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Analysis of commercial land leasing of the district governments of Beijing in China

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ABSTRACT

In this paper, by using the data of the districts of Beijing from 2004 to 2015, the factors influencing commercial land leasing by the district governments and commercial land leasing price under public land ownership are studied. The variables to present the mathematical models for parcel-level demand and district-level supply are discussed, then the mathematical models are presented to explore whether the price formation and spatial distribution of commercial land leasing have relationship with some factors of the land characteristics, the district characteristics and the location characteristics of the land. The results show how commercial land leasing price changes by these factors and what factors the government concerns about when leasing commercial land under public land ownership. The policy implications when leasing commercial land in Beijing are presented, and these are suitable to other large cities of developing countries.

1. Introduction

The commercial development, as an essential part of tertiary industry, is very important for the economic development of a country. Commercial land leasing is not only related to commercial house price, but also affects the economic development (Li, 2003) and urbanization of the city (Ho and Lin, 2004) as well as the harmony of the society. In China, commercial land use rights are sold to developers by local governments. Commercial land leasing is affected by various factors to obtain the maximum of the total profits and promote sustainable development of a city. So it is important to analyze the government's behavior and the corresponding influencing factors for leasing commercial land under public land ownership.

In China, there is clearly division of the central government and municipal governments for land market (Fu and Lin, 2013). The central government aims to promote urban land marketization by formulating policies, and the municipal governments have more interests in maximizing long-term profits by adopting policies (Liu et al., 2016). The central government gave the authority to the municipal governments to transfer the land use rights, thus the municipal governments can compete with each other in attracting investments (Tan et al., 2009) to develop the economy rapidly (Cheung and Coase, 2008; Xu, 2011). The policies formulated for leasing land can be affected by the fiscal incentive from the government (Tao et al., 2010; Li and Kung, 2015), and there is a close relationship between land leasing and land policies in China (Liu et al., 2014a). With the rapid urban expansion in China, the land shortage is a problem. A great quantity of rural land around cities is converted to urban use (Liu et al., 2013, 2014b; Yang et al., 2018), and the development of urbanization results in the loss of plenty of arable land (Liu et al., 2010). Thus, it is important to study optimization and allocation of the regional land resources (Liu et al., 2018b). Liu et al. (2018b) analyzed the efficiency of land allocation in China by using panel data. For a local government in China, the choice to lease different land types will affect economic development of a city (Cheng, 2020a). The decisions of allocation for non-agricultural land are vital (Gal and Hadas, 2013). Land-use decisions are important for the competition among the land-use sectors to eliminate land-use conflicts (Steinhausser et al., 2015). Hence, it is necessary to think about what factors influencing a local government to lease land for different uses for a developing country.

The government's behavior of land leasing is affected by many factors, such as land prices (Du et al., 2014), land policy (Long, 2014; Wang et al., 2012; Kanianska et al., 2014; Liu et al., 2018a), government management (Janssen, 2003; Koroso et al., 2013), government's decisions (Ooi et al., 2011), political competition, political change (Kanianska et al., 2014; Cheng, 2020b), promotion of local officials (Solé-Ollé and Viladecans-Marsal, 2012; Li, 2014), modes of land leasing (Tao et al., 2010; Yang et al., 2015), economic growth (Lin and Ho, 2005; Li, 2014), etc. The land and real estate markets can be also changed by these factors. The economic development can be promoted by the change of land use rights, such as the urbanization of the farmland (Lin, 2007). Gross domestic product (GDP) and the land

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supply interrelate (Du and Peiser, 2014). The economic growth of the city and the developments of urbanization can be influenced by each other, which makes the intensity change of urban land leasing (Lin, 2007; Gong et al., 2014). Thus, there is a close relationship between the urban and economic development of a city and land leasing.

Land prices, house prices and land leasing can be affected by other important factors, such as local public goods. The public transit has an impact on land use (Calvo et al., 2013) and prices (Sun et al., 2015). The location of the important transportation node, such as airport, is very essential for land prices (Li, 2011). Land development can be attracted and the urbanization can be expanded by rail transit and mass transit (Pan and Zhang, 2008; Zhang and Wang, 2013). The rail transit system has a significant effect on the value of commercial properties (Du and Mulley, 2007). Land use can be increased by transportation projects, and land value can be influenced by these too (Lavee, 2015). The economic activity and consumer amenities are positively contributed to subway stations (Zheng et al., 2016). The subway system shows a positive effect on commercial property values (Xu et al., 2016). Subway stations are built in suburban districts by some municipal governments in China to gain more revenues from future land transactions (Yang et al., 2016). Besides transportation systems, land price and leasing can be affected by universities, schools and public amenities too. Land and house prices can be increased by proximity to clean air, major universities, high-quality schools and environmental amenities (Zheng and Kahn, 2008; Zheng et al., 2014; Sun et al., 2015).

Currently, with the decrease of cultivated land and the increase of urban land, the government needs to consider how to balance the urban land through leasing land and make the land market development more sustainably. The factors influencing land leasing should be studied to understand land leasing system more deeply and give suggestions on leasing land for district governments. There are a few researches on the government's leasing commercial land based on the data of the districts of a city. In China, land leasing is the behavior of district governments, then the data of the districts, especially for the large cities, should be used for the corresponding study. Moreover, most empirical researches focus on land prices, no research combines price formation and land supply together to investigate commercial land leasing. In this study, the multi-factorial commercial land leasing, including land, district and location factors, is studied to analyze the district government behavior more relatively comprehensively. Also, two aspects, including land price and total land area, are used to present mathematical models for analyzing the factors of commercial land leasing. In addition, the commercial land leasing of the district government based on the data of district levels is discussed in this study. And the policy implications are presented and these can be applied to some large cities of developing countries for leasing commercial land.

Beijing is the capital of China, and is the center of politics, culture, international communication, and technological innovation. It covers a large area and has a huge population. There is a high GDP and high real estate investment in Beijing. The commercial land is leased by the district government in Beijing. Studying the influencing factors of commercial land leasing in Beijing by using the data of the districts can offer a reference for other large cities in China and other developing countries implementing public land ownership.

In this paper, by using the data of the districts of Beijing from 2004 to 2015, the factors influencing commercial land leasing by the district government under public land ownership are studied. Also, how these factors affect commercial land price is explored. The variables to present the mathematical models for parcel-level demand and district-level supply are discussed, then the mathematical models are presented to explore whether the price formation and spatial distribution of commercial land leasing have relationship with some factors of the land characteristics, the district characteristics and the location characteristics of the land.

The regression results show that the commercial land price is affected by the area and floor area ratio of the commercial land, the location of the district, the distances between the leased commercial land and Beijing Capital International Airport, the district center, the nearest entrance or exit of highway, the nearest park and the nearest industrial park in Beijing. And the total area of commercial land is affected by the distances between the district and the nearest industrial park in Beijing. Also, the government in Beijing prefers to lease commercial land with larger area or higher floor area ratio. Meanwhile, the government prefers to lease commercial land near district center, entrances or exits of highway, or parks. Compared with suburban districts and counties, the government prefers to lease commercial land to center districts. Thus, more commercial land resources are considered in center districts. The government tends to lease commercial land away from Beijing Capital International Airport or industrial parks.

This study will help the governments make sustainable land policies on land leasing decisions in the coming decades. The development process in large cities of China is very similar to the one in other developing countries, and the land leasing background is alike among other countries under public land ownership. The policy implications can be applied to some large cities of developing countries for leasing commercial land.

