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To build above the limit? Implementation of land use regulations in urban China

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ABSTRACT

This paper studies the implementation of land use regulations in urban China. In particular, we investigate land developers' compliance with floor-to-area ratio (FAR) regulations using a unique set of residential land parcel data from 30 major Chinese cities matched with the corresponding residential development projects built on those parcels. In our sample, in more than 20% of the cases, developers built above the regulatory FAR limits in the ex post land development, and the total floor area built in those cases increased 21.5% over the regulatory limit. Our analysis finds that attractive land location attributes tend to induce developers to pursue upward adjustments of FAR. Moreover, developers who are more likely to have special relationships with government officials tend to make larger upward adjustments. Our estimates suggest that there exists a significant gap between the privately optimal FAR that maximizes land value and the regulatory FAR. This gap is only modestly reduced by corrupt ties with government officials, implying that FAR regulations have imposed a highly restrictive constraint on China's urban land development even given imperfect compliance.

1. Introduction

A considerable body of literature studies the effect of land use regulations on housing supply in various countries (e.g., Cheshire and Sheppard, 2002, 2005; Glaeser and Gyourko, 2003; Quigley and Raphael, 2005; Glaeser et al., 2005a, 2005b; Cheshire, 2006; Saiz, 2010; Turner et al., 2014). However, the existing literature is generally silent about the actual enforcement of land use regulations, thus leaving unanswered questions about the nature and magnitude of the effects of such regulations. This issue is especially relevant in developing countries like China where compliance with regulations should not be taken for granted and corruption in real estate development is widespread (Cai et al., 2013; Fang et al., 2014). A better understanding of this issue may also shed light on the gap between government land use regulations and private optimal decisions. Understanding this gap has important policy implications for developing economies as inefficient land use may severely curb the process of urbanization and distort the urban landscape for decades to come (Glaeser, 2011).

In this paper, we study the implementation of land use regulations in urban China by focusing on the floor-to-area ratio (FAR) regulation. FAR is a density regulation for land development, serving as an upper limit on the ratio of the total floor area to the lot size of the land to be developed. FAR regulations are common in many countries and are considered one of the most important land use regulations (e.g., Bertaud and Brueckner, 2005; Gao et al., 2006; Gomez-lbanez and Ruiz Nunez, 2009; Bertaud, 2011; Brueckner and Sridhar, 2012; Brueckner et al., 2015).

Objective data on compliance are notoriously hard to obtain. However, we are able to measure compliance with FAR regulations by comparing the regulatory FAR of a land parcel when it is sold with the actual FAR of the residential development project on the land after its development. Both are required by law to be revealed publicly. Specifically, we identify 854 exactly matched pairs of land parcels and their corresponding residential development projects in 30 major Chinese cities. In 181 of these 854 cases, the land developers built above the regulatory upper limits that were set when the land parcels were acquired. The developers adjusted the FAR upward in 21.2% of all the cases, covering approximately 25.2% of the total land area developed. In terms of magnitude, the average upward adjustment over the regulatory FAR limit is 39.9%. For those cases in which upward adjustments occurred, the floor area built increased 21.5% over the regulatory limit, which added a total

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housing market value of 88.5 billion in 2012 RMB yuan.[1] Including all 854 cases, the total floor area was increased by 4.3% beyond the total regulatory limit due to upward adjustments of FAR. The increased housing supply created by these upward adjustments is much greater in several coastal cities where land is more valuable. For example, the total floor area increased 28.9% in Shenzhen, 6.9% in Shanghai, 6.2% in Nanjing, Dalian and Jinan, and 5.7% in Qingdao.[2]

To understand the phenomenon of "building above the limit," we create a simple model of how private land developers determine their desired FARs in the presence of a regulatory upper limit by extending the framework of DiPasquale and Wheaton (1996). A developer is free to build up to the regulatory upper limit. However, if the developer wants to build above the limit, he is required to pay an adjustment cost. Informed by our interviews with government officials and land developers, we suppose that the adjustment cost is increasing in location attractiveness and decreasing in special ties between the developer and government officials. Our model predicts that the developer tends to build further above the limit if the land parcel is more attractive and if he has a corrupt deal with government officials.

In our empirical analysis, we first construct two variables that are essential to the developer's FAR decision: a continuous variable that measures the location attractiveness for each land parcel and a dummy variable that indicates whether the land sale is likely to involve a corrupt deal between the developer and government officials. We construct the variable of location attractiveness as an index of the collective value of all relevant location attributes, e.g., distance to the city center, school quality, and access to public services such as subways, parks, hospitals, etc. We consider a land sale likely to be corrupt if the land was located in an attractive location but sold noncompetitively at auction.

We then estimate a structural MLE model based on our theory. Our estimation yields three key findings. First, attractive location attributes induce pursuit of upward FAR adjustments. Second, if a land parcel is more likely sold through a corrupt deal, then ex post, its developer tends to build more floor area above the regulatory limit. Finally, based on our estimates, there exists a significant gap between the FAR that maximizes the market land value and the regulatory FAR. Corruption may facilitate an upward adjustment and reduce the gap, but only modestly. This suggests that FAR regulations have imposed a highly restrictive constraint on China's urban land development even in the absence of strict compliance.

This paper contributes to the literature on land use regulations. (For a review, see Gyourko and Molloy, 2015.) We show that private developers' compliance is not a negligible factor when evaluating the effects of land use regulations. In this sense, our study echoes the literature that studies the endogenous implementation of environmental regulations by polluting firms (Holland and Moore, 2008; Sigman and Chang, 2011; Cai et al., 2016). Our paper is also related to the literature on corruption, in particular, the corruption in China's real estate sector. The heavily regulated real estate industry and the bureaucratic system in China offer a unique setting for studying corruption (Svensson, 2005). Two recent papers have investigated corruption linked to real estate development in Chinese cities. Cai et al. (2013) analyze a large dataset of land sale transactions in China and present evidence of corruption in the urban land auctions held by China's city governments. Using a matched dataset of land sales and ex post developments, our paper complements theirs by showing that corruption may facilitate upward adjustments of FAR in ex post land development. Using a dataset on housing mortgage loans from a leading commercial bank in China, Fang et al. (2014) find that bureaucrats from government agencies critical to real estate development enjoy larger price discounts on their house purchases than regular homebuyers.

The rest of the paper is structured as follows. Section 2 discusses the institutional background of the urban land markets and FAR regulations in China. Section 3 models the FAR decision of a profit-maximizing developer in the presence of a regulatory upper limit and specifies the estimation equations accordingly. We introduce the data for empirical analysis in Section 4, and present the estimation results in Section 5. Section 6 discusses the implications of our empirical findings. Section 7 concludes.

2. Background

In China, all urban land is owned by the state. Since 1988, the use rights of vacant urban land have been allocated through leaseholds by each city's land bureau. In the 1990s, most use rights allocations were done by "negotiation" between developers and government officials. To control widespread corruption in such negotiated land deals, in 2002 the Ministry of National Land and Resources banned negotiated sales after August 31, 2004. Since then, all urban leasehold sales for private development have been conducted through public auctions. In each city, land auctions are held by the local land bureau, with details of all transactions posted to the public on the Internet. Although public auction is generally viewed as a way to prevent corruption in land allocations, there is still wiggle room. Two-stage auctions (called *guapai* in Chinese) and English auctions (called *paimai* in Chinese) are the two main auction types used by land bureaus. As Cai et al. (2013) show, a corrupt land bureau official tends to select the format of the two-stage auction in order to help her partner developer win the land he is interested in. Specifically, the developer can signal that this land parcel is already taken by bidding at the reserve price at the beginning of the first stage of the auction and hence significantly deter the entry of other competitors into the auction.

