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The coupled relationships between land development and land ownership at China's urban fringe: A structural equation modeling approach

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ABSTRACT

The rate of land urbanization has grown rapidly in recent decades in China, and a growing body of literature has investigated the driving forces behind it. The dual nature of China's land ownership system, in which top-down and bottom-up land development form two separate tracks, is frequently cited in these studies. While top-down land development is dominant, bottom-up land development, which has traditionally been overlooked in academic studies, may be equally pivotal for land development in China. This study extends traditional urban economic analyses and demonstrates how land ownership and land development are interconnected in China. This study applies structural equation modeling to data taken from Shenzhen, a city where the two tracks of land development coexist, to estimate the reciprocal relationships between land ownership and land development. The results show that the influence of land ownership on land development is significant and that collective ownership has a positive influence on land development; likewise, land development also influences ownership: land development tends to facilitate the conversion of land from collective to state ownership. The study recommends more tailored policies and strategies targeted toward improving management of collective-owned lands while simultaneously advancing urban redevelopment.

1. Introduction

In the past two decades, China has experienced a period of unprecedented and rapid urbanization; in fact, the urbanization of land is proceeding more rapidly than urbanization of the population (Gao et al., 2016). From 1996–2016, China's built-up urban areas grew by 161 %, from 20,660 km^2 to 54,000 km^2, while the proportion of the population living in urban areas grew by just 26.87 %, from 30.48%–57.35% (China Urban Statistics Yearbook, 1996–2016). The rapid rate of land development in China, driven by local governments' economic motivations, has caused multiple environmental and social problems while encroaching on agricultural land, which threatens food security and environmental sustainability (Cao et al., 2008; Lin and Ho, 2005).

The Chinese central government has taken a series of measures to limit the growth of built-up area and protect existing arable land, including defining growth boundaries of urban expansion, implementing stricter policies of land expropriation, maintaining balance between cultivated and occupied land, and setting land compensation rates (Cheng et al., 2015; He et al., 2013). Land quota, for instance, is a rigid and important land use policy tool to control urban expansion. Every year, the central government allocates a quota of land for construction to each local government via an annual land use plan. If there is insufficient land quota for a development project, it will be rejected by the government (Chien, 2015; Shen et al., 2017; Wang et al., 2010; Zhang et al., 2014). Although existing literature has made important contributions in examining the impacts of land policies on protecting arable land, there are still controversies regarding the effectiveness of these measures, and studies have indicated that the mechanism of land development is more complex than expected (Cheng et al., 2015; He et al., 2013; Lichtenberg and Ding, 2008; Liu et al., 2015; Zhong et al., 2012).

A growing body of literature has tried to examine the driving forces underlying the rapid land development in China. Several market-oriented factors, such as location and accessibility, have been empirically proven to be drivers of land development in China (Ding, 2001; Li et al., 2010; Wu and Wang, 2017). In addition, urban planning as a non-market factor was recognized in recent literature as an increasingly

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important factor that remedies market failures and/or achieves particular land use development goals (Moroni and Minola, 2019; Tong and Feng, 2019; Xu et al., 2019). Existing literature has also highlighted the dual nature of China's land development system and calls for more research into the influence of China's dual land-ownership on its rapid land development (Gao et al., 2016).

In China's dual land-ownership system, urban land is owned by the state while rural land is owned by village collectives. Conversion of undeveloped rural land to built-up land for urban use typically follows one of two tracks: (1) in the top-down track, local governments (municipal governments and their sub branches), as the managers of the state-owned land, expropriate rural undeveloped land from villagers and prepare and sell it in the urban land market, leading the whole process of land development; (2) in the bottom-up track, villagers maintain their collective ownership of land, developing it by themselves (Choy et al., 2013; Shen, 2006; Shen et al., 2006; Yang et al., 2015). While top-down land development has traditionally dominated China's land development (Bao and Peng, 2016; Lin, 2007; Liu et al., 2012; Qian, 2008; Tao et al., 2010; Wu and Yeh, 1997; Xie et al., 2002; Zheng et al., 2014), a few recent studies have expanded the discussion, showing that bottom-up development – often overlooked – may be equally pivotal to China's land development (Lai et al., 2017a,2017b; Tian and Yao, 2018). From 1996–2012, the area of new construction land in China reached an annual average of 4827 km^2, of which 50.69 % (2447 km^2) was in rural areas developed primarily via the bottom-up track; simultaneously, the population in rural areas decreased by 133 million, indicating a mismatch between population and land growth (The Chinese National New Urbanization Plan 2014–2020).