2. Purpose and methodology

The purpose of this study is to analyze the factors influencing commercial land leasing by the district government under public land ownership based on the data of the districts of Beijing from 2004 to 2015. Also, how these factors affect commercial land price and supply is discussed.

For the methodology, to present the mathematical models, the variables, such as land characteristics, the district characteristics and the location characteristics, are selected. These variables consider different aspects, such as the nature of the land, the geographical location and proximity of the land, economic development, political influence and environmental characteristics of the district.

The mathematical models are presented for parcel-level demand and district-level supply of commercial land leasing. It is analyzed whether the price formation and spatial distribution of commercial land leasing have relationship with some factors of the land characteristics, the district characteristics and the location characteristics of the land. And the ordinary least squares method is used to obtain the formulae of the mathematical models.

Based on the district data of Beijing from 2004 to 2015, by using the mathematical models for parcel-level demand and district-level supply, the regression results can be obtained. From the results, some factors the government concerned when leasing commercial land under public land ownership are analyzed, and how commercial land leasing price changes by these factors is discussed. Then, the policy implications are presented and these can be applied to some large cities of developing countries under public land ownership.

3. The land leasing development in Beijing

There are 18 districts in Beijing. Dongcheng, Xicheng, Xuanwu, Chongwen, Shijingshan, Haidian, Chaoyang and Fengtai are the center districts; Tongzhou, Changping, Daxing, Fangshan, Mentougou, Shunyi, Huairou and Pinggu are suburban districts; and Miyun and Yanqing are the counties, which became districts on Nov. 17, 2015. Fig. 1 shows the map of Beijing with center districts, suburban districts and counties.

The reform of land leasing in Beijing began in 2002, while the Regulations of Tender, Auction, and Listing of Leasing the Right to the Use of the State-owned Land (May 9, 2002) was enacted by the state. It was stipulated that the use right of each type of profit-oriented land must be leased by tender, auction or listing, which abolished the negotiation of land leasing. Afterwards, Beijing government enacted several regulations, such as Supplementary Provisions About Stopping Negotiation of Land Leasing for the Profit-Oriented Land (January 1,

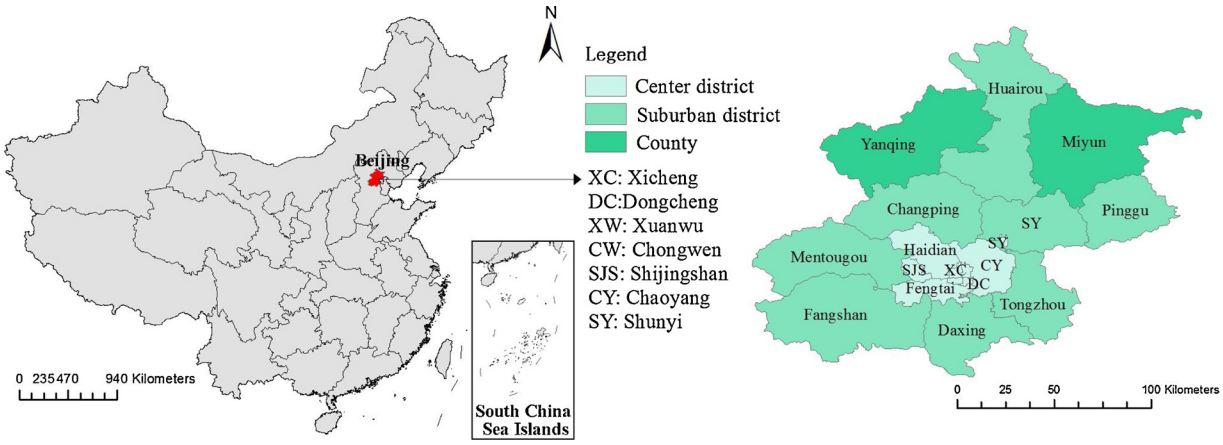

Fig. 1. The map of Beijing with center districts, suburban districts and counties.

2004), to emphasize the importance of tender, auction and listing of land leasing and prohibit the black case work of negotiation.

About the assignment of land use rights, the Interim Regulation of the People's Republic of China Concerning the Assignment and Transfer of the Right to the Use of the State-owned Land in the Urban Areas (September 15, 1990) was implemented by Beijing government. In Article 9 of this regulation, the governments at the municipal and county levels should be in charge of assigning the land use rights, which is carried out in a step-by-step approach. About the land use planning, in Article 10, the land administration departments of the governments, urban planning and construction management department, and housing administration department should draw up a plan concerning the land parcel, purpose, year limit and other conditions of the assignments of land use rights. The plan should be implemented by the land administration departments after the approval of the State Council.

Thus, the government should be in charge of land use planning and leasing in Beijing.

4. Mathematical models of commercial land leasing in Beijing

To discuss the governments' behavior on commercial land leasing in Beijing, in this paper, two aspects of commercial land leasing, including the price formation for parcel-level demand and spatial distribution for district-level supply of commercial land, are considered. Combined with these two aspects, commercial land leasing by the government will be explored. The multi-collinearity of the independent variables is tested by the variance inflation factors, which is acceptable for the value of variance inflation factors smaller than 6.

4.1. Variables

The district government needs to consider different factors affecting commercial land leasing to maximize the total profits and promote sustainable development of the city. But in reality, the district government can't balance these factors quantitatively in their decisions to lease commercial land, especially for large cities, such as Beijing and Shanghai, in China. To analyze these factors quantitatively, mathematical models for commercial land leasing should be presented by considering the variables. The variables are divided into three categories, including land, district and location characteristics.

About the land characteristics, the variables, such as the area of the commercial land, floor ratio of the commercial land, modes of commercial land leasing and location of the district, are considered.

The area is the basic characteristic of a piece of commercial land. The floor area ratio of commercial land is the ratio of built area to land area. It is a very important factor associated with the land prices and profits from the developers. The modes of land leasing, which include tender, auction, and listing, affect land leasing and land prices (Yang et al., 2015). In Beijing, the districts are divided into three levels, including the center districts, suburban districts and counties, which are shown in Section 3. Different district levels would show different commercial land prices.

About the district characteristics, the variables such as GDP of the district and tenure of district mayor are considered.

GDP growth, which is an important index of the economic development of a district, has a close relationship with the land supply (Du and Peiser, 2014). Thus, GDP of a district is assumed to be one of the factors influencing commercial land leasing in this paper. The economic development (Maskin et al., 2000; Jin et al., 2005) of the city and the land leasing (Li, 2014) are influenced by local officials. In Beijing, the district mayor is the top leader of the district, and can decide commercial land leasing, thus the tenure of district mayor is considered as a factor or variable.

About the location characteristics, the variables, such as the distances of the commercial land to city center, district center, airports, railway station, the nearest subway, the nearest entrance or exit of highway, the nearest university, the nearest park and the nearest industrial park, are considered.

In China, the location of the land is one of the most important factor which affects the land price (Deng et al., 2012) and the governments' behaviors on land leasing (Du and Peiser, 2014).

Tiananmen Square is considered as the center of Beijing. It is near Great Hall of the People, Monument of the People's Heroes, Beijing Municipal Government, the Palace Museum, National Museum of China, National Grand Theater, etc. The famous commercial areas, such as Wangfujing and Xidan, are near the Tiananmen Square. Also, it is connected to subway Lines 1 and 2. The locations of district governments of Beijing are regarded as the district centers. Two airports are considered, including Beijing Capital International Airport and Nanyuan Airport, which were established in 1958 and 1901, respectively. Beijing Railway Station is regarded as the railway station in Beijing. It is the oldest and most well-known railway station, and is one of the most important transportation hubs in Beijing.