The city's land reserve and allocation committee conducts land use planning and sets the general guidelines for regulations on land use with the aims of promoting "rational" land use, guarding "public interests," and protecting historic heritage and natural resources. This committee consists of the city's political leaders and key figures from relevant local government agencies, such as the land bureau and the urban planning bureau. Following those guidelines and other relevant laws and provisions, the city's urban planning bureau then independently determines use type and detailed development restrictions (e.g., regulatory FAR limit, building height, green area rate, etc.) before each land parcel is released to the land bureau for auction.

The FAR regulation is one of the most important land use regulations in urban China. By law, any land parcel to be auctioned off must have a designated regulatory FAR level. Also, after the land is developed, the city's planning bureau must complete an official inspection of the residential project before it is put up for sale, in order to ensure compliance with the FAR regulation. In most cases, the FAR regulation takes the form of an upper bound constraint on the ratio of a building's total floor area to the lot size on which the building is to be constructed. Lower bound constraint cases are very rare and almost always not binding in our exactly matched sample, so we focus on the upper bound constraint in this paper.

FAR is not equivalent to building height. A developer can achieve a higher FAR by reducing open space and building more densely on a given land parcel without increasing building height. A developer can freely choose the FAR level for a project as long as it is not higher than the regulatory upper limit. However, if a

[1] The fact that FAR was adjusted upwards by 39.9% and the floor area built increased 21.5% among the cases of upward adjustment indicates that smaller land parcels underwent greater adjustments than larger land parcels.

[2] Appendix A reports the upward adjustment statistics and the resulting increase in total floor area by city.

developer wants to build above the FAR constraint, he must first file an application with the local government for a FAR adjustment. Although the details of this process vary by city, in general it includes the following steps, guided by the Urban and Rural Planning Law.[3] First, the developer submits an official application to the city's planning bureau. The planning bureau then conducts the first round review. In the review, the planning bureau coordinates with other government branches (e.g., the Development and Reform Commission, Land Bureau, Transportation Bureau, Environment Protection Bureau, Cultural Heritage Bureau, etc.) to ensure that the proposed adjustment does not violate any law or regulation. If the case passes the first round review, then as the second step, the planning bureau asks for assessments of the potential costs and benefits of the proposed adjustment from independent appraisers. The selection of outside experts must follow certain rules to ensure objectivity. Thirdly, the planning bureau publicly posts the application, along with its own review report and the outside evaluation reports, for at least 30 days. Meanwhile, the planning bureau seeks opinions from relevant parties, especially those who may be affected by the proposed adjustment. An official hearing may be held if necessary. Finally, if the planning bureau decides to pass the case, it submits a formal report to the upper-level government for final approval. This application process is rather complicated and time-consuming. It is not uncommon for it to take more than a year. This imposes a significant cost on developers that seek FAR adjustments.

Note that obtaining approval for a FAR adjustment from authorities is essential for developers who want to adjust the FAR. Without permission, the developer is not legally allowed to sell the housing units on the market. (Titles cannot be transferred to buyers.) After obtaining the final approval, the developer then needs to pay a predetermined land compensation payment to the city's land bureau for the additional floor area above the original limit. Detailed payment rules are set by each city's land bureau and vary by city. In general, the compensation payment is positively associated with the market value of the land parcel as estimated by an independent land appraiser. Sometimes, if the developer promises to provide extra public services such as paving a public road, part or all of the compensation payment may be waived.

The overall cost of a FAR adjustment is thus composed of the costs associated with the application process and the land compensation fee. The application process is lengthier and thus more costly if the magnitude of the intended adjustment is larger, so is the compensation fee. The compensation fee usually consists of a base part and a part that increases with the attractiveness of the land location. If the developer has no connection with the government officials, the adjustment cost may be very high. However, with a corrupt deal, the government can green-light the upward adjustment of FAR for a lower cost. For example, the corrupt land bureau official who helps a developer win the land auction may later endorse the application for an upward adjustment on behalf of the developer. And she may help lobby and coordinate other participating government branches in the review process of the developer's application for an upward adjustment. Her doing so makes the developer more likely to get the permission in a more timely fashion, which can save him substantial costs. Moreover, there are grey areas in how the land compensation fee is determined, and corrupt ties with government officials can save developers a significant amount of money on the fee.

[3] In 2012, the Ministry of Housing and Urban-Rural Construction issued a provision for the adjustment of regulatory FARs, based on the Urban and Rural Planning Law.

3. Theoretical framework and estimation specification

3.1. Theoretical framework

Our model builds upon the benchmark model by DiPasquale and Wheaton (1996). A developer sets the FAR to maximize his profit from development. He faces some trade-offs. On the one hand, a larger FAR raises gross profit by increasing the number of housing units built on each land unit. On the other hand, a larger FAR may reduce the housing price because increases in density reduce the amount that consumers are willing to pay. We first set out the hedonic equation for the housing price per floor area:

$$p = \alpha - \beta F, \tag{1}$$

where α denotes the location attractiveness of the land, which represents the collective value of all relevant location attributes; F denotes the actual FAR; and β represents the marginal reduction in housing price per floor area as the FAR is increased ($\beta > 0$).[4]

Meanwhile, as the FAR increases, construction costs rise. The cost per floor area in housing construction is specified as follows:

$$C = \mu + \tau F, \tag{2}$$

where μ represents the basic cost of construction per floor area and τ represents the incremental cost as FAR is increased ($\mu > 0$, $\tau > 0$).

Building above the regulatory upper limit, F_R, incurs an adjustment cost. We specify the general functional form of the adjustment cost per additional floor area as follows:

$$\psi(\alpha, r), \text{ if } F > F_R; \text{ zero, otherwise}, \tag{3}$$

where $\psi_\alpha > 0$, reflecting that the adjustment cost increases with the land's location attractiveness. r is a dummy variable indicating whether the developer has some corrupt ties with government officials. In (3), $\psi(\alpha, 1) < \psi(\alpha, 0)$, meaning that if corrupt ties exist, the adjustment cost will be lowered.[5]

The developer chooses the optimal FAR to maximize the value per land unit. Incorporating (1)–(3), we have the developer's objective function as:

$$\begin{aligned} Max_F\ p_l &= (p - C)F - I(F > F_R) \cdot \psi(\alpha, r)(F - F_R) \\ &= (\alpha - \mu)F - (\beta + \tau)F^2 - I(F > F_R) \cdot \psi(\alpha, r)(F - F_R), \end{aligned} \tag{4}$$

where I is an indicator function. In (4), we assume that $\alpha > \mu$ so that the land of interest is valuable enough to build upon. Solving the maximization problem, we have the FAR that maximizes the

[4] Following DiPasquale and Wheaton (1996), we use the functional form of Eq. (1) for hedonic price, in order to keep our analysis tractable. It appears to us that there is little empirical evidence showing any significant interaction between FAR and local amenities in hedonic house price regressions in the literature. To our best knowledge, there are two papers that study hedonic house prices in Chinese cities and include FAR as a housing attribute in their regressions (Liao and Wang, 2012; Wu et al., 2013). Both papers use a separable functional form similar to our specification and find a significantly negative effect of FAR on housing price as we do.

