is computed by spatially merging the project with the PM2.5 raster data in 2018. The PM2.5 data comes from the Atmospheric Composition Analysis Group, Washington University in St. Louis (Van Donkelaar et al., 2021). In Panel B, the green ratio corresponds to the actual proportion of green space relative to the total land area for each residential project. Prefecture fixed effects are controlled for in Panels A and B.

Local governments trade-off between the benefits and costs of high construction density to design the optimal FAR limits and achieve their own objectives. In the last decades, city leaders in China have an incentive to pursue economic growth during their term time. Li and Zhou (2005) find that local officials are more likely to be promoted if provinces experience economic prosperity under their governance. Land development offers the promise of promoting economic growth and relieving financial pressure (Lichtenberg & Ding, 2009). If local leaders only care about raising fiscal revenue to invest in infrastructure projects and boost GDP, they will design the FAR limit to be as high as the developer's optimal construction density to maximize the land value. Nevertheless, if local governments can collect sufficient fiscal revenue from other sources such as local taxes and administrative fees, they will be less financially reliant on land sales and might consider designing lower FAR limits to reduce the negative externalities caused by high density.

2.2 | Theoretical framework

In this subsection, I develop a static spatial equilibrium model with local governments, households, and developers to explore the optimal FAR design for local officials and to guide the empirical analysis.

The model is built on the spatial equilibrium framework developed by Roback (1982), Rosen (1979), and Diamond (2017) and aims to illustrate how local governments trade-off between the benefits and costs of high construction density and design the optimal FAR limits. I extend the classic Rosen–Roback framework by introducing the political incentives of local officials (Li & Zhou, 2005) and the land finance model in China. The set of players and the timing of the game are as follows: Local governments simultaneously choose an optimal FAR limit for all land parcels, sell these land parcels to developers, and spend all fiscal revenue, including budgetary revenue and land revenue, on the provision of local public goods. Households then make their location decision among cities based on their expected utility level, and the payoffs are realized. Developers bid for land parcels based on the market housing price, the construction cost, and the FAR design. In the end, the urban system reaches a spatial equilibrium, and each household settles in one city and has no incentive to move.

2.2.1 | Households

Suppose that there is an urban system which consists of multiple cities. Homogenous households with wage w can move across cities with no migration cost and make their location decision based on the expected utility level. Each household's utility U is determined by the consumption of housing h, the consumption of tradable goods c, public goods g provided by local government, and local amenities θ. Suppose that p represents housing price per square meter and the price for tradable goods is normalized to one. The utility function and budget constraint for a household are as follows:

$$U = h^{\alpha} c^{1-\alpha} g\theta \tag{1}$$

$$s.t.\, w = ph + c \tag{2}$$

where $0 < \alpha < 1$. To maximize individual utility level, each household will consume housing h and tradable goods c as follows:

$$\frac{h}{c} = \frac{\alpha}{(1-\alpha)\, p} \tag{3}$$

Let d denote the housing stock of a city with population L, and suppose that the local government releases N land parcels with size S and FAR upper limit f to the housing market. Under the assumption of housing market clearing:

$$hL = NSf + d \tag{4}$$

Housing price p, housing consumption h, and tradable good consumption c are thus determined as follows:

$$p = \frac{wL\alpha}{NSf + d} \tag{5}$$

$$h = \frac{NSf + d}{L} \tag{6}$$

$$c = \frac{1-\alpha}{\alpha} \left(\frac{NSf + d}{L} \right) p \tag{7}$$

2.2.2 | Land markets and developers

Suppose that homogeneous developers bid for land parcels released by the local government and let r denote the land price per square meter. The construction cost per square meter i is a convex function with respect to the FAR limit f (i.e., $\frac{\partial i}{\partial f} > 0$, $\frac{\partial^2 i}{\partial^2 f} > 0$), meaning that the marginal construction cost increases as the building height increases. Developers bid for land parcels based on the market house price p, the FAR limit f, and the construction cost i. After acquiring land plots, developers will build projects with construction density f.[6] Developer's profit π is thus given by:

$$\pi = Sfp - Sr - Si \tag{8}$$

Under the assumption of perfect competition and free entry and exit, developers make zero profit, and land price r is given by:

$$r = \frac{wfL\alpha}{NSf + d} - i \tag{9}$$

This article assumes that $\frac{\partial r}{\partial f} > 0$, meaning that local governments can collect more land sale revenue by setting higher FAR limits for the land plots.[7]

2.2.3 | Negative externalities

High population density is associated with negative externalities such as congestion and pollution (Borck & Schrauth, 2021; Carozzi & Roth, 2023; Duranton & Turner, 2018). Higher construction density f also leads to worse views and less sunshine. These negative externalities will adversely affect local amenities θ[8].

Let $\frac{NSf+d}{NS+S_0}$ denote the overall construction density within a city, where S_0 denotes the land area of housing stock d, and NS denotes the area of new land supply. $\theta\left(\frac{NSf+d}{NS+S_0}\right)$ denotes the amenity value considering all the negative externalities caused by construction density and is defined as a convex function with respect to f (i.e., $\frac{\partial\theta(\frac{NSf+d}{NS+S_0})}{\partial f} < 0$, $\frac{\partial^2\theta(\frac{NSf+d}{NS+S_0})}{\partial^2 f} < 0$). $\theta\left(\frac{NSf+d}{NS+S_0}\right)$ can be simplified as $\theta(f)$ because all the parameters in this function are exogenously determined except for f.

[6] This assumption is in line with Figure 7 and Cai et al. (2017) that the upper FAR limits are usually binding for residential projects in China.

[7] This assumption is plausible and can be supported by the bindingness of FAR limits (Figure 7) and the positive land price-FAR limit elasticities as indicated by Table A3 and the estimates from Brueckner et al. (2017). Supporting Information Appendix C shows that the assumption $\frac{\partial r}{\partial f} > 0$ is the same as the assumption $\frac{d}{NSf+d}p > \frac{\partial i}{\partial f}$ under the spatial equilibrium.

[8] For instance, Section 4.1 provides empirical evidence about the negative effect of high construction density on air quality.

2.2.4 | Local officials design the optimal FAR limits

Suppose that the local government simultaneously designs FAR limit f for N land parcels with size S and sells them to developers. Local government then spends all fiscal revenue including land sales NSr and budgetary revenue B on the public good provision. Budgetary revenue B includes local taxes and administrative fees but does not include land sale revenue.

This article assumes that the provision of public good g follows a simple production function with local government's total revenue ($NSr + B$), productivity A, and β, which satisfies that $0 < \beta < 1$:

$$g = A(NSr + B)^{\beta} \tag{10}$$

Households make location choices based on their expected utility level as documented in Equation (1). Under the assumption of housing market clearing:

$$U = A(w - w\alpha)^{1-\alpha}\left(\frac{NSf + d}{L}\right)^{\alpha}(NSr + B)^{\beta}\theta \tag{11}$$

Equation (11) illustrates the positive and negative effects of high FAR design on a household's utility level: First, higher FAR limits can lead to more new housing units, which brings down housing costs and improves housing affordability (*supply effect*). Second, higher FAR limits can generate more land sale revenue and enable local governments to provide more public goods (*fiscal effect*). Third, the negative externalities associated with high construction density will adversely influence local amenity value and household utility level (*negative externality effect*).

This article assumes an "open city" scenario, meaning that households can move freely across cities to achieve the highest utility level, and there is no migration cost. When the urban system reaches a spatial equilibrium, every household will have the same utility $\bar{U}$ and no incentive to move. The population L within a city is thus endogenously determined as follows:

$$\overline{U} = A(w - w\alpha)^{1-\alpha}\left(\frac{NSf + d}{L}\right)^{\alpha}(NSr + B)^{\beta}\theta \tag{12}$$

Equation (12) suggests that the population size within a city will increase if there are more housing supply and public goods, and will decrease if there are more negative externalities caused by high density.

The "politician tournament theory" (Li & Zhou, 2005) proposes that local leaders in China are incentivized to boost the local economy so that their promotion probability can increase. This article thus assumes that the optimal FAR limit f^* for local officials is the FAR level that can maximize the aggregate economic output within a city, which is proxied by the population size L[9]:

$$f^* = \arg\max_{f}(L) \tag{13}$$

[9] The objective of local officials to increase population size is supported by the competition among local governments to attract young talents in China (qiang ren da zhan). Local governments provide a series of benefits to undergraduates and postgraduates who decide to settle in. These benefits include relatively easy access to local household registration (i.e., hukou) and local housing subsidies.

This article then proves the following inequality:

$$\frac{\partial f^*}{\partial B} < 0 \tag{14}$$

As long as $\frac{d}{NSf+d}p > \frac{\partial i}{\partial f}$.[10] Inequality (14) leads to the main proposition to be tested in this article:

Main proposition—Local governments with more budgetary revenue are less financially reliant on land sales and will opt to design lower FAR limits in order to reduce the negative externalities caused by density and to maximize local population size.