Subway is an important factor influencing land leasing, land prices and house prices. The economic activity and consumer amenities can be increased with the proximity to subways (Zheng et al., 2016). Besides subways, land prices are also affected by the important transportation node, such as airport (Li, 2011). Moreover, land and house value is affected by highways (Chernobai et al., 2011; Beenstock et al., 2016; Levkovich et al., 2016). The less the distance between the distribution center and the nearest entrance or exit of highway is, the higher the rent is (Tchang, 2016). Universities, parks and industrial parks are assumed to be factors influencing commercial land leasing too. Universities show the levels of quality of educational institutions. Land

prices are influenced by the proximity to major universities and high-quality schools (Sun et al., 2015). Green areas as the environmental externalities increase the property values (Chen, 2017). Industrial park is a very important factor of urban land planning for industrial development (Arabsheibani et al., 2016).

These variables consider different aspects, such as the nature of the land, the geographical location and proximity of the land, economic development, political influence and environmental characteristics of the district. These variables are presented to obtain the mathematical model for analyzing the influencing factors of commercial land leasing by the district government comprehensively.

4.2. Mathematical model for commercial land price in Beijing

From above, the mathematical models are proposed by the author for parcel-level demand and district-level supply to explore whether the price formation and spatial distribution of commercial land leasing have relationship with the factors of the land characteristics, the district characteristics and the location characteristics of the land.

The mathematical model of the price formation of commercial land leasing is

$$\ln LP_{it} = a + \sum_{m=1}^{M} \alpha_m A_{mit} + \sum_{j=1}^{J} \beta_j D_{jit} + \sum_{k=1}^{K} \gamma_k L_{kit} + Yr\_dum + Dis\_dum + u_{it} \quad (1)$$

where LP_{it} is the price of every piece of leased commercial land of district i in year t, A_{mit} is the land characteristic A_m of district i in year t, D_{jit} is the district characteristic D_j of district i in year t, L_{kit} is the location characteristic L_k of district i in year t, M is the number of land characteristics, J is the number of district characteristics, K is the number of location characteristics, Yr_dum is the year dummy variable, Dis_dum is the district dummy variable, a is the constant, and u_{it} is error term. The definitions and summary statistics of the variables for price formation model are shown in Table 1. In this table, 'Obs.' denotes observations, and 'Std. Dev.' denotes standard deviation.

Eq. (1) can be written to

$$\ln LP_{it} = a + \boldsymbol{\alpha}\boldsymbol{A} + u_{it} \quad (2)$$

where

$$\boldsymbol{\alpha} = (\alpha_1, \alpha_2, \ldots, \alpha_M, \beta_1, \beta_2, \ldots, \beta_J, \gamma_1, \gamma_2, \ldots, \gamma_K, 1, 1) \quad (3)$$

$$\boldsymbol{A} = (A_{1it}, A_{2it}, \ldots, A_{Mit}, D_{1it}, D_{2it}, \ldots, D_{Jit}, L_{1it}, L_{2it}, \ldots, L_{Kit}, Yr\_dum, Dis\_dum)^{\mathrm{T}} \quad (4)$$

Thus, the expectation and variance equaling to zero can be obtained, that is

$$\mathrm{E}(\ln LP_{it} - a - \boldsymbol{\alpha}\boldsymbol{A}) = 0 \quad (5)$$

$$\mathrm{E}(A_j(\ln LP_{it} - a - \boldsymbol{\alpha}\boldsymbol{A})) = 0 \quad (6)$$

where A_j is the weight of $\boldsymbol{A}$.

Then, the estimator $\hat{\boldsymbol{\alpha}}$ of the coefficient vector $\boldsymbol{\alpha}$ will be calculated according to the sampling data,

$$\hat{\boldsymbol{\alpha}} = (\hat{\alpha}_1, \hat{\alpha}_2, \ldots, \hat{\alpha}_M) \quad (7)$$

then from Eqs. (5) and (6) we have

$$\frac{1}{N}\sum_{n=1}^{N}(\ln LP_{itn} - \hat{a} - \hat{\boldsymbol{\alpha}}\boldsymbol{A}_n) = 0 \quad (8)$$

$$\frac{1}{N}\sum_{n=1}^{N} A_{jn}(\ln LP_{itn} - \hat{a} - \hat{\boldsymbol{\alpha}}\boldsymbol{A}_n) = 0 \quad (9)$$

where N is the sample number.

From Eq. (8) we obtain

$$\bar{y} = \hat{a} + \hat{\boldsymbol{\alpha}}\overline{\boldsymbol{A}}_n \quad (10)$$

then

$$\hat{a} = \bar{y} - \hat{\boldsymbol{\alpha}}\overline{\boldsymbol{A}}_n \quad (11)$$

where

$$\bar{y} = \frac{1}{N}\sum_{n=1}^{N} \ln LP_{itn} \quad (12)$$

$$\overline{\boldsymbol{A}}_n = \frac{1}{N}\sum_{n=1}^{N} \boldsymbol{A}_n \quad (13)$$

Due to the random sample number, obtained from Eq. (9),

Table 1
The definitions and summary statistics of the variables for price formation model.

Category	Variable	Description	Obs.	Mean	Std. Dev.
	$\ln(LP_{it})$	Final price of every piece of leased commercial land of district i in year t. ($)	436	$8.53e^7$	$11.01e^7$
A_{1it}	$\ln(Area_{it})$	Construction land area of the commercial land leasing for district i in year t. (m^2)	436	41930.52	90742.26
A_{2it}	$\ln(FAR_{it})$	Floor area ratio of the commercial land for district i in year t.	436	3.62	3.23
A_{3it}	MOD_{it}	Modes of commercial land leasing for district i in year t =1 when the mode is listing; = 0 when the mode is tender.	436	0.71	0.45
A_{4it}	$LOC1_{it}$	Location of district i =1 when i is center district; = 0 otherwise. (County is for comparison.)	436	0.39	0.49
A_{5it}	$LOC2_{it}$	Location of district i =1 when i is suburban district; = 0 otherwise. (County is for comparison.)	436	0.58	0.49
D_{1it}	$\ln(GDP_{it})$	GDP for district i in year t. ($)	436	$11.67e^9$	$11.18e^9$
D_{2it}	DM_{it}	Tenure of district mayor of district i in year t.	436	4.21	1.74
L_{1it}	$\ln(TA_{it})$	Distance of the commercial land for district i in year t to Tiananmen Square. (m)	436	24784.62	18201.06
L_{2it}	$\ln(GOV_{it})$	Distance of the commercial land for district i in year t to the government of district i. (m)	436	8127.69	8992.08
L_{3it}	$\ln(SUB_{it})$	Distance of the commercial land for district i in year t to the nearest subway. (m)	436	8690.69	14038.51
L_{4it}	$\ln(HIGH_{it})$	Distance of the commercial land for district i in year t to the nearest highway. (m)	436	2722.03	5109.53
L_{5it}	$\ln(UNI_{it})$	Distance of the commercial land for district i in year t to the nearest university. (m)	436	11540.34	14125.46
L_{6it}	$\ln(PAR_{it})$	Distance of the commercial land for district i in year t to the nearest park. (m)	436	5806.32	3863.4
L_{7it}	$\ln(IP_{it})$	Distance of the commercial land for district i in year t to the nearest industrial park. (m)	436	3668.27	3878.18
L_{8it}	$\ln(BC_{it})$	Distance of the commercial land for district i in year t to Beijing Capital International Airport. (m)	436	30863.83	15544.46
L_{9it}	$\ln(NY_{it})$	Distance of the commercial land for district i in year t to Nanyuan Airport. (m)	436	28949.12	20406.78
L_{10it}	$\ln(RS_{it})$	Distance of the commercial land for district i in year t to Beijing Railway Station. (m)	436	24582.9	18044.58

$$\sum_{n=1}^{N} A_{jn}(\ln LP_{itn} - \hat{a} - \hat{\boldsymbol{a}}\boldsymbol{A}_n) = 0 \tag{14}$$