[5] The total adjustment cost consists of a fixed part and a variable part that equals total extra floor area multiplied by the adjustment cost per extra floor area. In reality, the fixed part of adjustment costs typically involves just a simple paper processing fee in application which is tiny compared to the variable part of the total adjustment costs. Seldom corruption targets to reduce this tiny part of the costs. In addition, in practice, it is very difficult to mis-state the extra floor area because it must be consistent with the housing information in the public sale. Therefore, our functional form of adjustment costs focuses on adjustment cost per extra unit of floor area by implicitly assuming that corruption only affects the variable part of adjustment costs. If we consider the savings on the fixed part of adjustment costs due to corruption, we need to calculate the total profit function. Our main results will not be affected. The only difference is that under corruption, the range of location attractiveness in which upward adjustment takes place will be larger than that in the current specification.

value per land unit as follows:

$$F = \begin{cases} \bar{F}_0 = \frac{\alpha-\mu}{2(\beta+\tau)} & \text{if} \quad F_R \geq \bar{F}_0 \\ F_R & if \quad \bar{F}_1 \leq F_R < \bar{F}_0 \\ \bar{F}_1 = \frac{\alpha-\mu-\psi(\alpha,r)}{2(\beta+\tau)} & if \quad F_R < \bar{F}_1 \end{cases}, \tag{5}$$

where $\bar{F}_0$ is the level that maximizes the value per land unit in the absence of regulation, and $\bar{F}_1$ is the optimal level conditional on upward adjustments. We assume that $1-\psi_\alpha > 0$, so that there exists a certain range of α such that the developer is willing to bear the adjustment cost to build above the limit. In (5), $\bar{F}_0$ and $\bar{F}_1$ both increase with location attractiveness α. However, $\bar{F}_1$ increases with α at a lower rate than $\bar{F}_0$ because $\psi_\alpha > 0$.

The two variables α (location attractiveness) and r (corruption) are key determinants in the FAR decision. In particular, when α is relatively low, $\bar{F}_0$ is lower than F_R and therefore it is optimal for the developer to choose an FAR level below F_R. As α rises, $\bar{F}_0$ becomes larger than F_R; however, before α becomes sufficiently large, the adjustment cost will prevent the developer from building above the limit. So the developer sets the FAR just at the upper limit. Finally, induced by a sufficiently high α, $\bar{F}_1$ exceeds F_R; it is then optimal for the developer to set the FAR above the upper limit F_R even if he has to incur adjustment costs. In addition, $\bar{F}_1$ is higher if r equals one, which means that with the help of some corrupt deal, the developer is more likely to build above the limit and add more extra floor area.

3.2. Estimation specifications

For estimation purposes, we impose a linear functional form on the adjustment cost per extra unit of floor area:

$$\psi(\alpha, r) = \psi_0 + \psi_1\alpha - \chi r, \tag{6}$$

where $\psi_0 > 0$, $\psi_1 > 0$, and $\chi > 0$. In (6), there are three items: a constant ψ_0; $\psi_1\alpha$, which is the part of the adjustment cost that increases in the land location attractiveness; and $-\chi r$, which is the effect of corruption in reducing the adjustment cost (see Section 2 for institutional details). For simplicity, we assume that the effect of corrupt ties with the government, indicated by r, is independent of land location attractiveness. We discuss more about this assumption in the empirical section (Section 5.3).

We adopt a maximum likelihood estimation approach in order to address the nonlinear nature of the FAR decision in the presence of an upper limit. The estimation model is a Tobit-switching model. Let $\{F_i : i = 1, 2, ..., N\}$ be a random variable that follows the developer's FAR decision as defined by (5), where i indexes each land observation in the sample. According to (5) and (6), we have the base estimation specification as follows:

$$F_i = \begin{cases} \bar{F}_{0i} = \eta_0\alpha_i + x_i\delta_0 + u_{0i} & \text{if} \quad u_{0i} \leq -\eta_0\alpha_i - x_i\delta_0 + F_{Ri} \\ F_{Ri} \quad \text{if } u_{0i} > -\eta_0\alpha_i - x_i\delta_0 + F_{Ri}, & \\ & u_{1i} \leq -\eta_1\alpha_i - \lambda r_i - x_i\delta_1 + F_{Ri}, \\ \bar{F}_{1i} = \eta_1\alpha_i + \lambda r_i + x_i\delta_1 + u_{1i} & \\ & \text{if} \quad u_{1i} > -\eta_1\alpha_i - \lambda r_i - x_i\delta_1 + F_{Ri} \end{cases} \tag{7}$$

where $\eta_0 = 1/(2(\beta+\tau))$, $\eta_1 = (1-\psi_1)/(2(\beta+\tau))$ and $\lambda = \chi/(2(\beta+\tau))$, and x_i is a vector of land characteristics such as land size, land use type, geographic and climate characteristics, etc. These characteristics may affect the costs of construction and FAR adjustment corresponding to μ and ψ_0 in the functional forms of $\bar{F}_0$ and $\bar{F}_1$ in (5). Note that a constant is also included in x_i in the estimation. The error terms u_{0i} and u_{1i} capture the unobserved heterogeneity across developers in the costs of construction as well as their private valuation of location attributes. Meanwhile, u_{1i} additionally captures the unobserved variation in adjustment cost when an upward adjustment occurs. To implement the MLE, we impose the following joint normal distribution assumption on the error terms:

$$\begin{pmatrix} u_{0i} \\ u_{1i} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{bmatrix} \sigma_0^2 & \rho\sigma_0\sigma_1 \\ \rho\sigma_0\sigma_1 & \sigma_1^2 \end{bmatrix} \right). \tag{8}$$

The estimation procedure is standard, and details are omitted for the sake of space.

We expect both η_0 and η_1 to be positive, with η_1 smaller than η_0 given that the land compensation fee portion of the adjustment cost increases with location attractiveness (i.e., $\psi_1 > 0$). We also expect λ to be positive given that corruption helps reduce the adjustment cost (i.e., $\chi > 0$). Using these parameter estimates, we can also predict the hypothetical FAR levels under different scenarios, such as without regulation or without corruption.

4. Data

We focus on residential land sales in 30 major Chinese cities.[6] For each land sale, the land bureau posts detailed information on its official website www.landlist.cn. The basic information includes the use type, land area, reserve price, sale price, sale date (if the sale has occurred), regulatory lot size for construction, regulatory total floor area, auction type, etc. We collect data for 9394 completed auctions from 30 cities between 2002 and 2012.[7] For each land sale, we calculate the regulatory FAR as regulatory total floor area divided by regulatory lot size for construction, which is considered to be the upper limit imposed on FAR for land development. Additionally, we obtain the geographic coordinates for each land parcel from www.Soufun.com. Using the coordinates, we calculate for each land parcel the distance to the city center and the distance to the nearest subway stop.[8,9]

For 11 cities having more than 300 land transactions in our sample, Table 1 reports the summary of land attribute statistics by city. Panel A in Table 1 describes the city level characteristics, such as the actual population size and the annual population growth rate based on the 2000 and 2010 Chinese population censuses. Panel B in Table 1 shows the characteristics of residential land parcels by city. Compared with cities in the central and western regions, cities in the eastern region on average have higher population growth rates but lower regulatory FARs. Within each city, a large variation exists in the regulatory FARs. In addition, the distance to the city center also varies greatly across land parcels within each city, suggesting spatially widespread distribution of land development.