There are several reasons for the proliferation of bottom-up land development. Compared to top-down land development, the bottom-up mode is cheaper for individual developers by avoiding top-down land development costs such as land leasing fees, taxes, and other fees and funds that developers have to pay to local governments, which can account for 50 % of the eventual commercial housing price (Tao and Wang, 2010). On the other hand, while rural migrants' enormous demand for affordable housing makes low-cost bottom-up land development such as urban villages popular (Hao et al., 2011; Liu et al., 2010), local governments are less able to control bottom-up land development. Consequently, bottom-up land developments are profitable and less constrained by urban planning, inspection, and approval procedures (Song et al., 2008), which further propels the sprawl of bottom-up, informal, unauthorized, and sometimes even illegal land development in rural or urban fringe areas (Li et al., 2019).

Although the dual land-ownership system and its influence on land development have gained academic attention in recent years (Lai et al., 2014; Wu, 2009; Ye et al., 2013), such research is still in its infancy. Two main gaps exist in the literature. First, most of the existing studies are descriptive and qualitative. Although earlier qualitative research – examining the land-development process, mechanisms, trends, and issues – has made important contributions, additional quantitative research is much needed if we are to understand the relationships between land ownership and development. Second, few existing studies recognize the reciprocal nature of the relationship between land ownership and land development. The consensus in the literature is that land ownership influences land-development outcomes while largely ignoring whether land development conversely affects land ownership.

A set of studies hinted at the reciprocal impact of land development on land ownership by showing that rural collectives prefer to retain ownership of their undeveloped lands for future bottom-up development (Shen, 2006; Shen et al., 2006; Wong et al., 2003). Meanwhile local governments tend to transfer the collective ownership of undeveloped lands to the state if future land-use plans indicate these lands will be developed soon. The reciprocal relationships have also shown some new trends. Local governments have recently shown a growing interest in acquiring inefficiently developed collective land for redevelopment as opposed to directly acquiring collective-owned undeveloped lands (Arkaraprasertkul, 2018; Chen, 2015; Li et al., 2018; Wang et al., 2018; Wu and Wang, 2017). This new phenomenon may be due to the shrinking land quota allocated from China's central government (Wang et al., 2010; Zhang et al., 2014). For local governments, redevelopment on inefficiently used land has become a promising source for urban growth.

This study intends to fill the gap in the literature by using an advanced statistical tool to disentangle the coupled relationships between land ownership and land development. Our main research questions are whether the connection between land ownership and land development is reciprocal and if so, to determine the nature of this reciprocal relationship. We applied a structural equation modeling (SEM) approach to data from two years (1996 and 2010) from a land parcel dataset concerning land in Shenzhen, China. Different from traditional multivariate regression analysis, which only detects correlations between a response variable and one or more explanatory variables, SEM allows the modeling of reciprocal causal relationships. In the model, land development is assumed to be influenced by land ownership, which is simultaneously impacted by land's development status. Our study area, Shenzhen, is located in the Pearl River Delta and is considered a typical desakota area, exhibiting dense population and mixed land use (Ginsburg, 1991). From 1996–2010, the city experienced its most rapid urbanization. Until 2010, collectives owned nearly half of the city's developed lands, and both tracks of land development are currently active, making Shenzhen a suitable study case.

The rest of the paper is organized as follows. Section 2 lays out the relationships between land ownership and land development and their potential predictors. We introduce our study area – Shenzhen – in Section 3. Section 4 describes the SEM method. Results are presented in Section 5. The discussion and conclusions are drawn in Section 6.