Substituting Eq. (11) into Eq. (14) yields

$$\sum_{n=1}^{N} A_{jn}(\ln LP_{itn} - (\bar{y} - \hat{\boldsymbol{a}}\overline{\boldsymbol{A}}_n) - \hat{\boldsymbol{a}}\boldsymbol{A}_n) = 0 \tag{15}$$

that is

$$\sum_{n=1}^{N} A_{jn}(\ln LP_{itn} - \bar{y}) = \hat{\boldsymbol{a}} \sum_{n=1}^{N} A_{jn}(\boldsymbol{A}_n - \overline{\boldsymbol{A}}_n) \tag{16}$$

Solving Eq. (16) we have

$$\hat{a}_i = \frac{\sum_{n=1}^{N} A_{jn}(\ln LP_{itn} - \bar{y})}{\sum_{n=1}^{N} A_{jn}(A_n - \overline{A}_n)} \tag{17}$$

Then, the estimator $\hat{\boldsymbol{a}}$ of the coefficient vector $\boldsymbol{a}$ is obtained.

4.3. Mathematical model for commercial land supply in Beijing

The mathematical model established for district-level supply of commercial land use rights is

$$\ln LA_{it} = a + \sum_{m=1}^{M} \alpha_m V_{mit} + Yr\_dum + Dis\_dum + u_{it} \tag{18}$$

where LA_{it} is the area of total leased commercial land of district i in year t, V_{mit} is the location characteristic V_m of district i in year t, M is the number of location characteristics, Yr_dum is the year dummy variable, Dis_dum is the district dummy variable, a is the constant, and u_{it} is the error term for district i in year t. The definitions and summary statistics of the variables of total land area and its influencing factors for commercial land use in Beijing are shown in Table 2.

Eq. (18) can be written as

$$\ln LA_{it} = a + \boldsymbol{a}\boldsymbol{V} + u_{it} \tag{19}$$

where

$$\boldsymbol{a} = (\alpha_1, \alpha_2, \ldots, \alpha_M, 1, 1) \tag{20}$$

$$\boldsymbol{V} = (V_{1it}, V_{2it}, \ldots, V_{Mit}, Yr\_dum, Dis\_dum)^{\mathrm{T}} \tag{21}$$

Then there is the expected value

$$\mathrm{E}(\ln LA_{it} - a - \boldsymbol{a}\boldsymbol{V}) = 0 \tag{22}$$

and the covariance

$$\mathrm{E}(V_j(\ln LA_{it} - a - \boldsymbol{a}\boldsymbol{V})) = 0 \tag{23}$$

where V_j is the component of the vector $\boldsymbol{V}$.

For given sample data, we can estimate $\hat{\boldsymbol{a}}$, which is the approximation of the coefficient vector $\boldsymbol{a}$, and

$$\hat{\boldsymbol{a}} = (\hat{a}_1, \hat{a}_2, \ldots, \hat{a}_M) \tag{24}$$

then we have

$$\frac{1}{N}\sum_{n=1}^{N} (\ln LA_{itn} - \hat{a} - \hat{\boldsymbol{a}}\boldsymbol{V}_n) = 0 \tag{25}$$

and

$$\frac{1}{N}\sum_{n=1}^{N} V_{jn}(\ln LA_{itn} - \hat{a} - \hat{\boldsymbol{a}}\boldsymbol{V}_n) = 0 \tag{26}$$

From Eq. (25) we have

$$\bar{y} = \hat{a} + \hat{\boldsymbol{a}}\overline{\boldsymbol{V}}_n \tag{27}$$

then

$$\hat{a} = \bar{y} - \hat{\boldsymbol{a}}\overline{\boldsymbol{V}}_n \tag{28}$$

where

$$\bar{y} = \frac{1}{N}\sum_{n=1}^{N} \ln LA_{itn} \tag{29}$$

$$\overline{\boldsymbol{V}}_n = \frac{1}{N}\sum_{n=1}^{N} \boldsymbol{V}_n \tag{30}$$

Because of the arbitrariness of the number of the samples, Eq. (26) can be rewritten as

$$\sum_{n=1}^{N} V_{jn}(\ln LA_{itn} - \hat{a} - \hat{\boldsymbol{a}}\boldsymbol{V}_n) = 0 \tag{31}$$

Substituting Eq. (28) into Eq. (31) yields

$$\sum_{n=1}^{N} V_{jn}(\ln LA_{itn} - (\bar{y} - \hat{\boldsymbol{a}}\overline{\boldsymbol{V}}_n) - \hat{\boldsymbol{a}}\boldsymbol{V}_n) = 0 \tag{32}$$

i.e.,

$$\sum_{n=1}^{N} V_{jn}(\ln LA_{itn} - \bar{y}) = \hat{\boldsymbol{a}} \sum_{n=1}^{N} V_{jn}(\boldsymbol{V}_n - \overline{\boldsymbol{V}}_n) \tag{33}$$

Then we have

$$\hat{a}_i = \frac{\sum_{n=1}^{N} V_{jn}(\ln LA_{itn} - \bar{y})}{\sum_{n=1}^{N} V_{jn}(V_n - \overline{V}_n)} \tag{34}$$

According to the regression of the mathematical models and collected data, Table 3 shows the results for price formation model. Table 4 shows the results for district-level supply model.

5. Data of the variables in mathematical models

In this paper, the pooled cross sections data, which have both cross-sectional and time series features, are used in the mathematical model for parcel-level demand of commercial land leasing. The panel data are used in the mathematical model for district-level supply of commercial

Table 2
The definitions and summary statistics of the variables for district-level supply model.

Category	Variable	Description	Obs.	Mean	Std. Dev.
	$\ln(LA_{it})$	Construction land area of total leased commercial land of district i in year t. (m^2)	216	85091.69	169437.4
M_{1it}	$\ln(DCC_{it})$	Distance between district i in year t and People's Square. (m)	216	17538.98	17704.8
M_{2it}	$Subway_{it}$	Numbers of subway stations in district i in year t.	216	8.7	13.26
M_{3it}	$Highway_{it}$	Numbers of highway entrances and exits in district i in year t.	216	84.3	103.22
M_{4it}	$\ln(DIP_{it})$	Distance between district i in year t and the nearest industrial park. (m)	216	181.21	744.76
M_{5it}	$LOC1_{it}$	Location of district i =1 when i is center district; = 0 otherwise. (County is for comparison.)	216	0.44	0.5
M_{6it}	$LOC2_{it}$	Location of district i =1 when i is suburban district; = 0 otherwise. (County is for comparison.)	216	0.44	0.5

Table 3
The results for price formation model.