Intuitively, if local governments cannot collect abundant fiscal income from sources other than land sales, they will opt to design relatively high FAR limits to generate more revenue from the land markets. On the contrary, if local governments can collect sufficient budgetary revenue from taxes and fees, they will be less financially reliant on land sales and will design relatively low FAR limits to reduce the negative externalities caused by high density.

2.2.5 | The consequence of land finance model

Would the optimal FAR design be different if the land finance model was entirely abolished in China? Under this scenario, local governments could only spend the budgetary revenue B on public good provision, and the population size of a city under the spatial equilibrium would be determined by the following equation:

$$U = A(w - w\alpha)^{1-\alpha}\left(\frac{NSf + d}{L}\right)^{\alpha} B^{\beta}\theta \tag{15}$$

Suppose that local governments design the optimal FAR limit f^* to maximize population size L. It is easy to prove that: [11]

$$\frac{\partial f^*}{\partial B} = 0 \tag{16}$$

Equation (16) suggests that under the scenario when the land finance model was entirely abolished in China, the optimal FAR limit f^* would not be influenced by local budgetary revenue B anymore. In this case, f^* would only be determined by the trade-off between the additional housing supply and the negative externalities caused by high density. To further quantify the impact of the land finance model on land use regulation design, this article conducts two counterfactual exercises, and the results are reported in Section 3.4.

[10] See proof in Supporting Information Appendix C. As long as the marginal increase in construction cost $\frac{\partial i}{\partial f}$ is not extremely high (i.e., higher than the $\frac{d}{NSf+d}$ of local house price), the impact of local budgetary revenue on FAR limit is negative. The assumption $\frac{d}{NSf+d}p > \frac{\partial i}{\partial f}$ is the same as the assumption $\frac{\partial r}{\partial f} > 0$ under the spatial equilibrium.

[11] See proof in Supporting Information Appendix C.

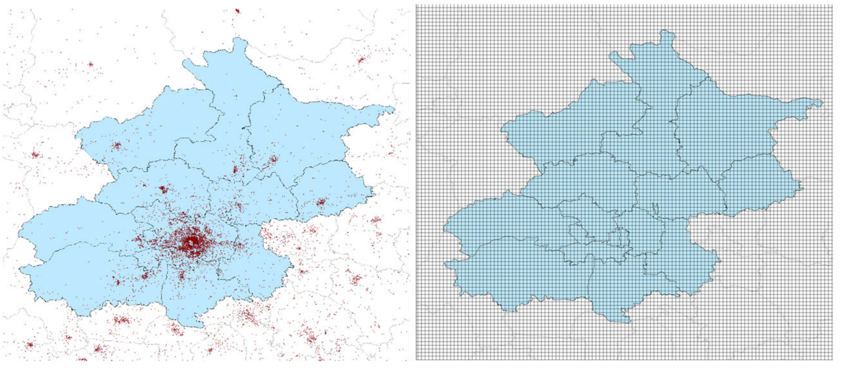

FIGURE 5 Geocoded land parcels and 0.02° × 0.02° grids.
[Color figure can be viewed at wileyonlinelibrary.com]
Note: The red dots correspond to the geocoded land parcels in Beijing (represented by the blue polygon) and nearby cities.

3 | EMPIRICAL ANALYSIS

3.1 | Data and descriptive analysis

This article's baseline estimation sample uses 416,566 residential land transactions in 354 prefecture-level cities and 2335 counties in China from 2007 to 2019. The data source is the official website of China land market, which is organized by the Ministry of Natural Resources.[12] Since 2007, the central government in China has systematically collected and publicized land transaction records, and the digitized land transaction information can be found from this website. With reference to Fu et al. (2021), I clean the land transaction dataset by removing duplicated observations, dealing with outliers and missing values, and so forth (see Supporting Information Appendix D for details). I then assess the reliability and coverage of the cleaned land transaction dataset by comparing statistics computed from this dataset with those from the China Land and Resources Statistical Yearbooks. Figure 2 shows that the cleaned land transaction dataset used in this article accounts for between 49% and 91% of total land sales in China from 2007 to 2017. The land transaction dataset records detailed information at the plot level including land transaction price, address, the date of transaction, the upper limit of FAR, the type of land use, a land quality grade (ranging from 1 to 18) evaluated by local governments, land area, the type of land transfer, a dummy variable indicating whether the land plot is for resettlement housing, the source of the land plot, and the land bidder. This article identifies the land use of each plot based on its planning description and selects residential land transactions for the main empirical analysis. Residential land sale serves as the major source of the land revenue and accounts for 73% of all the land sales in this article's land transaction dataset.[13] This article also estimates a sample including land parcels for commercial and special uses, and the results are reported in the appendix.

I use Baidu Map API to geo-code all the land parcels based on their location information. The geocoded land parcels cover most major cities in China and are also widely spread within cities. For instance, Figure 5 shows the geocoded land plots both in the central area and at the urban fringe of Beijing. To control for the time-invariant local characteristics in the main estimation, this

[12] The weblink for the China land market is https://landchina.com.

[13] Wang et al. (2020) also documented that nearly three quarters of the land sale revenue created through public auctions comes from the sale of residential land.

article creates a fishnet that covers all the land transactions in the baseline sample and the size of each spatial grid is 0.02° × 0.02° (approximately 2.2 km × 2.2 km). Figure 5 shows these spatial grids in Beijing, and each grid represents a relatively small geographical unit. According to this article's baseline estimation sample, on average, there are 9 land transactions within a grid, and 19 grids within a county. By controlling for grid fixed effects in the main specification, this article compares land parcels within a small neighborhood and mitigates the concern of unobserved time-invariant local features such as historical construction density and geographical conditions.

This article also collects nation-, prefecture-, and county-level characteristics from different sources including the National Bureau of Statistics, China Financial Statistics of Cities and Counties, City Statistical Yearbook, China Land and Resources Statistical Yearbook, local statistical yearbooks, and local government statistical reports. The administrative adjustment records are collected from the Ministry of Civil Affairs. I merge the geocoded land parcels with the county- and prefecture-level data to construct the baseline estimation sample. The key explanatory variable, budgetary revenue of local government, is standardized for the interpretation of the estimated coefficients. This article subtracts the sample mean of budgetary revenue from itself and divides this difference by the standard deviation. This transformation allows me to interpret the estimated coefficient as an increase in the FAR limit due to a one standard deviation increase or decrease in local budgetary revenue.

In addition, this article collects data on residential projects from Fang.com, which is one of the largest real estate agencies in China. It provides information on 42,951 residential projects constructed between 2007 and 2019 in 261 cities in China. For each residential project, the dataset records the land area of the project, the total construction area, FAR, the green ratio, the total number of dwellings, the total number of buildings, developer, address, and the time when the developer completes the construction. Each project is geocoded using its address information.

Finally, this article collects annual PM2.5 estimates (0.01° × 0.01° resolution)[14] in China from Atmospheric Composition Analysis Group, Washington University in St. Louis (Van Donkelaar et al., 2021).[15] I also collect the nightlight data from the National Centers for Environmental Information's National Geophysical Data Center.[16]

Basic summary statistics computed for the baseline estimation sample are detailed in Table 1. Panel A provides information on 416,566 residential land plots. The average value of the land transaction price is 53 million RMB (around 7.2 million USD),[17] and the average size of the land parcel is 22,000 m^2. The key land use regulation explored in this article, FAR upper limit, has a mean value of 2.8 and a standard deviation of 1.6. As Figure 6 shows, most land parcels have FAR upper limits between 1 and 6, and there is significant bunching at round numbers. Panel B of Table 1 documents the descriptive statistics for county-level and prefecture-level characteristics from 2007 to 2019. The key explanatory variable in the empirical analysis, budgetary revenue at the county level, has a mean value of 1,461 million RMB (around 200 million USD).[18]

To empirically evaluate the bindingness of FAR upper limits, I merge the land transaction dataset with the residential project dataset and identify the exact land plot that a residential project

[14] The resolution is approximately 1.1 km × 1.1 km.

[15] The data source is https://sites.wustl.edu/acag/datasets/surface-pm2-5. Van Donkelaar et al. (2021) develop and apply a methodology for monthly estimates and uncertainties during the period 1998–2019, which combines satellite retrievals of aerosol optical depth, chemical transport modeling, and ground-based measurements to allow for the characterization of seasonal and episodic exposure, as well as aid air-quality management.

[16] https://www.ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

[17] Based on the currency exchange rate in October 2023.

[18] Based on the currency exchange rate in October 2023.

TABLE 1 Descriptive statistics.