We collect information on Residential Development Projects (RDPs) with new property for sale as of May 2012 from www.Soufun.com. For each RDP, we have data on the average housing price per square meter of floor area in May 2012, referred to as RDP price, the actual FAR, a dummy variable indicating whether the units in the RDP are decorated, green space ratio, and the geographic coordinates.

Using the coordinates of both land parcels and RDPs, we draw a ring that extends out to 1.5 km from the geographic center of each land parcel and match all RDPs located in this ring to the land parcel. The land-RDP pairs thus matched are referred to as the

[6] The 30 cities are: Beijing, Changchun, Changsha, Chengdu, Chongqing, Dalian, Guangzhou, Ha'erbin, Haikou, Hangzhou, Hefei, Huhehaote, Jinan, Kunming, Nanchang, Nanjing, Nanning, Ningbo, Qingdao, Shanghai, Shenyang, Shenzhen, Shijiazhuang, Suzhou, Taiyuan, Tianjin, Wuhan, Wuxi, Xi'an, and Zhengzhou.

[7] 93% of the land sales in our sample were completed after August 31, 2004.

[8] We use the coordinates of the 1992 light center (i.e., the brightest cell at night in each city's central area) from Baum-Snow et al. (2016) to identify the actual city center. They suggest that despite the fact that light has increased enormously over the past two decades, the light centers have not changed.

[9] Among the 30 cities in our sample, Beijing, Chengdu, Chongqing, Guangzhou, Shanghai, Shenzhen, and Suzhou had subway systems by 2012.

Table 1
Summary statistics.

	East region								Central and west regions		
	Shanghai	Beijing	Tianjin	Hangzhou	Nanjing	Dalian	Qingdao	Wuxi	Chengdu	Wuhan	Xi'an
Panel A: city level characteristics											
Actual population 2000 (million)	16.74	13.57	10.01	6.88	6.23	5.89	7.49	5.18	11.24	8.05	7.41
Actual population 2010 (million)	23.02	19.61	12.94	8.7	8	6.69	8.72	6.37	14.05	9.79	8.47
Annual population growth 00–10 (%)	3.24	3.75	2.60	2.38	2.52	1.28	1.50	2.09	2.25	1.97	1.34
Panel B: residential land parcel characteristics											
Regulatory FARs	1.65	2.12	1.87	2.28	1.78	2.16	1.92	2.03	3.32	3.00	3.79
	[2.33]	[2.92]	[2.86]	[3.00]	[2.60]	[3.48]	[3.20]	[3.00]	[5.00]	[4.80]	[6.36]
	(0.62)	(0.85)	(0.87)	(0.72)	(0.69)	(1.11)	(1.05)	(0.79)	(1.36)	(1.29)	(1.63)
Distance to city center (km)	24.99	27.22	33.53	14.39	25.79	37.85	29.11	14.37	19.68	16.89	10.38
	(12.96)	(16.78)	(20.55)	(7.98)	(9.11)	(34.52)	(23.44)	(13.78)	(13.29)	(11.78)	(7.79)
Observations	444	430	636	477	393	566	413	378	447	603	309
Panel C: residential land parcel characteristics generally matched sample (1500 m ring)											
Regulatory FARs	1.683	2.158	2.004	2.318	1.855	2.219	2.160	2.135	3.445	3.212	3.903
	[2.500]	[2.942]	[3.200]	[3.000]	[2.800]	[3.700]	[3.787]	[3.000]	[5.070]	[4.999]	[6.434]
	(0.701)	(0.865)	(0.989)	(0.723)	(0.734)	(1.224)	(1.157)	(0.801)	(1.324)	(1.290)	(1.645)
Distance to city center (km)	22.973	26.605	32.144	13.297	25.735	23.648	20.092	9.997	18.098	14.642	8.768
	(13.109)	(16.432)	(20.466)	(7.269)	(9.075)	(22.769)	(17.680)	(8.834)	(12.787)	(10.700)	(5.309)
Observations	278	355	409	408	295	371	278	299	392	480	278
Panel D: matched RDPs	Mean	St. dev.	Observations								
Average price per floor area (RMB yuan)	11,790	11,289	4726								
Actual FAR	2.724	1.463	4726								
Green space ratio	0.369	0.088	4726								
Dummy: decorated units in RDP	0.298	0.457	4726								
Distance to city center (km)	18.797	24.169	4726								
Distance to nearest subway stop (km)	10.471	58.519	1520								

Notes: Standard deviations are in parentheses. 90th percentiles are in brackets.

generally matched pairs. In total, we match 6035 residential land parcels with 4726 RDPs. On average, the 1.5-km ring of one land parcel contains about four RDPs. An RDP may fall into the rings of multiple land parcels. On average, each RDP belongs to the rings of five land parcels. The location attractiveness of each parcel is inferred from the prices of RDPs located within the 1.5-km ring of the parcel. (See Section 5.1 for details.) We do not use the actual land sale prices to measure the land location attractiveness because these prices may be distorted from their true market value due to corruption (see Cai, Henderson, Zhang, 2013). For each RDP, we also calculate the distance to the city center and the distance to the nearest subway stop using information from the coordinates. Panel D presents the summary statistics of housing characteristics for all RDPs in the generally matched sample. We also report the summary of statistics for all land parcels in the generally matched sample in panel C of Table 1 for the sake of comparison with panel B. They show similar patterns.

From the sample of generally matched pairs, we identify 854 exactly matched pairs in 27 of the 30 cities.[10] An exactly matched pair contains a land parcel and an RDP that is built only on this land parcel. For this exactly matched sample, we are able to find detailed information on the regulatory FAR levels specified by local land bureaus. In Fig. 1, the left panel plots the regulatory upper limits of FAR versus the actual FARs of these exactly matched pairs, and the right panel shows the density distribution of the difference between these two levels. Among the 854 pairs, the actual FARs of 181 pairs surpass the regulatory upper limits, while the actual FARs of the rest are equal to or below the upper limits. Having such a distribution enables us to estimate the non-linear FAR decision rules of developers in the presence of upper limit restrictions.[11]

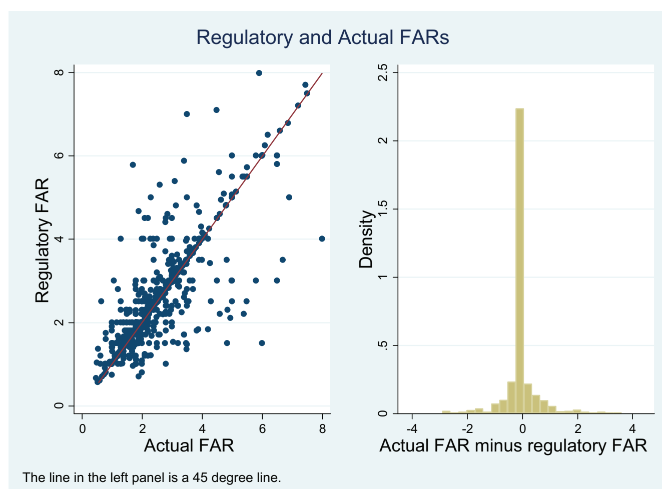


Fig. 1. Regulatory FAR limits and actual FARs.