Variable	Coefficient	Robust standard errors
Commercial land characteristics		
$\ln(Area_{it})$	0.75197***	0.04519
$\ln(FAR_{it})$	0.56628***	0.09145
MOD_{it}	−0.05404	0.08201
$LOC1_{it}$	3.12394*	1.78735
$LOC2_{it}$	2.45258**	1.23914
District characteristics		
$\ln(GDP_{it})$	−0.24429	0.47092
DM_{it}	0.00918	0.03241
Location characteristics		
$\ln(TA_{it})$	−0.25091	0.27463
$\ln(GOV_{it})$	−0.157***	0.04078
$\ln(SUB_{it})$	−0.05602	0.03691
$\ln(HIGH_{it})$	−0.09782**	0.04298
$\ln(UNI_{it})$	0.00396	0.05425
$\ln(PAR_{it})$	−0.13236**	0.05741
$\ln(IP_{it})$	0.02301**	0.0113
$\ln(BC_{it})$	0.3891***	0.12864
$\ln(NY_{it})$	0.01937	0.17527
$\ln(RS_{it})$	−0.06411	0.23202
Constant	18.2291	11.18306
District dummy	Yes	
Year dummy	Yes	
Observations	436	
R^2	0.8811	
Independent variable: $\ln(LP_{it})$		

Notes: ***: significant at the 1 percent level; **: significant at the 5 percent level; *: significant at the 10 percent level.

Table 4
The results for district-level supply model.

Variable	Coefficient	Robust standard errors
Location characteristics		
$\ln(DCC_{it})$	0.36628*	0.21874
$Subway_{it}$	−0.0636	0.06696
$Highway_{it}$	0.04065	0.0599
$\ln(DIP_{it})$	−0.74884***	0.19573
$LOC1_{it}$	2.06998	2.11064
$LOC2_{it}$	−0.83754	2.1649
Constant	3.0108	3.6009
District dummy	Yes	
Year dummy	Yes	
Observations	216	
R^2	0.3141	
Independent variable: $\ln(LA_{it})$		

Notes: ***: significant at the 1 percent level; *: significant at the 10 percent level.

land leasing.

The data for GDP and tenure of district mayor of 18 districts in Beijing from 2004 to 2015 are collected from the yearbooks of Beijing and the corresponding districts from 2004 to 2015.

The land leasing data for commercial land use, including land price, area, floor area ratio, and land leasing modes in Beijing from 2004 to 2015 are collected according to the website of Beijing Planning and Land Resources Bureau. The land price is the final one of each piece of leased commercial land. The land area is the construction land area planed on each piece of leased commercial land. The floor area ratio of commercial land is the ratio of built area to land area. Land leasing modes include tender and listing. From the website of Beijing Planning and Land Resources Bureau, for commercial land, there are 436 pieces of the land falling within 18 districts from 2004 to 2015 in Beijing. The distribution of leased commercial land in Beijing from 2004 to 2015 is shown in Fig. 2.

The land prices and GDP inflation are adjusted by consumer price index (CPI) in this paper. The CPI of Beijing from 2005 to 2015 is collected. Compared with the land prices and GDP in 2004, the ones from 2005 to 2015 are adjusted based on the CPI.

The distances between a leased commercial land and Tiananmen Square, district government, Beijing Capital International Airport, Nanyuan Airport, Beijing Railway Station, the nearest subway, nearest entrance or exit of highway, nearest university, nearest park, and nearest industrial park are computed by using a GIS software. The toolbox 'Analysis Tools' is used in the software to calculate these distances. 18 subway lines and 22 highways are considered in Beijing. 60 main universities, 50 parks, and 72 industrial parks are considered in Beijing. Most universities were built before 2000. Fig. 3 shows the subway stations and highways in 2015. Fig. 4 shows the distribution of main universities, parks and industrial parks.

6. Findings

From the results of price formation model in Table 3, for the land characteristics, the commercial land area is statistically very significant. The commercial land price increases by 0.75 % when the area of it increases by 1%. The larger the commercial land area is, the higher the commercial land price is. The government prefers to lease commercial land with larger area. The floor area ratio of the leased commercial land is statistically very significant. The commercial land price increases by 0.57 % when the floor area ratio of it increases by 1%. For the commercial land use, the developers are willing to make more profits through a larger floor area ratio of the land. Due to great profits, the government tends to lease commercial land with higher floor area ratio. The district location is statistically significant. The commercial land price decreases with the increase of the grade of location of the district. The commercial land price is the highest in center districts. And it is more expensive in the suburban districts than that in the counties. The commercial land price in center districts is 3.12 % higher than that in counties. The commercial land price in suburban districts is 2.45 % higher than that in counties. The transportation system and environment are more favorable for the commercial land development in center districts. The government inclines to lease commercial land to center districts. Also, compared with counties in Beijing, the government prefers to lease commercial land to suburban districts.

For the location characteristics, the distance between the leased commercial land and the district government is statistically very significant. The commercial land price decreases by 0.16 % when the distance between the leased commercial land and the district government increases by 1%. The commercial land price is higher when the land is closer to the district government. Due to the great conveniences and complete accessibilities around the district government, the government prefers to lease commercial land near it. The distance between the leased commercial land and Beijing Capital International Airport is statistically very significant. The commercial land price increases by 0.39 % when the distance between the leased commercial land and Beijing Capital International Airport increases by 1%. Beijing Capital International Airport is far away from the city center, and a lot of industrial land is located around it. Further, there are many commercial areas near the city center, thus the commercial land around the airport is less attractive than that near the city center. The government tends to lease commercial land away from Beijing Capital International Airport. The distance between the leased commercial land and the nearest entrance or exit of highway is statistically significant. The commercial land price decreases by 0.1 % when the distance between the leased commercial land and the nearest entrance or exit of highway increases by 1%. The highway, as one of the most important transportations, is favorable for commercial land use to have more convenient environment and better development. The government prefers to lease commercial land near the entrance or exit of highway. The distance between the leased commercial land and the nearest park is statistically significant. The commercial land price decreases by 0.13 % when the