	Obs.	Mean	SD	Max	Min
Panel A: Land parcel characteristics					
FAR upper limit	416,566	2.8	1.6	15	0.01
Transaction price (10,000 RMB)	416,566	5313	21,734	1406,000	0
Land area (10,000 m^2)	416,566	2.2	5.6	2364.4	0.00004
Whether the land plot is for resettlement housing	416,566	0.05	0.2	1	0
Distance to CBD (km)	416,566	10.5	15.3	149.4	0
Transfer type 1 (zhao)	416,566	0.007	0.1	1	0
Transfer type 2 (pai)	416,566	0.2	0.4	1	0
Transfer type 3 (gua)	416,566	0.5	0.5	1	0
Transfer type 4 (negotiation)	416,566	0.3	0.5	1	0
Transfer type 5 (huabo)	416,566	0.1	0.3	1	0
Panel B: Local characteristics					
County-level budgetary revenue (million RMB)	25,404	1460.7	3328.2	107,150	0.06
Population (million)	3339	4.5	3.1	34.2	0.2
% GDP in the agricultural sector	3339	13	8.2	49.9	0.04
% GDP in the tertiary sector	3339	38.8	9.5	83.5	8.6
Number of high schools	3339	220.2	137.8	1361	10
Number of hospital beds	3339	17,932.3	16,380.6	177,410	1352

Abbreviation: FAR, floor area ratio.

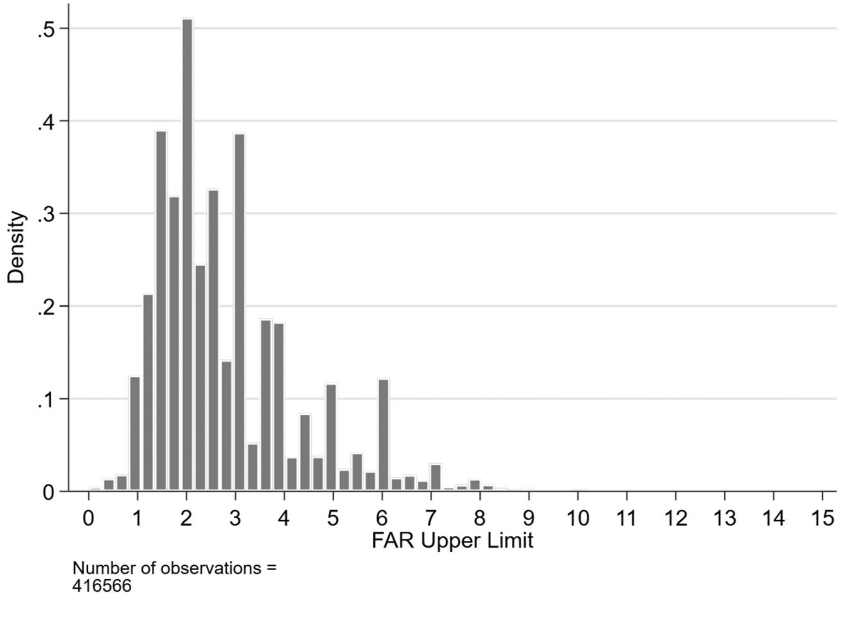

FIGURE 6 Histogram of floor area ratio (FAR) limits.

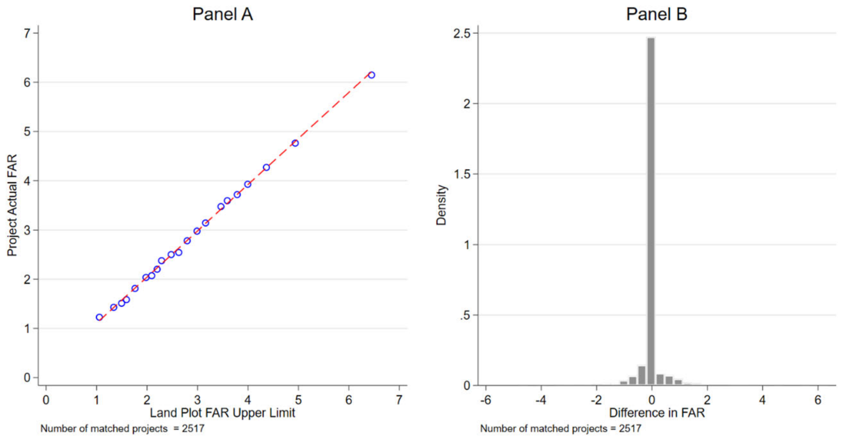

FIGURE 7 Bindingness of floor area ratio (FAR) limits.
[Color figure can be viewed at wileyonlinelibrary.com]
Notes: Panel A plots the relationship between the land parcel's FAR upper limit and the corresponding residential project's actual FAR. Panel B plots the distribution of the difference between the land parcel's FAR upper limit and the corresponding residential project's actual FAR.

is built upon. I use the following criteria to match these two datasets: The difference between the land area of the residential project and the land parcel area is fewer than 10 m^2; the bidder for the land parcel is the same as the developer of the residential project; the transaction year of the land parcel is no later than the completion year of the residential project; the residential project and the land parcel are located in the same city. In the end, there are 2517 matched pairs that can satisfy these matching criteria. Based on these matched observations, Panel A of Figure 7 plots a strong positive relationship between the land plot's FAR upper limit and the corresponding residential project's actual FAR. Panel B then presents the distribution of the difference between the actual FARs and the FAR upper limits. We could observe that 1482 matched pairs bunch at the zero difference, and 2025 matched pairs are built with the FAR difference fewer than 0.2.[19] Panels A and B together suggest that the FAR upper limits are usually binding in practice, and developers tend to construct residential projects as densely as they can.

Figures 8 and 9 present the spatial patterns of local budgetary revenue and residential FAR upper limit at the county level in China, respectively. Figure 8 shows that regional core cities and cities along the southeast coast tend to collect more budgetary revenue. These cities, including Tier 1 cities such as Beijing and Shanghai, are reckoned as the more economically advanced cities in China. Conversely, Figure 9 presents the weighted average FAR limit for residential use based on the land transaction data between 2007 and 2019.[20] Contrary to Figure 8, regional core cities and cities along the southeast coast tend to set relatively low FAR limits for residential land plots. As Figure 1 suggests, these cities are also faced with more severe housing affordability issues. Figures 8 and 9 together indicate that cities with more budgetary revenue tend to design lower FAR limits, which is in line with the main proposition from the theoretical framework. I will formally test the impact of local fiscal capacity on FAR design in the following section.

[19] The finding about the bindingness of the FAR upper limit is in line with Cai et al. (2017). Note that sometimes it is possible for developers to build above the upper FAR limit if they could get the approval for a FAR adjustment from local authorities.

[20] The average FAR limit is weighted by the size of land plot.

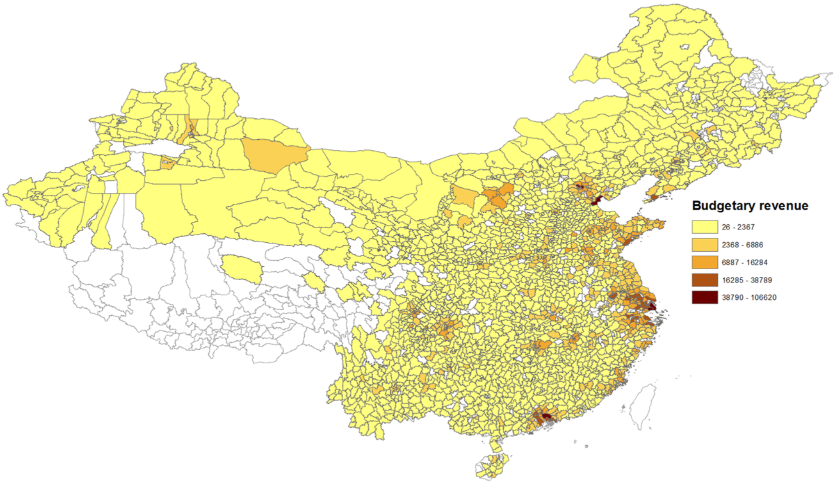

FIGURE 8 County-level Budgetary Revenue in 2018. [Color figure can be viewed at wileyonlinelibrary.com]
Note: County-level budgetary revenue in million RMB in 2018.

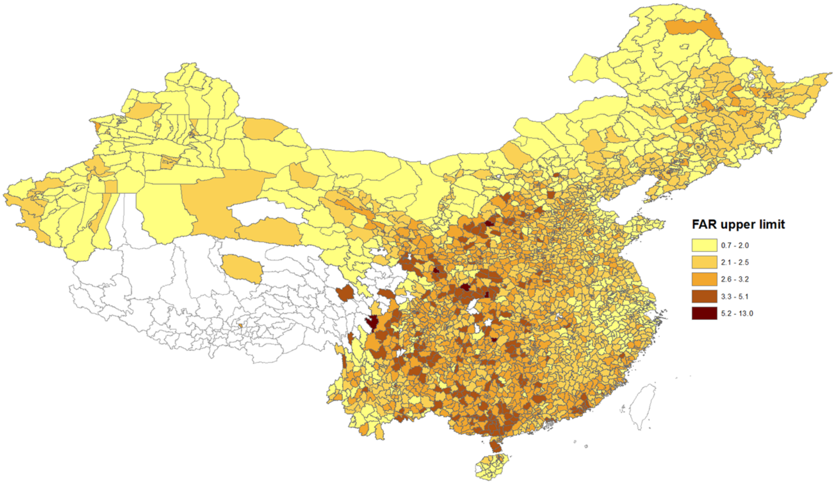

FIGURE 9 Weighted average floor area ratio (FAR) (residential land). [Color figure can be viewed at wileyonlinelibrary.com]