In our exactly matched sample, while the housing data covers RDPs that had new apartment units for sale in May 2012, the land data is largely historical, consisting of land sales that occurred between 2002 and 2012. Although the information on the starting time of each RDP development is not available, based on our interviews with people in the real estate industry, most of the RDPs in our data should have started development between 2007 and

[10] They are Beijing (89), Changchun (19), Changsha (9), Chengdu (70), Dalian (63), Guangzhou (18), Ha'erbin (17), Haikou(4), Hangzhou (50), Huhehaote (2), Jinan (8), Kunming (6), Nanchang (39), Nanjing (61), Nanning (1), Ningbo (19), Qingdao (44), Shanghai (27), Shenyang (26), Shenzhen (16), Shijiazhuang (13), Taiyuan (10), Tianjin (50), Wuhan (69), Wuxi (63), Xi'an (33), and Zhengzhou (28). Numbers of observations are in parentheses.

[11] In 21 of the 854 exactly matched pairs, a regulatory lower bound is also set. This is presumably done by the local government to restrict construction of low-density housing such as luxury villas. However, the lower bound of FAR is usually a non-binding constraint. Therefore, in this paper, we focus on the FAR upper limit constraint.

Table 2
Correlations between location attractiveness measure and observed location attributes.

Dependent variable: land location attractiveness α				
Independent variables	1	2	3	4
	Generally matched sample		Exactly matched sample	
log(distance to city center)	−0.589***	−0.411***	−0.570***	−0.395***
	(0.012)	(0.036)	(0.038)	(0.072)
log(distance to nearest subway stop)		−0.281***		−0.371***
		(0.018)		(0.037)
City fixed effects	Y	Y	Y	Y
R squared	0.622	0.628	0.583	0.593
Observations	6035	1750	854	307

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. In Panel B, heteroskedasticity-robust standard errors are in parentheses. Columns 1 and 2 use land parcels from the generally matched sample. Columns 3 and 4 use land parcels from the exactly matched sample. Column 2 uses a subsample from column 1 which contains subway information. Similarly, column 4 uses a subsample from column 3 which contains subway information.

2012, given the time needed for development and marketing. Because city governments typically allow two years between a land sale and the commencement of development, it is not unreasonable to see some RDPs in our housing data matched with land parcels sold in 2005. However, only a very small proportion (5.5%) of the land sales in the exactly matched sample occurred in 2004 or earlier. One possible explanation for this is that when those land parcels were sold, the existing structures on them had not been cleared and the residents living there had not been relocated. This may well have delayed land development.

We hand-collect the information on the turnover of party secretaries for each city between 2000 and 2012 from the city's government website. This includes the month of turnover as well as the names of the old and new party secretaries. This data sheds light on the political environment in each city over our sample period and helps provide supporting evidence for our corruption indicator, which will be discussed in detail later.

5. Estimation results

5.1. Measure of land location attractiveness

Using the generally matched sample, we measure α_i, the location attractiveness of land parcel i, based on the prices of RDPs located in the 1.5-km ring around i. In particular, we run the following hedonic price regression using RDP-land pairs in the generally matched sample:

$$\log(p_j) = \kappa_i + Z_j\gamma_Z + e_j, \tag{9}$$

where j is the index of an RDP, p_j is the price per floor area of RDP j, and e_j is an error term. In (9), κ_i is the fixed effect of land parcel i around which a 1.5-km ring contains RDP j. This ring fixed effect captures the effect of the location attributes of land parcel i on the housing prices of RDPs located within the 1.5-km ring of land parcel i. The estimate of κ_i is our measure of the location attractiveness of land parcel i. We standardize the land location attractiveness across the whole sample to have a mean of zero and a standard deviation of one. In the regression, we also control for a set of RDP characteristics that may correlate with both housing price and location attractiveness such as actual FAR, green space ratio, and decoration degree.[12]

To check whether the location attractiveness thus constructed indeed reflects the collective value of land location attributes, we run regressions of this measure on various observed location attributes such as distance to city center and distance to nearest subway stop. The results are reported in Table 2. Clearly, the estimated coefficients all show correct signs consistent with the standard urban theory.

Our location attractiveness measure is constructed based on price data in 2012 because historic RDP price data is not available. This raises the issue that the local amenities of a neighborhood may change over time. We essentially assume that, at the time the development started, the developer and the government officials who determine FAR adjustments were able to anticipate future changes in local amenities up to 2012. This is a plausible assumption given that urban planning in Chinese cities typically takes place five years in advance, and the development of most of the RDPs in our data started after 2007.[13] We also do robustness checks by using an alternative location attractiveness measure that is discussed in Section 5.4.

5.2. Indicator of corruption

For each land parcel, we define the corruption indicator as $r_i \equiv NC_i{}^*Top_{i20}$, where NC_i is a dummy for noncompetitive sale and Top_{i20} is a dummy indicating whether land parcel i lies at the top 20 percentile or above in the distribution of the estimated α within the sample of generally matched pairs. Specifically, $NC_i = 1$ if the ratio of sale price to reserve price is below 1.005. The idea of defining the corruption indicator as such is that if a "hot" land parcel generates no competition in a public land auction, then it is very likely that the developer has some special ties with government officials.[14] This method is similar to the practice in the literature that uses ex post bidding prices to detect illegal activities in public auctions (Porter and Zona, 1993). We use the 20th percentile in the main regressions, but present results using other percentiles as robustness checks (see Section 5.4).

To provide supporting evidence for our corruption indicator, we investigate the relationship between the likelihood of a land parcel being sold via a noncompetitive sale and the political turnover of the party secretary of the city.[15] Using land parcels from the generally matched sample, we run a linear probability regression of land being sold via a noncompetitive sale on a political dummy that indicates if the land transaction occurs three months prior to a new

[12] Consistent with Liao and Wang (2012), and Wu et al. (2013), the hedonic price regression shows a significantly negative effect of FAR on housing price. The results are available upon request.

[13] The urban plans provide information on changes in key local attributes such as highways, subways, large shopping plazas and public schools for different neighborhoods within a city over the next few years.

[14] A concern about our corruption indicator is that land located in desirable neighborhoods may have some undesirable characteristics that remain unobserved to us. Then, the non-competitive nature of the sale is not a result of corruption but is instead due to the unobserved unattractiveness of the land itself. If this is the case, then the estimated effect of corruption on upward adjustments to FAR will be biased downward, which is only against our expected result.

[15] In the Chinese government, the party secretary in a city is the highest ranked city official and acts as "chairman of the board," while the city mayor is more like the president of a corporation.

Table 3
Supporting evidence for corruption indicator.

Dependent variable: dummy: noncompetitive sale				
	1 LPM	2 LPM	3 Probit	4 Probit
Dummy: 3 months immediately prior to party secretary turnover	−0.074***	−0.075***	−0.250***	−0.251***
	(0.025)	(0.025)	(0.088)	(0.090)
Dummy: 3 months immediately prior to party secretary turnover∗location attractiveness		−0.046*		−0.146
		(0.026)		(0.104)
Location attractiveness	−0.031***	−0.028***	−0.103***	−0.095***
	(0.009)	(0.009)	(0.030)	(0.030)
Land characteristics	Y	Y	Y	Y
Season, year, city dummies	Y	Y	Y	Y
Observations	4267	4267	4267	4267

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. Standard errors in parentheses are calculated on the basis of 2000 bootstrap replications. Land characteristics include log land area, a dummy indicating if the land was partially designated for commercial properties, and a dummy indicating if the land was partially designated for public establishments.