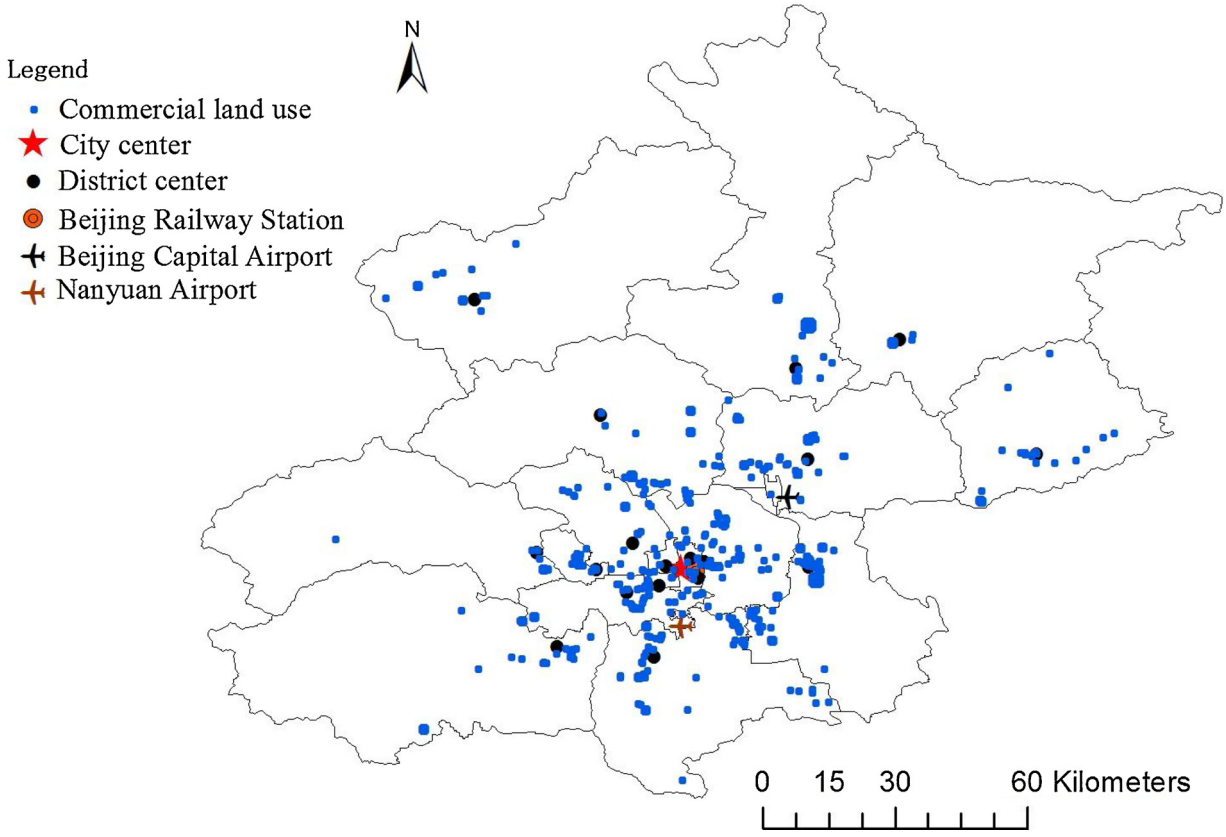

Fig. 2. The distribution of leased commercial land in Beijing from 2004 to 2015.

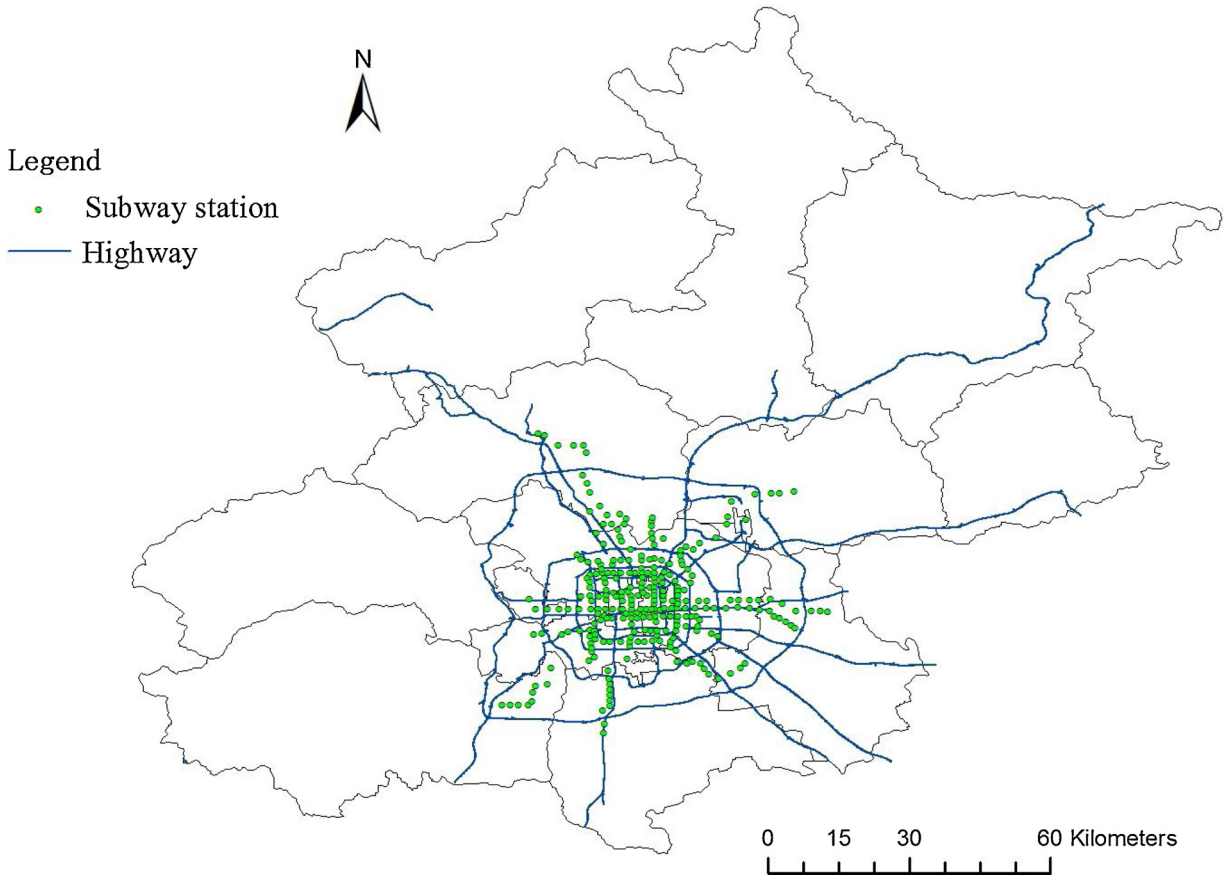

Fig. 3. The subway stations and highways in Beijing in 2015.

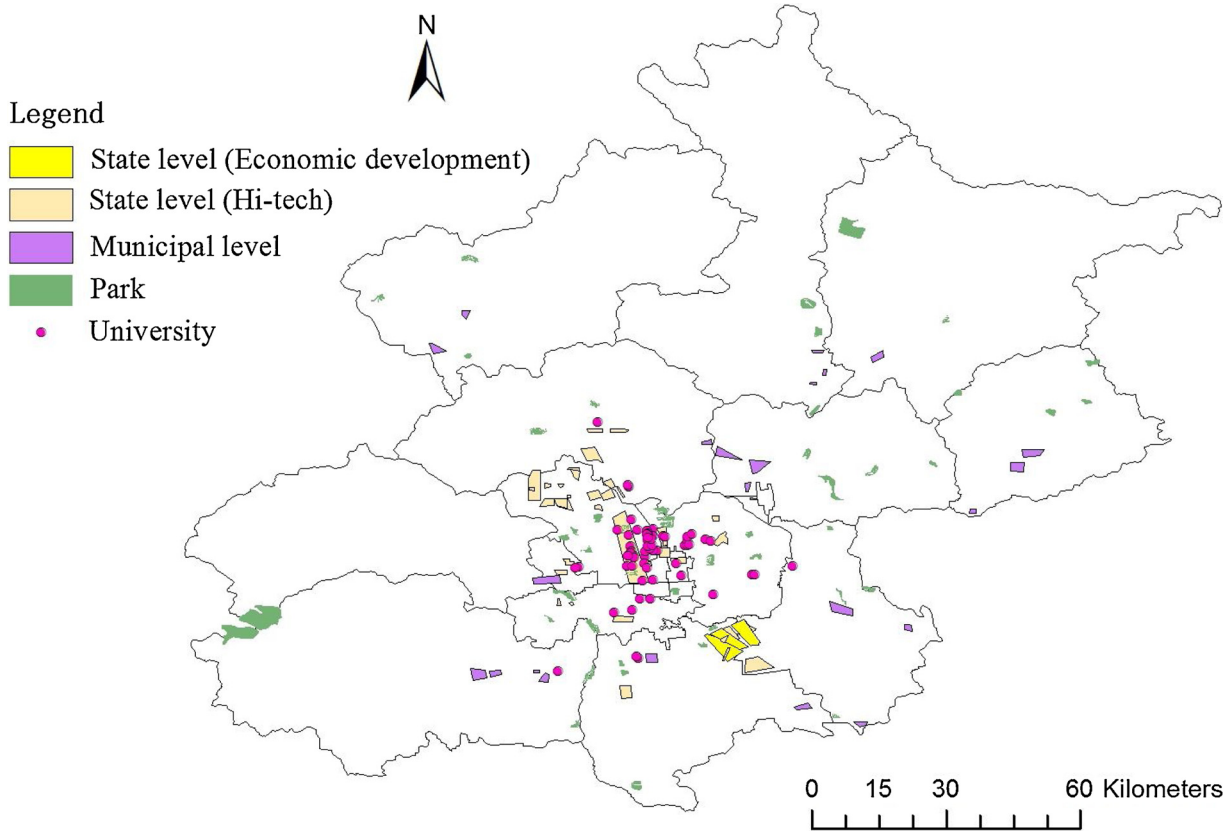

Fig. 4. The distribution of main universities, parks and industrial parks in Beijing.