3.2 | Empirical specifications and identification strategy

3.2.1 | Main specification and endogeneity concerns

This article's empirical strategy is designed to test the main proposition in the theoretical framework and explore the determinants of FAR limits in China using land transaction data. I first estimate the following equation using Ordinary Least Squares regression (OLS):

$$FAR_{icdgym} = \phi_d + \rho_g + \beta Budget_{dy} + \delta_{ym} + \gamma\prime X_i + \tau\prime Z_{cy} + \varepsilon_{icdgym} \tag{17}$$

where i indexes individual land parcel, y indexes transaction year, and m indexes transaction month. The key explanatory variable, $Budget_{dy}$, represents the budgetary revenue of county d in year y. A vector of county fixed effects is represented by ϕ_d and a vector of spatial grid fixed effects is represented by ρ_g. δ_{ym} is a set of time dummies (year-month fixed effects) and X_i is a set of land parcel controls including land area, distance to the central business district (CBD), type of land transfer, land quality, a dummy variable indicating whether the land plot is for resettlement housing, and the source of the land plot. Z_{cy} is a set of prefecture-level time-varying characteristics including population, local industry composition, number of high schools, and number of hospital beds in city c in year y. This article estimates this equation by OLS, clustering standard errors at the grid level to account for potential spatial autocorrelation in FAR design and local housing market conditions. The parameter of interest is β, measuring the impact of local budgetary revenue on FAR restriction.

One important caveat with the OLS estimates of Equation (17) is that the explanatory variable $Budget_{dy}$ is likely endogenously determined, causing the estimate to be biased. There are two major endogeneity concerns. First, as FAR limit is highly correlated with land value, and certain types of local taxes such as land appreciation tax and stamp duty are computed based on land price, FAR limit is likely to have a direct effect on local government's budgetary revenue, which leads to the concern of reverse causality. This simultaneity issue will underestimate the negative impact of local budgetary revenue on FAR limit.[21] Second, unobserved local features might bias the OLS estimate. For instance, high population density in the preexisting informal housing upon the land plot will increase the resettlement costs for land acquisition (Fu & Somerville, 2001), and local governments might design high FAR limits to compensate for the increasing acquisition costs. Meanwhile, the literature suggests that informal housing contributes to accommodating migrant inflows in Chinese cities (Niu et al., 2021), and the density of informal housing might therefore have a positive effect on local budgetary revenue. This confounding factor is not fully controlled for in the main specification due to data availability and will underestimate the negative effect of budgetary revenue on FAR limits.[22] Other unobserved local factors such as the historical construction density, geographical conditions, and corruption in the land auction market (Cai et al., 2013) might be correlated with both local budgetary revenue and FAR design as well, leading to potential bias in the OLS estimate.

3.2.2 | Identification strategy

To address the endogeneity concerns as discussed in Section 3.2.1, this article first creates $0.02° \times 0.02°$ (approximately 2.2 km × 2.2 km) spatial grids covering the whole country and applies a grid fixed effect strategy to compare land parcels within a small geographic unit. This method allows me to control for time-invariant local features such as historical construction density, geographical conditions, and the long-term general land use plan at the city level. Because of the comprehensive coverage of land transactions in the baseline dataset, there are still rich variations in FAR limits after I include the grid fixed effects. I also control for the effects of county-level time-invariant features and macro trends by including county fixed effects and year-month fixed effects, respectively. To mitigate the concern of high-skilled labor sorting into cities with better job

[21] See details regarding how the simultaneity issue biases the OLS estimates in Supporting Information Appendix D.

[22] See details regarding how this confounding factor biases the OLS estimates in Supporting Information Appendix D.

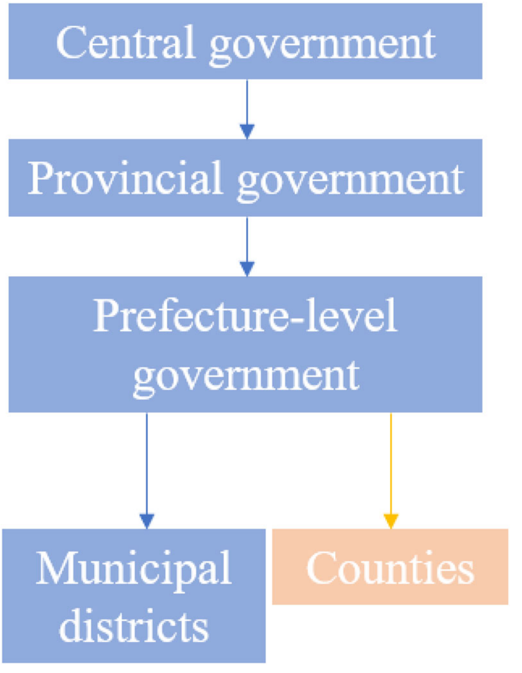

FIGURE 10 Local administrative division in China. [Color figure can be viewed at wileyonlinelibrary.com]

opportunities and amenities, I control for time-varying prefecture characteristics on local industry composition, population size, and medical and educational resources in the main specification.

However, two potential endogeneity issues might still remain after I control for multiple fixed effects and the time-varying local characteristics: First, FAR limit is likely to be correlated with local budgetary revenue through taxes related to land value, leading to the concern of reverse causality. Second, unobserved time-varying local factors such as corruption and the density of informal housing are likely to affect both FAR design and budgetary revenue. To address these endogeneity issues, this article proposes an instrument variable strategy by exploiting the exogenous variation generated by a central government administrative adjustment policy named "Turning Counties into Districts" (TCID). The details of this policy are discussed as follows.

China has established a unitary centralized power system since 1949. The system of Chinese local administrative division has four levels (from top to bottom): provincial-level, prefecture-level (city-level), county-level, and town-level. As shown in Figure 10, the county-level administration consists of municipal districts, which are more urban and directly governed by prefecture-level governments, and counties, which are more rural and have a higher degree of administrative autonomy in different aspects such as fiscal budget and land supply. This administrative autonomy introduces more flexibility for county leaders to adjust policies based on local economic conditions. However, it also causes administrative barriers and inefficiencies among different levels of governments. For instance, if a prefecture government plans to implement a city-wide subway network, the county government might oppose and delay this project because the subway station will generate noise and pollution to the county residents.

During the last decades, there has been a rapid process of urbanization in China, and many rural counties have been turned into municipal districts to be directly governed by the prefecture-level governments. The major aim of the TCID policy is to boost local economic development

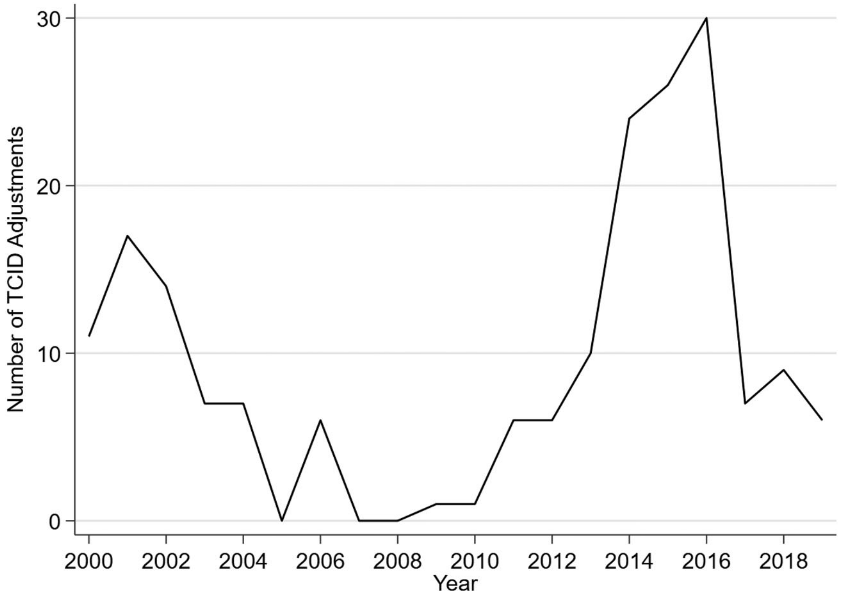

FIGURE 11 The number of Turning Counties into Districts (TCID) adjustments.

by breaking administrative barriers and promoting cooperation among different levels of governments. To apply for the TCID adjustment, prefecture-level governments will first investigate the potential counties to be adjusted and cooperate with the county-level governments to prepare for an administrative adjustment proposal. Then, they will submit the proposal to the provincial government and the central government. The central government reviews the adjustment plan and makes the policy decision according to a range of local economic and social conditions. The criteria for TCID adjustments are mainly based on two documents published by the Ministry of Civil Affairs and the State Council (i.e., the central government) in 1993 and 2014, respectively. The conditions include requirements on urban population, population density, the upper limit of employment in the agricultural sector, local budgetary revenue, GDP, medical resources, and so on. For instance, "the criteria for establishing municipal districts" published by the Ministry of Civil Affairs in 2014 states that a prefecture can apply to turn its rural county into a municipal district if it can satisfy a series of requirements on population size, population density, and economic development level. Besides, the county to be adjusted needs to achieve an urbanization rate of at least 50%, and the agricultural sector should account for less than 20% of the total GDP.