2. Conceptual framework

Land development is a complex process. Based on traditional urban economics theories, market forces such as locational factors, biophysical factors, and neighborhood conditions are influential forces that impact land development (Alonso, 1964; Mills, 1967; Muth, 1970; Qiu and Xu, 2017; Verburg et al., 2004). In the Chinese context, several of the same market forces influence both land development (grey solid lines in Fig. 1) and land ownership (dark solid lines in Fig. 1). According to China's Land Administration Law (CLAL), rural land is owned by rural collectives, while urban land is owned by the state. When considering whether to acquire a collective-owned parcel, the local governments, as the managers of state-owned land, will first consider the types of land use on the parcel, that is, whether current or recent planned uses are rural or urban. The land parcels close to urban centers or other urban use parcels will be more likely to be converted from collective ownership to state ownership. The neighborhood context of a land parcel might also influence its land ownership. Land that is surrounded by more developed areas is more likely to be acquired and transferred to state ownership by the local government (Ding, 2001).

Most importantly, our study hypothesizes the existence of reciprocal relationships between land development and land ownership (dashed lines in Fig. 1). As discussed in the introduction section, existing literature has directly or indirectly indicated that different land ownerships may lead to different purposes, costs, and hence outcomes of land development. The status of land development may also relate to the cost and purpose of land ownership conversion. Land use policies and planning serve as the mediators that connect land development and ownership and facilitate their reciprocal relationships. Land use polices such as land quotas are closely related to the costs and potential revenues of land development, which could determine how land development might influence land ownership and vice versa. Urban planning, by setting long-term goals such as balancing environmental protection and economic development, ensuring social equality, and

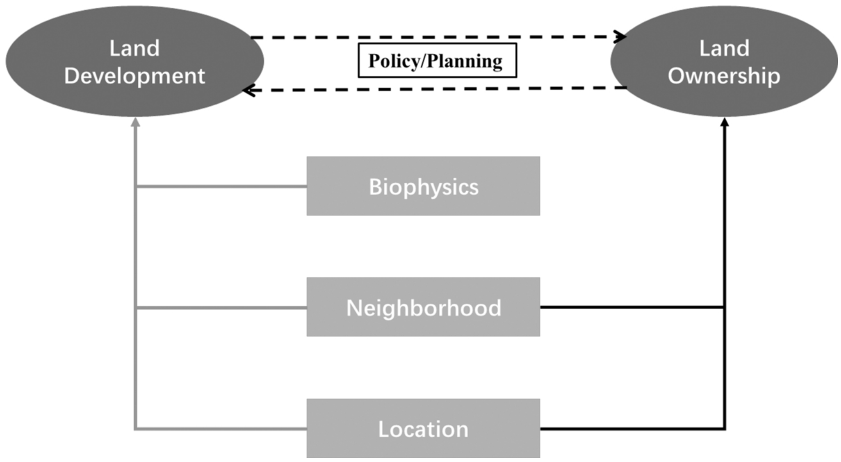

Fig. 1. The Conceptual Framework.

revitalizing undeveloped areas, could also influence the land market and, by extension, the nature of the reciprocal relationships (Campbell, 1996; Ellis, 2001; Gennaio et al., 2009; Gordon et al., 2009; Naess, 2001). The complex relationships between land development and ownership, mediated through policy and planning, are further elaborated below.

2.1. How land ownership affects land development

Land ownership – an integral part of institutions – is linked to the transaction costs of land property trades based on the theory of New Institutional Economics (Coase, 1937). Different land ownership results in different transaction costs during trading, which in turn influences land-development outcomes (Havel, 2014). In China's dual land-ownership system, different types of ownership can entail different property rights, legal rules, and social norms, all of which may influence transaction costs and hence land-development outcomes.