distance between the leased commercial land and the nearest park increases by 1%. The closer to the park, the higher the commercial land price is. The commercial land needs green space to promote the development. The government inclines to lease commercial land near parks. The distance between the leased commercial land and the nearest industrial park is statistically significant. The commercial land price increases by 0.02 % when the distance between the leased commercial land and the nearest industrial park increases by 1%. The commercial land is usually far away from the industrial parks. The land near city center is more attractive for commercial purpose. The government prefers to lease commercial land away from industrial parks.

According to the results of district-level supply model in Table 4, the distance between the district and the nearest industrial park is statistically very significant. The total land area of commercial land use decreases by 0.75 % when the distance between the district and the nearest industrial park increases by 1%. In Beijing, most districts have industrial parks, and only Chongwen District has no industrial parks. However, the area of Chongwen District is very small, thus the land leased to it will be relatively smaller than other districts. The most industrial parks are located in center districts, such as Haidian District. And more commercial land is leased in the districts with industrial parks.

7. Discussion and conclusions

From above, the price formation and spatial distribution of commercial land has a close relationship with some land characteristics and location characteristics. More specifically, the area and floor area ratio of the commercial land, the location of the district, the distances between the leased commercial land and Beijing Capital International Airport, the district center, the nearest entrance or exit of highway, the nearest park and the nearest industrial park affect the commercial land price in Beijing. And the distances between the district and the nearest industrial park affect the total area of commercial land in Beijing. The high transaction price of commercial land also means large profits gained by the government, therefore the government likes leasing commercial land with higher price. It is shown that the government in Beijing prefers to lease commercial land with larger area or higher floor area ratio. Meanwhile, the government prefers to lease commercial land near district center, entrances or exits of highway, or parks. Compared with suburban districts and counties, the government prefers to lease commercial land to center districts. Thus, there are more commercial land resources in center districts. The government tends to lease commercial land away from Beijing Capital International Airport or industrial parks.

About other relevant researches, Yang et al. (2015) emphasized on price differences among the modes of land leasing, and analyzed all types of land leasing in Beijing based on the data from 2006 to 2012. Li (2011) studied the land price changes in Shanghai according to the data of all types of land leasing from 1992 to 2006. The land leasing policy was reformed in 2003, thus the land leasing process became more formal and effective after 2003. Zheng and Kahn (2008) discussed land price and house price in Beijing based on the data of all types of land leasing from 2004 to 2006. For land price, the variables of the distance from land to city center, and the location of land are considered (Zheng and Kahn, 2008).

Compared with other relevant researches, the land price has a positive correlation with the area and floor area ratio, which is identical with the result of Yang et al. (2015). The land prices in the center districts are higher, which is identical with the result of Li (2011). The prices of land near park (Zheng and Kahn, 2008) are much higher, which is in agreement with the result in this study.

Compared with previous publications, this study aims to analyze the price formation and spatial distribution of commercial land leasing under public land ownership. The object of this study is commercial land leasing in Beijing. The data are collected from 2004 to 2015 after

the reform of land leasing in China in 2003, which is closer to the current land leasing situation. More variables from different aspects are considered comprehensively in this study. Also, the previous studies focused more on land price, and this study considers both land price and land supply.

The findings in this study have some policy implications.

Firstly, the district center is very important for the district governments when they lease commercial land, which would form hierarchical mechanism, develop the central business district, and promote the economic development of the district in the long run.

Secondly, the highway extension is important for formulating commercial land pattern through the changes of accessibility and expansion of suburban sprawl.

Thirdly, district governments concern more about local public goods, such as parks, while leasing commercial land, which could guide governments to focus on the formulation of more comprehensive commercial development.

Fourthly, district governments tend to lease less commercial land around Beijing Capital International Airport, which illustrates that the major airport has less attractive to the commercial developers.

In this study, the factors influencing commercial land leasing by the district government and commercial land leasing price in Beijing under public land ownership are analyzed based on the data of the districts from 2004 to 2015. And the mathematical models for parcel-level demand and district-level supply are proposed.

This study gives some advices for the governments to use and balance land resources, and make better land leasing decisions in the coming decades. From the results of this study, the governments can formulate more efficient land policies, and promote the development of the economics and society of the city. It is helpful for the sustainable development of the land system and the city.

The development process in large cities of China is very similar to developing countries, and the land leasing background is alike among other countries under public land ownership. The policy implications of this study can be applied to large cities in China and some large cities of developing countries.

CRediT authorship contribution statement

Jing Cheng: Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing - original draft, Writing - review & editing.

References

Arabsheibani, R., Sadat, Y.K., Abedini, A., 2016. Land suitability assessment for locating industrial parks: A hybrid multi criteria decision-making approach using Geographical Information System. Geogr. Res. 54 (4), 446–460.

Beenstock, M., Feldman, D., Felsenstein, D., 2016. Hedonic pricing when housing is endogenous: the value of access to the trans-Israel highway. J. Reg. Sci. 56 (1), 134–155.

Calvo, F., de Ona, J., Aran, F., 2013. Impact of the Madrid subway on population settlement and land use. Land Use Policy 31 (SI), 627–639.

Chen, Y.W., 2017. Environmental externalities of urban river pollution and restoration: a hedonic analysis in Guangzhou (China). Landsc. Urban Plan. 157, 170–179.

Cheng, J., 2020a. Analyzing the factors influencing the choice of the government on leasing different types of land uses: evidence from Shanghai of China. Land Use Policy 90, 104303.

Cheng, J., 2020b. Data analysis of the factors influencing the industrial land leasing in Shanghai based on mathematical models. Math. Probl. Eng. 2020, 9346863.

Chernobai, E., Reibel, M., Carney, M., 2011. Nonlinear spatial and temporal effects of highway construction on house prices. J. Real Estate Financ. Econ. 42 (3), 348–370.

Cheung, S.N.S., Coase, H.R., 2008. In: The Economic System of China: With Conference Opening and Closing Remarks by Ronald Coase. Melbourne: Arcadia Press.

Deng, Y.H., Gyourko, J., Wu, J., 2012. Land and Housing Price Measurement in China. Working Paper 18403. National Bureau of Economic research.

Du, H.B., Mulley, C., 2007. The short-term land value impacts of urban rail transit: quantitative evidence from Sunderland. UK. Land Use Policy 24 (1), 223–233.

Du, J.F., Peiser, B.R., 2014. Land supply, pricing and local governments' land hoarding in China. Reg. Sci. Urban Econ. 48, 180–189.

Du, J.F., Thill, J.C., Peiser, B.R., Feng, C.C., 2014. Urban land market and land-use changes in post-reform China: a case study of Beijing. Landsc. Urban Plan. 124, 118–128.

Fu, Q., Lin, N., 2013. Local state marketism: an institutional analysis of China's urban housing and land market. Chin. Sociol. Rev. 46 (1), 3–24.