From 2000 to 2019, 188 TCID adjustments have been completed in China. As Figure 11 shows, there are two major waves of the administrative adjustments, starting in the early 2000s and the early 2010s, respectively. Although the first wave is largely driven by the central government's instruction, the second wave mainly reflects the demand from the local government side. During the second wave, prefectures actively apply for turning their counties into municipal districts to avoid geographical and administrative obstacles for future urban development. Figure 12 presents an example of the TCID policy. In June 2002, a prefecture-level city Xi'an got the approval that Chang'an county (one of the light blue polygons) could be turned into a municipal district (dark blue polygon). After this adjustment, Chang'an district would be directly governed by the prefecture-level government.

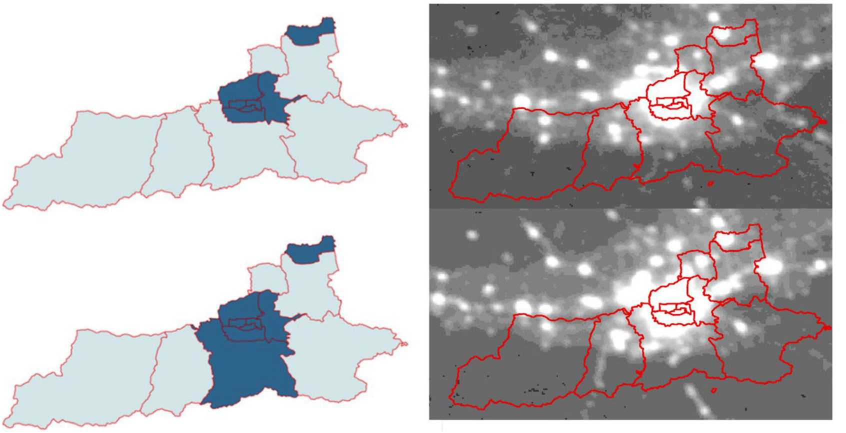

FIGURE 12 Turning County into District (TCID)—an example in Xi'an. [Color figure can be viewed at wileyonlinelibrary.com]

Notes: The top right figure shows the nightlight in Xi'an in 2001, before the TCID adjustment. The bottom right figure shows the nightlight in Xi'an in 2005, after the TCID adjustment. The nightlight data comes from the National Centers for Environmental Information's National Geophysical Data Center (data collected by the US Air Force Weather Agency).

TCID policy usually benefits the prefecture-level government by bringing in extra fiscal revenue from the county-level administration and allowing the prefecture to implement city-wide infrastructure projects. For instance, Foshan turned four of its counties into municipal districts in 2002. After the administrative adjustment, Foshan government spent 10 billion RMB on an infrastructure project to connect the four newly adjusted municipal districts with the preexisting central districts. This project significantly reduced transportation costs and led to an industry upgrading in the preexisting municipal districts because high-skilled workers and high-end industries would concentrate in the central area after all districts were well connected.

However, the TCID policy seems to be a double-edged sword for the rural county to be adjusted. On the one hand, the county can benefit from having access to the prefecture-level public goods after the adjustment. On the other hand, the county needs to transfer a large proportion of its fiscal revenue to the prefecture-level government and might compromise on the prefecture-level infrastructure plan. Some county residents are worried that after the TCID policy, more resources will be reallocated from the county to the preexisting central districts, because the prefecture officials might have a preference for the central area. For instance, Figure 12 presents the nightlight in Xi'an before and after the 2002 TCID adjustment, based on the DMSP-OLS nightlight data (with digital values ranging from 0 to 63). Although the average nightlight in the adjusted Chang'an district increased from 8.6 to 9.8 between 2001 and 2005, the nightlight in the neighboring preexisting municipal district, Yanta, became much brighter after the TCID adjustment and increased from 50.9 to 55.2 between 2001 and 2005.

This article assumes that the TCID policy will generate an exogenous increase in the preexisting central district's budgetary revenue due to the infrastructure improvement, the break of the administrative barriers, and the growing agglomeration economies. Meanwhile, there is no direct correlation between local FAR design and the implementation of the TCID policy, as the adjustment decision is based on certain criteria set by the central government and is not likely to be influenced by local land use regulations. The administrative adjustment might directly influence land plots within the newly adjusted districts because these districts will be directly governed by the prefecture-level government after the TCID policy. This article thus removes all the "new districts" in the estimation sample and the treatment group will only include the land plots within the preexisting municipal districts. This article then estimates the following first stage regression:

$$Budget_{dy} = \beta TCID_d \times Post_y + Controls + \varepsilon_{dy} \quad (18)$$

where d indexes individual county/district and y indexes year. The instrument, $TCID_d \times Post_y$ is an indicator variable that takes the value of 1 if d is a preexisting municipal district within a prefecture that gets the TCID approval and y is after the implementation of the administrative adjustment in the prefecture. I then follow a two-stage-least-square strategy to estimate the impact of the budgetary revenue on FAR design using the budgetary revenue variable instrumented with the TCID policy.

For the instrumental variable estimator to be consistent and unbiased, the conditions are as follows: First, the TCID policy affects local budgetary revenue directly (relevance). Second, the treatment is as good as randomly assigned (independence). Third, the policy influences FAR design only through changes in local budgetary revenue (exclusion restriction). This article proves the instrument relevance by reporting both the first-stage results and the F-statistics. Meanwhile, the TCID adjustments have been widely implemented across Chinese cities, and this article argues that the TCID policy does not have a direct correlation with local FAR design because the policy decision is based on certain criteria set by the central government.

However, there is an obvious concern about the potential selection bias of the treated cities. Prefectures can get the TCID approvals because they are experiencing a rapid process of urbanization and can meet central government's criteria. Some unobserved local trends during the rapid urbanization process might be correlated with both local FAR design and the TCID policy. To address this concern, this article applies a PSM approach. I first estimate a city's propensity to be treated using a logit regression with explanatory variables including population, population growth rate, and industry composition, which are the criteria that the central government uses to evaluate local government's application for the administrative adjustment. Next, I select one counterfactual city in the same year with the propensity score closest to the treated city. These matched cities offer a counterfactual urbanization path for how the treated cities would have experienced, had they not been approved to conduct the administrative adjustment. From estimating the PSM sample, this article can mitigate the concern of selection bias and compare cities experiencing similar urbanization processes before the TCID policy.

3.3 | Main results

Table 2 summarizes the results from estimating Equation (17) using a sample of residential land transactions in China between 2007 and 2019. Additional covariates are included in the estimation sequentially. Columns (1)–(3) in Panel A report the naïve OLS estimates. Column (1) controls for land parcel characteristics, year-month fixed effects, and county fixed effects. Column (2) includes the spatial grid fixed effects, and column (3) further controls for a vector of time-varying prefecture-level characteristics such as population, industry composition, and local amenities. The standard errors in all specifications are clustered at the grid level to allow for a degree of spatial autocorrelation. Columns (1)–(3) show that budgetary revenue has a negative impact on FAR design, and all estimates are statistically significant at 1% level. To quantify the results, the estimate from column (3) in Panel A suggests that a one standard deviation increase

TABLE 2 The effect of budgetary revenue on floor area ratio (FAR).

Specifications	(1)	(2)	(3)
Panel A: OLS results			
Budgetary revenue[a]	−0.052***	−0.067***	−0.033***
	(0.009)	(0.011)	(0.009)
R^2	0.389	0.525	0.523
Panel B: IV results			
Budgetary revenue[a]	−0.403***	−0.458***	−0.411***
	(0.050)	(0.066)	(0.080)
Kleibergen–Paap F-statistic	263.502	144.872	118.39
Panel C: first-stage results			
TCID × post	0.730***	0.611***	0.467***
	(0.045)	(0.051)	(0.043)
R^2	0.895	0.933	0.934
N	416,556	401,729	330,201
Land parcel characteristics[b]	Yes	Yes	Yes
Year-month FEs	Yes	Yes	Yes
County FEs	Yes	Yes	Yes
Grid FEs	No	Yes	Yes
Prefecture-level controls[c]	No	No	Yes

Notes: The dependent variable is FAR upper limit in Panels A and B. The dependent variable is the standardized budgetary revenue in Panel C.

Abbreviations: TCID, Turning Counties into Districts; FE, fixed effect.

[a]This variable corresponds to the standardized county-level budgetary revenue.

[b]Land parcel characteristics include land area, distance to CBD, type of transfer, land quality, a dummy variable indicating whether the land plot is for resettlement housing, and the source of the land plot.

[c]Prefecture-level controls include population, local industry composition, number of high schools, and number of hospital beds. Standard errors are clustered at the grid level.

*, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

in county-level budgetary revenue will decrease FAR limit by 0.03, which is around 2% of the standard deviation of FAR limit in the baseline sample. The negative coefficient from the OLS specification is in line with the main proposition that local governments with more budgetary revenue opt to design lower FAR limits.