Table 4
FAR decisions by developers.

	1	2	3	4	5	6	7	8
	$\bar{F}_0$	$\bar{F}_1$	$\bar{F}_0$	$\bar{F}_1$	$\bar{F}_0$	$\bar{F}_1$	$\bar{F}_0$	$\bar{F}_1$
Location attractiveness α	0.110**	0.032	0.110**	0.032	0.155***	0.107	0.144***	0.100
	(0.045)	(0.092)	(0.046)	(0.094)	(0.044)	(0.093)	(0.046)	(0.097)
Corruption indicator r		0.624**	0.012	0.631*		0.668**	0.153	0.756**
		(0.308)	(0.159)	(0.328)		(0.312)	(0.173)	(0.318)
σ_0	0.723***		0.723***		0.689***		0.688***	
	(0.057)		(0.055)		(0.054)		(0.053)	
σ_1	1.366***		1.366***		1.328***		1.326***	
	(0.130)		(0.130)		(0.120)		(0.123)	
Land characteristics	Y		Y		Y		Y	
Season dummies, linear year trend	Y		Y		Y		Y	
City natural amenities	N		N		Y		Y	
Observations	643		643		643		643	

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. Standard errors shown in parentheses are calculated on the basis of 2000 bootstrap replications.

party secretary taking office in the city (one if yes; otherwise zero). Political uncertainty increases immediately before the transition of party secretaries in a city, and corrupt government officials become more cautious in order to avoid being exposed. Column 1 of Table 3 reports the results. The coefficient on the political turnover dummy is −0.074 with t at −3.03, which implies that there exists a significant drop in the likelihood of land being sold via a noncompetitive sale during party leader turnover. In column 2, we additionally include an interaction term between the political turnover dummy and the land's location attractiveness in the regression. Its coefficient is negative at the 10% significance level. This suggests that when the political environment becomes tight on corruption, the decrease in the chance of land being sold via a noncompetitive sale is greater for more attractive land parcels. This lends support to our method of constructing the corruption indicator. Columns 3 and 4 of Table 3 report the estimation results from a Probit model. They are similar to the results in columns 1 and 2, respectively.

5.3. Main estimation results of developers' FAR decisions

With the construction of location attractiveness and the corruption indicator, we run the MLE estimation corresponding to the FAR decision specified in Eq. (7). The results are reported in Table 4. The estimation is based on 643 observations from the exactly matched sample for which we have information on reserve prices used in the construction of the corruption indicator.[16] Standard errors are calculated on the basis of 2000 bootstrap replications because location attractiveness α is a generated regressor. In all regressions, we include land characteristics (i.e., log land area and land use type dummies), dummies for sale seasons, and a linear year trend.[17]

Columns 1 and 2 in Table 4 present the baseline specification results. Column 1 corresponds to the specification of $\bar{F}_0$ in (7), the optimal FAR in the absence of regulation; and column 2 corresponds to the specification of $\bar{F}_1$ in (7), the optimal FAR with upward adjustment. We first investigate the effects of α on $\bar{F}_0$ and $\bar{F}_1$, denoted in (7) by η_0 and η_1, respectively. According to the theory, $\bar{F}_0$ and $\bar{F}_1$ should both increase with α. However, because the adjustment cost increases with α at rate ψ_1 (as shown in Eq. (6)), $\bar{F}_1$ increases with α at a slower rate than $\bar{F}_0$ does. Therefore, we expect that $\eta_0 > \eta_1 > 0$. Consistent with the theory, the estimate of η_0 is 0.110 with t at 2.481 (column 1), whereas the estimate of η_1 is 0.032 with t at 0.351 (column 2).

Next, we examine the effect of corruption (r) on $\bar{F}_1$, which corresponds to λ in (7). A corrupt deal ex ante reduces the ex post adjustment cost and hence encourages a greater upward adjustment of FAR. As expected, the estimated λ is 0.624 with t at 2.03 as shown in column 2. The magnitude of the effect is

[16] As discussed in Section 2, urban land lease rights were required by law to be sold in public auctions after August 31, 2004. Before that date, negotiated land sales were common and land sales through public auctions were rare. In the exactly matched sample, observations before August 31, 2014 account for 4.8% of all observations. Because of the policy change, these land sales occurred in a quite different policy environment than those in the rest of the sample. However, we conduct our analysis after dropping the subsample of observations of sales that occurred before August 31, 2004, and find that the results remain essentially the same (probably because of the small number of observations in this subsample).

[17] As a robustness check, we also redo the regressions with year dummies replacing the year trend. We obtain similar results. The limited sample size does not allow us to generate bootstrapped standard errors when controlling for year dummies; thus we report results with the year trend.

Table 5
Robustness checks using alternative corruption indicators.

	1	2	3	4	5	6	7	8
	$\bar{F}_0$	$\bar{F}_1$	$\bar{F}_0$	$\bar{F}_1$	$\bar{F}_0$	$\bar{F}_1$	$\bar{F}_0$	$\bar{F}_1$
Location attractivenessα	0.153***	0.112	0.155***	0.107	0.155***	0.139	0.154***	0.136
	(0.045)	(0.096)	(0.044)	(0.093)	(0.045)	(0.093)	(0.042)	(0.093)
Corruption indicators*r*								
Dummy: noncompetitive sale*dummy: top 10th percentile		0.921*						
		(0.516)						
Dummy: noncompetitive sale*dummy: top 20th percentile				0.668**				
				(0.312)				
Dummy: noncompetitive sale*dummy: top 30th percentile						0.247		
						(0.244)		
Predicted probability: two-stage auction								0.870**
								(0.430)
σ_0	0.670***		0.689***		0.689***		0.689***	
	(0.056)		(0.054)		(0.054)		(0.054)	
σ_1	1.328***		1.328***		1.335***		1.329***	
	(0.126)		(0.120)		(0.119)		(0.124)	
Observations	643		643		643		643	

Notes: *significance at 10%; **significance at 5%; ***significance at 1%. Standard errors shown in parentheses are calculated on the basis of 2000 bootstrap replications. All regressions control for land characteristics, season fixed effects, a linear year trend, and city-level natural amenities.

economically substantial: land parcels that are indicated to have been sold in corrupt deals have greater ex post FARs (after upward adjustments) than otherwise identical land parcels by 0.624, representing about a 30% increase for an average FAR of 2.0.

Thus, the empirical evidence from the baseline estimation results supports our theoretical hypotheses that (i) attractive location attributes increase the benefits of building more floor area and hence are correlated with more upward adjustments of FAR, and (ii) corrupt ties with government officials reduce adjustment costs and hence induce developers to choose to build more floor area above the regulatory limit.

According to the theory, the corruption indicator r should have no effect on $\bar{F}_0$. Thus in our baseline specification of $\bar{F}_0$, no corruption indicator is included. To check the validity of this specification, we include r in the specification of $\bar{F}_0$ and run the MLE again. Columns 3 and 4 report the results. The estimates of η_0, η_1, and λ are little affected. As expected, the partial effect of r on $\bar{F}_0$ is statistically insignificant and has small magnitude.