Gal, Y., Hadas, E., 2013. Land allocation: agriculture vs. Urban development in Israel. Land Use Policy 31 (SI), 498–503.

Gong, J.Z., Chen, W.L., Liu, Y.S., Wang, J.Y., 2014. The intensity change of urban development land: implications for the city master plan of Guangzhou. China. Land Use Policy 40, 91–100.

Ho, P.S.S., Lin, G.C.S., 2004. Converting land to nonagricultural use in China's coastal provinces: evidence from Jiangsu. Mod. China 30 (1), 81–112.

Janssen, T.L.C., 2003. Estimating the effect of land leases on prices of inner-city apartment buildings. Urban Stud. 40 (10), 2049–2066.

Jin, H.H., Qian, Y.Y., Weingast, R.B., 2005. Regional decentralization and fiscal incentives: federalism, Chinese style. J. Public Econ. 89 (9-10), 1719–1742.

Kanianska, R., Kizekova, M., Novacek, J., Zeman, M., 2014. Land-use and land-cover changes in rural areas during different political systems: a case study of Slovakia from 1782 to 2006. Land Use Policy 36, 554–566.

Koroso, N.H., van der Molen, P., Tuladhar, A.M., Zevenbergen, J.A., 2013. Does the Chinese market for urban land use rights meet good governance principles? Land Use Policy 30 (1), 417–426.

Lavee, D., 2015. Land use for transport projects: estimating land value. Land Use Policy 42, 594–601.

Levkovich, O., Rouwendal, J., van Marwijk, R., 2016. The effects of highway development on housing prices. Transportation 43 (2), 379–405.

Li, L.H., 2003. Economic reform in the urban land system in China. J. Contemp. China 34 (12), 207–224.

Li, L.H., 2011. The dynamics of the Shanghai land market – an intra city analysis. Cities 28 (5), 372–380.

Li, J., 2014. Land sale venue and economic growth path: evidence from China's urban land market. Habitat Int. 41, 307–313.

Li, H., Kung, K.S.J., 2015. Fiscal incentives and policy choices of local governments: evidence from China. J. Dev. Econ. 116, 89–104.

Lin, G.C.S., 2007. Reproducing spaces of Chinese urbanization: new city-based and land-centered urban transformation. Urban Stud. 44 (9), 1827–1855.

Lin, G.C.S., Ho, S.P.S., 2005. The state, land system, and land development processes in contemporary China. Ann. Assoc. Am. Geogr. 95 (2), 411–436.

Liu, Y.S., Wang, J.Y., Long, H.L., 2010. Analysis of arable land loss and its impact on rural sustainability in Southern Jiangsu Province of China. J. Environ. Manage. 91 (3), 646–653.

Liu, Y.S., Wang, G.G., Zhang, F.G., 2013. Spatio-temporal dynamic patterns of rural area development in eastern coastal China. J. Geogr. Sci. 23 (2), 173–181.

Liu, Y.S., Fang, F., Li, Y.H., 2014a. Key issues of land use in China and implications for policy making. Land Use Policy 40, 6–12.

Liu, Y.S., Yang, R., Long, H.L., Gao, J., Wang, J.Y., 2014b. Implications of land-use change in rural China: a case study of Yucheng, Shandong province. Land Use Policy 40, 111–118.

Liu, T., Cao, G.Z., Yan, Y., Wang, Y.R., 2016. Urban land marketization in China: central policy, local initiative, and market mechanism. Land Use Policy 57, 265–276.

Liu, Y.S., Li, J.T., Yang, Y.Y., 2018a. Strategic adjustment of land use policy under the economic transformation. Land Use Policy 74, 5–14.

Liu, Y.S., Zhang, Z.W., Zhou, Y., 2018b. Efficiency of construction land allocation in China: an econometric analysis of panel data. Land Use Policy 74, 261–272.

Long, H.L., 2014. Land use policy in China: introduction. Land Use Policy 40, 1–5.

Maskin, E., Qian, Y.Y., Xu, C.G., 2000. Incentives, information and organizational form. Rev. Econ. Stud. 67 (2), 359–378.

Ooi, T.L.J., Sirmans, C.F., Turnbull, G.K., 2011. Government supply of land in a dual market. Real Estate Econ. 39 (1), 167–184.

Pan, H.X., Zhang, M., 2008. Rail transit impacts on land use: evidence from Shanghai, China. Trans. Res. Record: J. Trans. Res. Board 2048 (1), 16–25.

Solé-Ollé, A., Viladecans-Marsal, E., 2012. Lobbying, political competition, and local land supply: recent evidence from Spain. J. Public Econ. 96 (1-2), 10–19.

Steinhausser, R., Siebert, R., Steinfuhrer, A., Hellmich, M., 2015. National and regional land-use conflicts in Germany from the perspective of stakeholders. Land Use Policy 49 (SI), 183–194.

Sun, W.Z., Zheng, S.Q., Wang, R., 2015. The capitalization of subway access in home value: a repeat-rentals model with supply constraints in Beijing. Trans. Res. Part A 80, 104–115.

Tan, R., Beckmann, V., van den Berg, L., Qu, F., 2009. Governing farmland conversion: comparing China with the Netherlands and Germany. Land Use Policy 26 (4), 961–974.

Tao, R., Su, F.B., Liu, M.X., Cao, G.Z., 2010. Land leasing and local public finance in China's regional development: evidence from prefecture-level cities. Urban Stud. 47 (10), 2217–2236.

Tchang, G., 2016. The impact of highway proximity on distribution centres' rents. Urban Stud. 53 (13), 2834–2848.

Wang, J., Chen, Y.Q., Shao, X.M., Zhang, Y.Y., Cao, Y.G., 2012. Land-use changes and policy dimension driving forces in China: present, trend and future. Land Use Policy 29 (4), 737–749.

Xu, C.G., 2011. The fundamental institutions of China's reforms and development. J. Econ. Lit. 49 (4), 1076–1151.

Xu, T., Zhang, M., Aditjandra, P.T., 2016. The impact of urban rail transit on commercial property value: new evidence from Wuhan, China. Trans. Res. Part A 91, 223–235.

Yang, Z., Ren, R.R., Liu, H.Y., Zhang, H., 2015. Land leasing and local government behaviour in China: evidence from Beijing. Urban Stud. 52 (5), 841–856.

Yang, J.W., Chen, J.X., Le, X.H., Zhang, Q., 2016. Density-oriented versus development-oriented transit investment: decoding metro station location selection in Shenzhen.

Transp. Policy (Oxf) 51 (SI), 93–102.
Yang, Y.Y., Liu, Y.S., Li, Y.R., Du, G.M., 2018. Quantifying spatio-temporal patterns of urban expansion in Beijing during 1985-2013 with rural-urban development transformation. Land Use Policy 74, 220–230.
Zhang, M., Wang, L.L., 2013. The impacts of mass transit on land development in China: the case of Beijing. Res. Transp. Econ. 40 (SI), 124–133.
Zheng, S.Q., Kahn, M.E., 2008. Land and residential property markets in a booming economy: new evidence from Beijing. J. Urban Econ. 63 (2), 743–757.
Zheng, S.Q., Sun, W.Z., Wang, R., 2014. Land supply and capitalization of public goods in housing prices: evidence from Beijing. J. Reg. Sci. 54 (4), 550–568.
Zheng, S.Q., Hu, X.K., Wang, J.H., Wang, R., 2016. Subways near the subway: rail transit and neighborhood catering businesses in Beijing. Transp. Policy (Oxf) 51 (SI), 81–92.