According to CLAL, collectives have more limited property rights than the state. While collective-owned undeveloped land can only be developed for villagers' own residences, town enterprises, or public facilities, state-owned lands can be developed for various urban functions such as large-scale residential projects for sale or for rent, commercial projects, offices, and other profitable uses. Transfers and leases of collective-owned land are limited, while state-owned lands can be leased and transferred more easily. Also, the CLAL allows governments to expropriate collective land for public interests, and ownership of rural land must be transferred to the state before it can be converted to urban uses. Consequently, local governments have a strong motivation to push for so-called top-down development because the fiscal revenue of local governments depends largely on state-owned land leasing fees (known as the "land finance" phenomenon) (Cao et al., 2008; Lin, 2014). They prefer to carry out urban construction planning and projects on state-owned undeveloped land parcels or certain collective-owned land parcels whose ownership can be transferred easily from collectives to the state. The development of state-owned lands may bear low transaction costs because of the clearly defined property rights, ease of lease or transfer, and favorable support from local governments, all of which contribute to rapid excessive land development in China (Cao et al., 2008; Lin, 2014; Tian, 2015; Wu et al., 2015). At the same time, studies have proposed that collective ownership in China prohibits or hinders land development due to the accompanying incomplete property rights and limited revenue gained through development activities (Deng, 2009; Huang et al., 2017; Lai et al., 2017a,2017b; Lai et al., 2014; Wang and Sun, 2014).

However, a more recent study showed that collective ownership might have a promotional effect on land development when controlling for other factors (Tong et al., 2018, 2019). First, although facing tremendous constraints, the transaction costs of bottom-up development might be lower than those of top-down development, especially when the cost of negotiation, enforcement, development period, and possible policy changes are considered. During the initial step of top-down land development – acquiring collective-owned lands – local governments usually encounter great difficulty negotiating with villagers due to disagreement over compensation contracts (Hao et al., 2011; Li et al., 2014; Tian et al., 2016). In contrast, villagers typically more easily reach internal agreement based on family ties and kinship (Li et al., 2014; Tian et al., 2016). Second, during the land development process, the local government intends to achieve various goals beyond monetary benefit, and the extra social and environmental costs in terms of ensuring natural resource conservation and social justice may delay or discourage top-down land development. Under these circumstances, land policies and urban planning could impose constraints on top-down land development. On the other hand, villagers usually aim to maximize their monetary profits in the near term, leading to faster land development. Third, top-down urban land development is heavily regulated and rigorously supervised by planning departments, which could prolong the development process (Tong et al., 2018). In contrast, the loose planning and supervising of rural land (or collective land) in turn facilitate the rapid growth of bottom-up development (Song et al., 2008; Zhang et al., 2003).

2.2. How land development affects land ownership

Land development influences land ownership through a major channel: expected profit from transfer of land ownership. According to the CLAL, when a collective-owned land parcel is undeveloped, the amount of compensation offered to land-lost farmers is calculated based on the original agricultural use of the land, which is quite low (Ding, 2007; Hao et al., 2011; Hui et al., 2013; Qian, 2015). Thus, collectives may be unwilling to transfer their undeveloped land to the local government, especially in the context of rapid urbanization in China. More and more collectives see huge potential profits in maintaining their land ownership and developing their land themselves through the bottom-up track. However, if a land parcel is already developed, collectives may be more willing to transfer the land to the local government, as they can obtain higher compensation based on the land's current non-agricultural use. As a result, undeveloped lands are more likely to be owned by collectives.

From the perspective of the local government, expropriating undeveloped collective-owned land used to be more convenient and profitable because of the low compensation rates offered for land used primarily for agriculture. However, the central government quickly realized that rapid urbanization in China built upon cheap, undeveloped rural lands was resulting in multiple negative consequences such as urban sprawl, inefficient land development, farmland degradation, creation of informal economies, and social instability (Ding, 2007). To reduce the loss of prime farmland, stricter policies were successively issued, especially the regulations of "Red Line of 1.8 Billion Mu (1.2 million km^2) Farmland," which was proposed in 2007. In 2014, the concept of permanent prime farmland was established, entitling 1.55 billion mu (1.03 million km^2) farmland with the most restricted protection policy to date, prohibiting development without the approval of the central government (MLR and MAR, 2014). In addition to land protection policies, the Land Use Annual Plan is also an important tool used by the central government to guide local land developments towards reasonable and economical uses. Every year, the central government collects land use plans from the locals for the following year. Taking into consideration farmland protection and national land supply, various departments within the central government then collectively formulate a final land use plan. Local governments use this important document to guide their land use decisions (MLR, 2004).