As discussed in Section 3.2.1, potential endogeneity issues might lead to biased OLS estimates. This article then applies the instrumental variable strategy to study the impact of budgetary revenue on FAR design, and the IV results are reported in Panel B of Table 2. All the coefficients have the expected signs and are statistically significant at 1% level. The more credible IV estimate in column (3) suggests that a one standard deviation increase in local budgetary revenue will decrease FAR limit by 0.41, which is around 26% of the standard deviation of the FAR limit in the baseline sample. The IV estimates are more negative than the OLS estimates in Panel A, which is in line with the expectation that reverse causality and unobserved confounding factors will underestimate the impact of budgetary revenue on FAR design.[23]

[23] See details regarding how these endogeneity issues will lead to an underestimate of the negative effect in Supporting Information Appendix D.

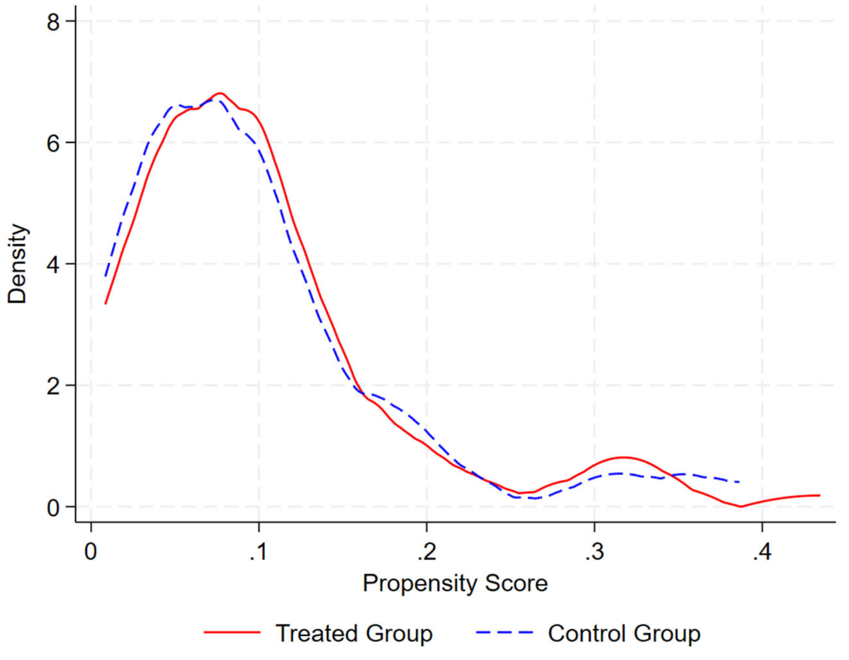

FIGURE 13 Kernel density of the propensity score.
[Color figure can be viewed at wileyonlinelibrary.com]

Notes: The graph plots the kernel density of the property scores for the prefectures in the propensity score matching (PSM) sample. The treatment group corresponds to the prefectures with the Turning Counties into Districts (TCID) adjustment. The control group corresponds to the prefectures without the TCID adjustment.

Regarding the validity of the instrument, the Kleibergen–Paap *F*-statistics in Panel B of Table 2 suggest that weak instrument is not a concern. In addition, Panel C of Table 2 reports the first-stage estimation results. The coefficients from columns (1)–(3) are all positive and statistically significant, meaning that as expected, the TCID policy will increase the budgetary revenue of the preexisting municipal districts.

A PSM method is then applied to mitigate the concern of potential selection bias. I first estimate a city's propensity to be treated using a logit regression with explanatory variables including population, population growth rate, and industry composition, which are the criteria that the central government uses to evaluate local government's application for the administrative adjustment. Next, I select one counterfactual city in the same year with the propensity score closest to the treated city. Figure 13 presents the Kernel distribution of the propensity scores for both the treated cities and the control cities in the PSM sample. It shows that the treated cities and control cities have comparable propensity scores, and they are likely to have a similar process of urbanization before the TCID adjustment. Table 3 then compares different local characteristics between the treated and the control cities one year before the TCID adjustment. The *T*-statistics are insignificant for all variables, either used or not used in the matching process, suggesting that after the PSM, the treated and the control cities are well balanced regarding different local economic and social characteristics. This article also applies an event study approach to test if there is a parallel trend in local budgetary revenue for the PSM sample before the TCID policy. Figure 14 shows the dynamic impacts of the TCID adjustment on the standardized budgetary revenue using the PSM sample. The black points correspond to the annual estimated coefficients,

TABLE 3 *T*-Tests for the propensity score matching (PSM) sample.

Variable	Control cities	Treated cities	*p* Value
Variables used in PSM			
Population (10,000)	135.6	145.1	0.638
Pop. growth rate (%)	0.2	0.6	0.615
% GDP (agricultural industry)	3.8	4.1	0.607
% GDP (tertiary industry)	44.8	46.9	0.251
Variables not used in PSM			
Budgetary revenue (million RMB)	14,118.5	14,113.0	0.999
Number of high schools	71.8	65.2	0.463
Number of hospital beds	12,046.0	12,343.3	0.879

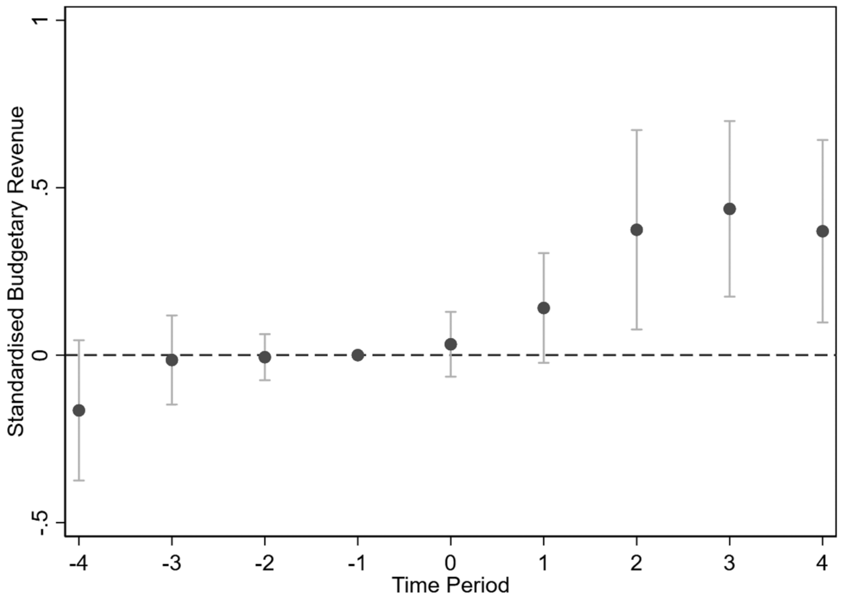

FIGURE 14 Event study analysis.

Notes: Time period corresponds to the year either before or after the implementation of the Turning Counties into Districts (TCID) policy. Black points correspond to the annual estimated coefficients. The coefficient of the year before the treatment is normalized to zero. Vertical lines correspond to 95% confidence intervals around those estimates. As documented in Section 3.1, local budgetary revenue is standardized by subtracting the sample mean of budgetary revenue from itself and dividing this difference by the standard deviation. The unit on the vertical axis is one standard deviation of the local budgetary revenue in the baseline sample.

and the coefficient of the year before the treatment is normalized to zero. The estimated coefficients are insignificant before the implementation of the TCID policy and become significant and positive after the administrative adjustment. This is in line with the expectation that the policy will break local administrative barriers and lead to an increase in local budgetary revenue. The insignificant point estimates before the TCID policy also suggest that the treated and control cities in the PSM sample should have followed a similar urbanization trend, had the treated cities not been approved to conduct the administrative adjustment.

TABLE 4 The effect of budgetary revenue on floor area ratio (FAR) (propensity score matching [PSM] sample).

Specifications	(1)	(2)	(3)
Panel A: OLS results			
Budgetary revenue[a]	0.006	−0.011	0.025***
	(0.011)	(0.012)	(0.013)
R^2	0.324	0.470	0.475
Panel B: IV results			
Budgetary revenue[a]	−0.224**	−0.304***	−0.288**
	(0.094)	(0.108)	(0.139)
Kleibergen–Paap F-statistic	90.764	56.141	50.265
Panel C: First-stage results			
TCID × Post	0.370***	0.321***	0.261***
	(0.039)	(0.043)	(0.037)
R^2	0.841	0.891	0.902
N	53,688	51,988	47,947
Land parcel characteristics[b]	Yes	Yes	Yes
Year-month FEs	Yes	Yes	Yes
County FEs	Yes	Yes	Yes
Grid FEs	No	Yes	Yes
Prefecture-level controls[c]	No	No	Yes

Notes: The dependent variable is FAR upper limit in Panels A and B. The dependent variable is the standardized budgetary revenue in Panel C.

Abbreviations: TCID, Turning Counties into Districts; FE, fixed effect.

[a]This variable corresponds to the standardized county-level budgetary revenue.

[b]Land parcel characteristics include land area, distance to CBD, type of transfer, land quality, a dummy variable indicating whether the land plot is for resettlement housing, and the source of the land plot.