In the functional form of adjustment cost (6), we assume that corruption does not affect the rate at which the adjustment cost increases with α (i.e., ψ_1 does not vary with r). To verify this assumption, we try adding the interaction term between α and r into the specification of $\bar{F}_1$ to capture the effect of corruption in reducing ψ_1. The estimated coefficient on the interaction term is small and statistically insignificant, which lends support to the assumption imposed on the functional form of the adjustment cost. The results are available upon request.

Another concern about our estimation specification is that city-level natural amenities (e.g., climate, geographic characteristics) may affect local housing supply via construction costs (Saiz, 2010). Meanwhile, the differentials in natural amenities across cities may also be associated with variations in location attractiveness (Gyourko et al., 2013). To address this concern, we additionally control for the city-level natural amenities including the number of days with more than 10 mm of rain, minimum temperature, maximum daily temperature range, sunshine exposure index, roughness of land surface, and range of land elevation in the regressions. The results corresponding to the specifications used in columns 1–4 are reported in columns 5–8, respectively. There is a modest increase in the magnitude of the estimated effect of location attractiveness (α) for both $\bar{F}_0$ and $\bar{F}_1$, but the estimate of η_1 is still statistically insignificant with a smaller magnitude than that of η_0. Meanwhile, the magnitude of the estimated effect of corruption (r) rises slightly. Overall, the results are robust to including the city-level natural amenity variables.

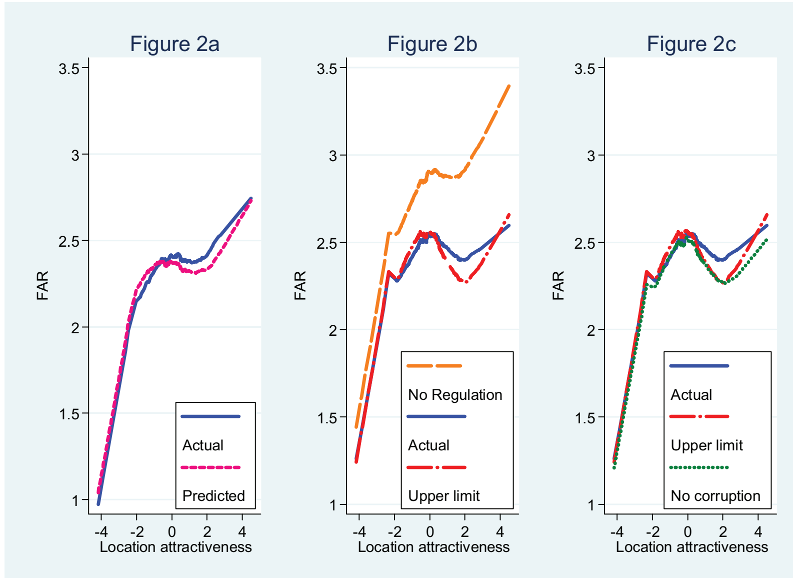
Our estimation specification implies that the variance of random term u_{1i} in $\bar{F}_{1i}$ (i.e., σ_1^2) is greater than that of u_{0i}in $\bar{F}_{0i}$(i.e., σ_0^2) because the former also includes the unobserved variation in adjustment cost when an upward adjustment occurs. Consistent with this, the estimates of σ_0 and σ_1 are around 0.7 and 1.3, respectively. In these estimations, we constrain ρ to be one. We also do the estimations by allowing ρ to vary between zero and one; the results show that the log likelihood function strictly increases with ρ.

5.4. Robustness checks

5.4.1. Alternative corruption indicators

We use the top 20th percentile as the cutoff point when we construct the corruption indicator for our main analysis. We experiment with other percentiles and construct alternative corruption indicators accordingly. Using these alternative indicators, we run the MLE following the specifications used in columns 5 and 6 of Table 4. The results are presented in Table 5. The estimated coefficients of α in both specifications of $\bar{F}_0$ and $\bar{F}_1$ (i.e., η_0 and η_1) are insensitive to these alternative corruption indicators. The estimated coefficients of corruption indicator r in the specification of $\bar{F}_1$ are 0.921 (with t at 1.78), 0.668 (with t at 2.14), and 0.247 with (t at 1.01) for the top 10th, 20th, and 30th percentile cutoffs, respectively. This pattern is consistent with the fact that a "hot" land parcel sold non-competitively is more likely to involve corruption than a "cold" land parcel. When the cutoff percentile approaches the top, a non-competitive land sale is more likely associated with some corrupt deal. As we expand the percentile to include land with relatively poor local attributes, we cover more of those parcels that are sold non-competitively but involve no corrupt deal.

Cai et al. (2013) study land auctions in urban China. Both their theory and empirical evidence show that the two-stage auction format is more likely to be selected by a corrupt government official in order to help her partner developer win the auction with a low price by deterring the entry of other potential bidders. As such, we use the predicted probability of land being sold through a two-stage auction as another alternative indicator of corruption. The probability is predicted from a linear probability model with the explanatory variables being the political turnover dummies and land characteristics similar to those used in Cai et al. (2013). The



Notes: All plots in Figure 2 are nonparametric and use a uniform kernel density regression smoother.

Fig. 2. Actual and predicted FARs by location attractiveness.

estimated coefficient of this corruption indicator in the specification of $\bar{F}_1$ is 0.870 with t at 2.02 (Table 5, column 8). The estimated effects of α on $\bar{F}_0$ and $\bar{F}_1$ are similar to those in the main results presented in Table 4.

5.4.2. Alternative location attractiveness measure

Our current location attractiveness measure is the collective value of location attributes estimated through hedonic price regressions. As a robustness check, we use log (distance to city center) as a proxy for the location attractiveness measure and re-run the main regressions as was done in Table 4. Although not as comprehensive as the estimated collective value based on price data, the distance to the city center is one of the most important within-city location attributes and is widely used in the literature. The results exhibit a fairly similar pattern to the main regression results shown in Table 4. We do not report the results in the paper for the sake of saving space but they can be provided upon requests.

6. Discussions

What is the effect of FAR regulation on housing supply? How restrictive is the regulatory burden imposed by FAR regulations on private land developers, given the substantial adjustments in ex post developments? How much do corrupt ties with government officials facilitate ex post adjustments? To address these questions, we generate predictions of the FAR levels that would occur under different scenarios, using parameter estimates from columns 5 and 6 of Table 4. Like all other counterfactual analyses, this exercise relies on the specific functional form of our model, thus the conclusions are all subject to this caveat. Nevertheless, the analysis provides suggestive measures for the evaluation of the impacts of FAR regulations and compliance on the housing supply.

By plugging in the estimated parameters of Eq. (7), we obtain the predicted FAR for each land parcel i, denoted by $\hat{F}_i$. For land parcels in the exactly-matched sample ranked by land location attractiveness (on the horizontal axis), Fig. 2a plots the actual FAR (F_i) with the solid line and the predicted FAR ($\hat{F}_i$) with the short-dashed line. One can see that the solid line is fairly close to the short-dashed line, which means that our model fits the data quite well.