[c]Prefecture-level controls include population, local industry composition, number of high schools, and number of hospital beds. Standard errors are clustered at the grid level.

*, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

This article then reestimates Equation (17) using the PSM sample, and the corresponding results are reported in Table 4. All the IV estimates in columns (1)–(3) are statistically significant and have the expected signs. The *F*-statistics suggest that weak instrument is not a concern, and the first-stage results reported in Table 4 show that the instrumental variable significantly correlates with budgetary revenue in an expected way. The most rigorous estimate in column (3) of Panel B suggests that a one standard deviation increase in local budgetary revenue will decrease FAR limit by 0.29, which is around 18% of the standard deviation of FAR limit in the baseline sample.

This article concludes from these findings that the impact of budgetary revenue on FAR limit is well identified. In line with the main proposition from the theoretical framework, I find that local budgetary revenue has a negative impact on FAR design. As the theoretical framework implies, local governments trade-off between the benefits (fiscal revenue and housing supply) and the costs (negative externalities) of high FAR design. If a local government can collect sufficient fiscal revenue from sources other than land sales, it will put more weight on the negative externalities caused by density and set lower FAR limits. Conversely, local governments with less budgetary revenue are more financially dependent on land sales and will design higher FAR limits to raise more fiscal revenue.

TABLE 5 Quantitative analysis.

Variable	Actual FAR[a]	Predicted FAR[b]	Counterfactual FAR[c]	Difference[d] (%)
Panel A: Land finance model abolished				
National mean level	2.86	2.86	3.12	8.91
Top 10% counties[e]	2.53	2.52	3.55	40.52
Bottom 10% counties[f]	2.94	2.94	2.97	0.92
Panel B: Hypothetical public transfer scheme				
National mean level	2.86	2.86	2.87	0.34
Top 10% counties[e]	2.53	2.52	2.63	4.05
Bottom 10% counties[f]	2.94	2.94	2.94	−0.18

[a]The mean value of the actual FAR limits based on the land transaction dataset.
[b]The mean value of the predicted FAR limits based on the IV specification.
[c]The mean value of the counterfactual FAR limits based on two scenarios as reported in Panels A and B.
[d]The difference between the predicted FAR and the counterfactual FAR.
[e]Counties with the top 10% budgetary revenue in 2007.
[f]Counties with the bottom 10% budgetary revenue in 2007.

3.4 | Quantitative analysis

In this section, I conduct two counterfactual exercises to quantify the impact of the land finance model on FAR design. To do so, I first predict local FAR limits by estimating specification (17) with the TCID instrument. The specification yields a prediction of FAR limit conditional on local budgetary revenue, different land plot and city characteristics, as well as grid, county, and time fixed effects. I then obtain a counterfactual scenario by predicting local FAR limits with the impact of budgetary revenue set to zero. This exercise is based on the theoretical framework's prediction that if the land finance model was entirely abolished, there should be no impact of local budgetary revenue on FAR limits. I conduct this counterfactual analysis for land plots located in three groups of counties: all the counties used in the baseline estimation sample, the top 10% counties based on their budgetary revenues in 2007, and the bottom 10% counties based on their budgetary revenues in 2007.

Panel A of Table 5 reports the estimates of this quantitative exercise. The predicted FAR limits are similar to the actual FAR limits, suggesting a good prediction power of the baseline IV specification. Panel A then shows that if the land finance model was entirely abolished in China, the average FAR limit for all counties would increase by 8.9% (from 2.86 to 3.12). Meanwhile, the impact of abolishing land finance model is heterogeneous across different counties. For the relatively rich and economically developed top 10% counties, the average FAR limits would increase significantly by 40.5%. As Figure 1 suggests, these cities are also faced with severe housing affordability issues, and relaxing FAR restrictions could hopefully improve housing affordability there. Conversely, if the land finance model was abolished, the FAR limits in the bottom 10% counties would only increase by 0.9%.

This article then conducts the second counterfactual analysis by assuming a hypothetical county-to-county public transfer scheme. The scheme collects 10% of the top 10% counties' budgetary revenue and provides a public transfer to the bottom 10% counties with the transfer amount equaling 20% of the bottom 10% counties' budgetary revenue. Panel B of Table 5 reports the estimates of FAR under this counterfactual scenario. With this hypothetical public transfer scheme, the relatively rich counties would set 4.1% higher FAR limits, and the relatively poor counties would set 0.2% lower FAR limits. The results suggest that under the current land finance model, a county-to-county public transfer scheme could hopefully mitigate spatial inequality and housing affordability issues.

4 | ADDITIONAL RESULTS AND ROBUSTNESS CHECKS

4.1 | Negative externalities caused by construction density

To test for the assumption in the theoretical framework that high density causes negative externalities, I conduct the following exercise to estimate the impact of new residential project completion on the neighborhood air quality. To do so, I merge 42,880 residential projects with the annual PM2.5 raster data ($0.01° \times 0.01°$ resolution) in China. For each residential project, I know the year of construction completion and its neighborhood air quality. I then apply a staggered difference-in-difference design to explore the effect of new construction on air quality. I select the projects completed between 2007 and 2019 to stay consistent with the baseline sample and estimate the following specification using OLS:

$$Ln(PM2.5)_{jy} = \phi_j + \beta New\,Project_{jy} + \delta_y + \varepsilon_{jy} \tag{19}$$

where j indexes each residential project and y indexes time periods. The variable $New\ Project_{jy}$ is a dummy variable which equals one if year y is equal to or after the completion year of the new residential project j, and zero otherwise. A vector of project fixed effects is represented by ϕ_j, and δ_y represents a set of time dummies (year fixed effects). The dependent variable $Ln(PM2.5)_{jy}$ measures the air quality for a small neighborhood where the new residential project j is located in year y. The parameter of interest is β, measuring the impact of the new residential project on its neighborhood air quality.

The estimation results are reported in Table A1. I first test the negative externality effect using the full sample of all residential projects and then split the full sample into three subsamples to explore if the effect will vary depending on different FAR designs. Column (1) suggests that on average, a new residential project completion will cause a 0.06% increase in PM2.5 in its neighborhood area, although the estimated coefficient is not statistically significant. Column (2) then reports a positive and statistically significant effect of 0.25% for high-rise buildings, and this effect is higher than the coefficient of 0.14% in column (3) for medium-rise buildings, suggesting that higher construction density leads to more air pollution. Besides, column (4) reports a marginal and statistically insignificant effect of low-rise buildings on the neighborhood air quality, suggesting that low-rise buildings accommodate fewer populations and do not necessarily lead to more air pollution.

I then employ an event study approach to test for the parallel trend assumption and to estimate the time-varying effects of new construction on neighborhood air quality. Panel A of Figure B1 presents the estimates for the dynamic effects of new developments on PM2.5 using all residential projects in the sample. The coefficient of the year before the completion of the construction is normalized to zero and the vertical lines represent the 95% confidence intervals. Differences in air quality for neighborhoods with and without new construction are stable before the treatment, consistent with the parallel trend assumption. The estimated coefficients become positive and statistically significant after the completion of the new projects, suggesting a significant impact of new development on the neighborhood air quality. Panels B–D of Figure B1 further present the time-varying impacts of new projects with different construction densities. In line with the results in Table A1, Figure B1 suggests that high-rise buildings will cause more air pollution in their neighborhoods compared with medium-rise buildings, and there is no significant difference in PM2.5 between the neighborhoods with and without new low-rise building completion. Table A1 and Figure B1 together support the assumption in the theoretical framework that high-density construction will cause some negative externalities.

4.2 | FAR limits for commercial use and special use

Does local budgetary revenue also influence the FAR design for nonresidential use? As Figures B2 and B3 show, there is no clear spatial pattern of the FAR upper limits for commercial and special uses in Chinese counties.[24] To answer this question, I reestimate specification (17) using two samples of land plots for commercial use and special use, respectively. Table A2 reports the estimation results and most estimated coefficients are marginal and statistically insignificant.

How to explain an insignificant impact of local budgetary revenue on the FAR design for nonresidential use? The theoretical framework indicates that local fiscal capacity matters for FAR design because of the substitution between local budgetary revenue and land sales. Compared with residential land parcels, the fiscal incentive of raising FAR limits for nonresidential land parcels is relatively low. Nonresidential land sales account for a relatively small proportion of the total land sale revenue, and some local governments intentionally lower the land price for commercial use to attract firms and boost the local economy. In addition, Table A3 reports the elasticity of land price per square meter with respect to FAR limit for different land uses. Columns (1)–(3) suggest that although this elasticity is around 39% for residential lands, it becomes lower for other land uses. Especially for special-use land plots, the elasticity is only around 5.4%,[25] which supports the argument that the insignificant effect of local budgetary revenue on nonresidential FAR design is driven by a weaker fiscal incentive.