Using the unconstrained optimal FAR decision rule $\hat{F}_i^{AR} = \hat{\eta}_0\alpha_i + x_i\hat{\delta}_0$, we calculate the predicted FAR in the absence of FAR regulation for each land parcel i, denoted by $\hat{F}_i^{AR}$. This is the counterfactual optimal FAR that maximizes the market value of the land without regulatory constraints. Fig. 2b plots the predicted FAR in the absence of regulation ($\hat{F}_i^{AR}$) with the long-dashed line[18] and the regulatory FAR (F_{Ri}) with the dash-dotted line against land location attractiveness. Fig. 2b shows that there is a large gap between the developers' optimal FAR levels ($\hat{F}_i^{AR}$), which would maximize the market value of land, and the regulatory limits set by authorities (F_{Ri}). Furthermore, this gap widens with land attractiveness. Averaged over land parcels, $\hat{F}_i^{AR}$ is 22.4% higher than F_{Ri}. Multiplying FAR by lot size, we find that the total housing supply in terms of floor area would be 17.3% higher in the absence of FAR regulation than with FAR regulation strictly enforced. For land developments having above-median attractiveness, the above two percentages rise to 28.1% and 23.2%, respectively. Therefore, FAR regulations in urban China significantly deviate from market incentives, especially for land in more attractive locations. This finding is consistent with the overall pattern from our raw data as shown in Table 1, which indicates that both the average and top 90th percentile of the regulatory FAR limits of cities in the Eastern region are significantly lower than those of cities in the Central and Western regions, despite the larger population size and greater population growth in the East.

In Fig. 2b we also plot the actual FAR (F_i) with the solid line, which accounts for FAR adjustments. One can see that the actual FAR levels (F_i) surpass the regulatory limits (F_{Ri}) only for land parcels in locations that are relatively more attractive. This is consistent with our finding that attractive location attributes tend to induce an upward adjustment of FAR. Including all upward adjustment cases, the floor area actually built is 21.5% larger than

[18] In addition to land location attractiveness, $\hat{F}_i^{AR}$ also varies with land characteristics (e.g., land use type), city natural amenities, etc. Thus, the two-dimensional plot of $\hat{F}_i^{AR}$ on location attractiveness in Fig. 2b is non-linear.

the total floor area set by regulatory FARs, while the floor area under the FAR absent of regulation is 24.7% higher than the floor area set by regulatory FARs. Thus, there is still a 3.2% gap between the floor area absent of regulation and the actual FARs. While this seems to suggest that ex post adjustments are effective in closing 87% of the gap in floor area between the market value that maximizes FAR and the regulatory FAR, this is not the whole picture because this calculation only includes those cases in which upward adjustments take place. The more important effect of FAR regulation on the housing supply comes from those cases in which regulatory FARs are binding and adjustment costs deter developers from seeking approval for adjustments. For all cases in the exactly matched sample, the total added floor area created by upward adjustments of FAR is equal to 4.3% of the total regulatory floor area. Since there is 17.3% gap between the total floor area in the absence of regulation and the total regulatory floor area, this implies that there is still 13% gap between the total floor area in the absence of regulation and the actual floor area after ex post adjustment. Therefore, upward adjustments of FAR only modestly increase the total housing supply, and FAR regulations have imposed a severely restrictive constraint on developers in China's urban land development despite imperfect compliance.

To evaluate how much corruption contributes to ex post adjustments, we calculate the predicted FAR decision for each land parcel i in the absence of corruption by setting the corruption indicator $r_i = 0$ in Eq. (7), denoted by $\hat{F}_i^{AC}$. In Fig. 2c, we plot the predicted FAR absent of corruption ($\hat{F}_i^{AC}$) with the dotted line, the actual FAR (F_i) with the solid line and the regulatory FAR (F_{Ri}) with the dash-dotted line. For the range of location attractiveness where upward adjustments occur, the FAR levels that would have been selected in the absence of corruption ($\hat{F}_i^{AC}$) mostly lie at the regulatory limits, suggesting that upward adjustments would not take place in the absence of corruption because of system rigidity and high adjustment costs. For all cases in the exactly matched sample, the total added floor area absent of corruption would be only 0.4% of the total regulatory floor area. This is only a small fraction of the 4.3% increase in the housing supply due to actual upward adjustments. Therefore, corrupt ties with government officials are critical for ex post adjustments of FAR.

7. Conclusion

Using a unique set of residential land sales data matched with residential development projects, this paper investigates the implementation of FAR regulations by private developers in urban China. We find that attractive location attributes more likely lead to upward adjustments of FAR. Moreover, developers who are more likely to have special relationships with government officials tend to build more floor area above the regulatory FAR limits. We also present evidence that regulatory FAR limits in urban China are much lower than the FAR levels that would maximize land value, especially for land parcels in relatively more attractive locations. Although corrupt ties with government officials facilitate upward adjustments of FARs, the remaining gap is still substantial. Thus, FAR regulations impose severely restrictive constraints on urban land development in China even given imperfect compliance. While these findings are clearly dependent on China's specific institutional setting in the real estate sector, we believe that some of the general principles that are at the core of our study should still hold in other contexts. These include the following: (i) with weak institutions, compliance with regulations is an important factor that affects how regulations are implemented; (ii) there will be more noncompliance when noncompliance provides more benefits (e.g., on more attractive land parcels); and (iii) there will be more noncompliance when the cost of noncompliance is smaller (e.g., when developers have special relationships with government officials).

By focusing on how developers set FARs given regulatory limits, our paper is a partial equilibrium analysis. A general analysis would need to consider how governments set regulatory FARs. Imposing low FAR limits on land developments in valuable but crowded neighborhoods may help correct the negative externalities that arise from dense developments (Brueckner et al., 2015). However, determining how much restriction is sufficient but not onerous is an important policy issue, especially for developing countries, as inefficient land-use regulations could impair a city's ability to grow (Glaeser, 2011). These social considerations, as well as government officials' own incentives and the political environment of the city in question, are all important in understanding how governments determine regulatory FAR limits. We leave a full analysis of this topic to future research. [19]

How should FAR regulations be structured in a developing country like China with relatively weak institutions? Glaeser (2011) suggests an alternative approach for city planners, one in which they replace quantity restrictions with a transparent system of fees. In such a system, developers are free to choose the FARs of their development projects, while city planners are responsible for developing reasonable cost estimates for tall or dense buildings and appropriately charging developers. Still, determining how to enforce such a fee system is challenging and remains open to further study.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jue.2016.03.003.

[19] One concern is whether the interpretation of our results regarding corruption will be seriously affected by the endogenous setting of regulatory FARs. We argue that it is not. There are two reasons. First, one would conjecture that in the whole game, a corruptive city government official would intentionally lower the regulatory FARs in order to increase her partner developer's chances of winning the land auction and reduce his cost for obtaining the land. Moreover, she could extract more bribery for ex-post help in FAR adjustments in future land development. To check this possibility, we run a regression of the regulatory FAR on the corruption indicator. We find the estimated coefficient of the corruption indicator is insignificant with a positive sign instead. Secondly, in an on-going project on how the city government sets regulatory FARs, we find that the promotion likelihood of a city leader significantly influences the overall pattern of the city's land development. However, there still exists a significantly negative FAR-distance gradient, indicating for each land parcel, the regulatory FAR still largely reflects the land's location attractiveness. Since corruption is more likely to happen in more attractive locations as Cai et al. (2013) show, this indicates that corruption is unlikely to distort the setting of regulatory FARs.

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