The estimation results from Table A2 also mitigate the endogeneity concern of unobserved spatial characteristics in the main specification. One might argue that there are fewer land plots available in the more economically developed cities, and the scarcity of land plots might have an impact on FAR design, as local governments will set high construction density given the limitation of horizontal urban expansion. However, if these cities are indeed concerned about the availability of land plots and opt to design high FAR limits for residential land parcels, they should also design high FAR limits for nonresidential land parcels. Instead, Table A2 shows that the impact of local budgetary revenue on FAR limits for nonresidential use is insignificant, suggesting that the main result is not affected by the geographical scarcity in more economically developed cities.

4.3 | Transfer payment from the central government

Another major source of fiscal revenue for local governments in China is the transfer payment from the central government. In this subsection, I estimate the impact of central government

[24] Commercial use corresponds to land plots that are used for office buildings, retail, hotels, restaurants, and so forth. Special use refers to land plots that are used for public administrative purposes, green space, medical purposes, educational purposes, religious purposes, and so on.

[25] The low elasticity estimate is reasonable, as the FAR design for special use (e.g., hospitals, green space, and schools) is determined by the technical requirements to satisfy the special purposes, and developers do not necessarily have a strong incentive to build more densely.

transfer payment on FAR design. The prefecture-level fiscal transfer data comes from China Financial Statistics of Cities and Counties. As the local public transfer data becomes unavailable after 2009, this article uses the share of local government's transfer payment in 2007 and the annual national transfer payment trend to estimate yearly transfer payments at the local level. As Equation (20) illustrates, $Transfer_{cy}$ represents the estimated transfer payment in prefecture-level city c in year y. $\frac{Transfer_{c2007}}{Total_{2007}}$ represents the share of city c's transfer payment relative to the national level in year 2007, and $Total_y$ denotes the national trend of transfer payment in year y:

$$Transfer_{cy} = \frac{Transfer_{c2007}}{Total_{2007}} \times Total_y \tag{20}$$

This article then studies the impact of the estimated local transfer payment on FAR limit by estimating a specification similar to Equation (17). The results are reported in Table A4. All estimates are negative and statistically significant at 1% level. The most credible estimate in column (3) suggests that a one standard deviation increase in transfer payment will decrease FAR limits by 0.14. This finding is in line with the proposition that if local governments can collect sufficient fiscal revenue from sources other than land sales, they will design relatively low FAR limits to reduce the negative externalities caused by density. The estimated effect of transfer payment on FAR design is larger than the OLS estimation as reported in Table 2, potentially because transfer payment comes from the central government and the endogeneity issues as discussed in Section 3.2.1 are less pronounced in this specification.

4.4 | Alternative measures of local fiscal capacity

This article then uses two alternative measures of local fiscal capacity to reestimate a specification similar to Equation (17) and test the robustness of the main results. I first explore the impact of county-level budgetary revenue per capita on FAR design, and Table A5 presents the estimated results. All the OLS and IV coefficients are negative and statistically significant at 1% level, suggesting that the impact of local budgetary revenue on FAR design is robust, and the main IV results are driven by the increase in local fiscal capacity (instead of the population growth) in the preexisting municipal districts.

As the FAR design is jointly decided by the county- and the prefecture-level governments, I also conduct a robustness check by estimating the impact of prefecture-level budgetary revenue on FAR design. The estimation results are reported in Table A6. All the estimated coefficients are still negative and statistically significant, suggesting that the impact of local budgetary revenue on FAR design is robust after I measure local fiscal capacity at a higher administrative level.

4.5 | The concern of household sorting

Different types of households might sort into neighborhoods with different public goods and amenities, and these households might have different demands and preferences on FAR design. This potential sorting behavior leads to a threat to this article's identification strategy. In the main specification, this article mitigates the concern of across-city household sorting by controlling for prefecture-level time-varying variables such as local industry composition, population size, and medical and educational resources. The grid fixed effects also contribute to control for neighborhood-level time-invariant characteristics. To further mitigate the concern of demand side factors and household sorting, I conduct the following two robustness checks.

I first apply a spatial boundary design by selecting land parcels that are within 2 km away from the county-level administrative boundary in China. For instance, Figure B4 presents the land plots that are within 2 km away from the county boundary in Beijing and nearby cities. These land parcels are geographically close to each other and tend to have near-identical neighborhoods and unobserved spatial features (e.g., access to local amenities and public service). I then reestimate Equation (17) using a subsample of land transactions that are within 2 km away from the county-level boundary. The estimation results are reported in Table A7. Five out of six estimated coefficients are statistically significant and negative, suggesting that the main results are robust after I take into account unobserved spatial characteristics that might influence the sorting of households.

The second robustness check compares land parcels with similar FAR limits, as the potential homebuyers and the building features are comparable for residential projects with a similar FAR design. For instance, land parcels with FAR limits between 1.2 and 3 are likely to be developed into medium-rise buildings with 6–18 stories, and land parcels with FAR limits above 3 are likely to be developed into high-rise buildings with more than 18 stories. I therefore reestimate Equation (17) using two subsamples of land parcels with different ranges of FAR limits. Table A8 reports the estimation results, and reassuringly, the IV coefficients derived from both the medium- and the high-density samples are all negative and statistically significant.[26]

Collectively, these results indicate that local household sorting is rather negligible and, therefore, unlikely to induce a substantial bias in the baseline estimates.

4.6 | Other robustness checks

I now turn to a series of other robustness checks to confirm the main findings and provide additional validation to this article's research strategy.

First, I reestimate Equation (17) using spatial grids of varied sizes. Columns (1) and (2) of Table A9 report the results after I control for $0.01° \times 0.01°$ (approximately 1.1 km $\times$ 1.1 km) grids, and columns (3) and (4) of Table A9 report the results after I control for $0.03° \times 0.03°$ (approximately 3.3 km $\times$ 3.3 km) grids. All the estimated coefficients are negative and statistically significant at 1% level, showing that the main empirical findings are robust to reasonable grid size choices.

Second, four Tier-1 cities (Beijing, Shanghai, Guangzhou, and Shenzhen) and two municipalities (Tianjin and Chongqing) are reckoned as the most economically developed cities in China. To avoid potential bias caused by the unobserved features in these six superstar cities, this article conducts a robustness check by estimating a sample excluding all land transactions in these cities. The results are reported in Table A10. In line with the baseline findings, the estimated coefficients are all negative and statistically significant at 1% level, suggesting that the main results are robust after I mitigate potential bias introduced by superstar cities.

[26] Because of the relatively high population density in major Chinese cities, it is not common to construct single-family houses and low-rise buildings. In the baseline sample, only 5.7% of land plots have FAR upper limits lower than 1.2. As indicated by Figure 7, most developers choose to build residential projects close to the FAR upper limits, suggesting that the demand for low-density housing is not dominant among homebuyers, and most households will choose to purchase properties in medium- and high-rise buildings.

Lastly, this article conducts a robustness check to address the concern of local government debt. After the 2008 financial crisis, the central government in China launched a fiscal stimulus program named the "four trillion stimulus package" to boost the economy. Following this stimulus program, local governments in China have increasingly issued debts to finance infrastructure investments, and most of these debts are guaranteed by future land sale revenue. Due to the fiscal pressure of repaying local debts, governments might set relatively high FAR limits to acquire more land sale revenue. As shown in Figure B5, the general government gross debt relative to GDP is below 40% in China between 2007 and 2013, and during this period, local government debt is not likely to have a major impact on FAR design. This article thus estimates a subsample of land transactions between 2007 and 2013 to test for the robustness of the main results. Table A10 reports that all estimates are negative and statistically significant, suggesting that local budgetary revenue has a negative effect on FAR design before the boom of local government debt in China.

5 | CONCLUSION

This article explores the determinants of FAR limits in China by proposing a spatial equilibrium framework and showing that local governments trade-off between the benefits and the costs of high construction density when designing FAR limits. Exploiting a comprehensive dataset of land transactions and a PSM-IV strategy, I find empirical results consistent with the theory's proposition that local governments with more budgetary revenue tend to design lower FAR limits. Further counterfactual exercises suggest that the land finance model contributes to housing affordability issues and spatial inequality in China. On the one hand, Tier-1 cities and cities along the southeast coast can collect sufficient budgetary revenue and will design relatively low FAR limits, which reduce housing supply and push up housing prices. The restrictive land use regulations also lead to wealth inequalities between the existing homeowners and the potential home buyers within these cities. On the other hand, some local governments in the less developed western and middle regions cannot collect abundant budgetary revenue and therefore choose to design higher FAR limits to acquire more land sale revenue. These cities are not experiencing economic prosperity as Beijing and Shanghai, and many high-rise buildings are constructed there but then left vacant. Despite the staggeringly high housing prices in Tier-1 cities in China, some properties in lower-Tier cities are sold for only 400 RMB/m^2, which is around 55 USD/m^2 (China Internet Information Centre, 2019).[27] Although this article studies the determinants of FAR design in China, future research can explore how Chinese cities can improve the current land finance model to develop and urbanize in a more sustainable way.

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[27] Based on the currency exchange rate in November 2023.

Meeting (LSE), UEA Virtual Meeting 2020, University of Aberdeen, MIT, University of Zurich, LSE, UCLA, and University of Reading. All errors are the sole responsibility of the author.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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