With the aforementioned extensive set of land use regulations, the perceived benefits of acquiring undeveloped land from collectives for local governments no longer outweigh its costs (Tian and Yao, 2018). Local governments may be more willing to spend more on acquiring collective-owned developed land that can satisfy the increasing demand for land development through redevelopment projects without breaching the limitation of land quota. This situation has occurred more frequently in well urbanized and marketized areas such as the Yangtze River Delta and Pearl River Delta, where there is less undeveloped land and the motivation to develop land is strong (He and Wu, 2005; Li and Liu, 2018; Qiu and Xu, 2017; Tan et al., 2019).

Although we propose a likely influence of land development on land ownership transfer, we need a tool that enables us to empirically test the hypothesis while controlling for other influential factors. Traditional regression models are not adequate to detect these reciprocal relationships within a single framework. Our study thus applies a structural equation modeling method, which is explained in detail below.

3. The case of Shenzhen

Shenzhen is in the southeast of China, along the South Sea coast. Before China's reform and opening in 1978, Shenzhen was a small, poor fishing village. However, it is advantageously located adjacent to Hong Kong. In 1980, a Special Economic Zone (SEZ) was established in Shenzhen (shown in Fig. 2), and many large enterprises and preferential policies began taking root here; meanwhile, the area also attracted many new residents and rural-urban migrants. Shenzhen experienced an unusually high level of economic growth over the past 40 years. In 2017, its built-up area totaled more than 900 km^2, with 12.53 million permanent residents and GDP of 2.23 trillion yuan, ranking it third economically among all cities in China.

To promote top-down land development in Shenzhen, the municipal government nominally transferred all collective-owned lands into state ownership in 1992 and 2004. In reality, however, the procedure of transferring land ownership and compensating villagers for each collective-owned land parcel was not completed; many land parcels were still practically controlled by villagers as of 2010, leading to the long-lasting two-track land-development process in Shenzhen. According to Shenzhen's 2010 land-use survey, state-owned land totaled 550.71 km^2 and collective-owned land totaled 343.18 km^2; of the collective-owned land, about 75 % is without land quota or complete construction approvals (shown in Fig. 3). Development on collective-owned land has tended toward compression of public space and increasing construction density, neither of which accommodate the public interest. For instance, residential and industrial developments accounted for 40 % of the area of state-owned land, but these uses reached 74 % for collective-owned land. On state-owned land, 44 % was reserved for open and green space, while only 18 % of collective-owned land was similarly allocated. Land management in Shenzhen has entered a bottleneck period: significant amounts of collective-owned lands have been developed without supervision and without the consideration of public interests, which may impede the process of urbanization.

4. Research method: structural equation model approach

4.1. Model specification

Structural equation modeling, developed in the 1990s, is an advanced multivariate analysis tool that has been applied in many fields, including economics, psychology, sociology, and genetics (Hershberger, 2003). SEM models the relationships among multiple independent and dependent variables simultaneously, which contributes to answering a set of interrelated research questions in a single analysis framework. The model consists of two major types of variables: endogenous variables and exogenous variables. All endogenous variables are influenced by and can be predicted by other variables, while exogenous variables are not affected by any of the other variables (Eveland Jr et al., 2005; Wong and Law, 1999; Wong et al., 2001). SEM can estimate direct effects, indirect effects, and total effect, which gives deeper and more comprehensive insight into the links between variables than ordinary linear models. Direct effects appear as direct links between exogenous variables and endogenous variables, while indirect effects reveal the relationships between exogenous and endogenous variables through the mediation of at least one additional variable. The total effect is equal to the sum of the direct and indirect effects. In addition, SEM can be applied to cope with the problem of endogeneity when it is caused by simultaneous causality (Eveland et al., 2005; Kim et al., 2014; Mcbee, 2010; Wong et al., 2001).

In this paper, the simultaneous causality between the land-development and land-ownership variables is hypothesized in the conceptual framework. As the binary variable is included in our study, a probit model was used to link the binary endogenous variable and other variables. Thus, we specify our SEM model as follows:

$$P(Y_1 = 1|Y_2, Z, X_1 X_2 \cdots\cdots X_m) = \Psi(\alpha_{11}Y_2 + \alpha_{12}Z + \beta_{11}X_1 + \beta_{12}X_2 + \cdots\cdots + \beta_{1k}X_m + \xi) \quad (1)$$

$$P(Y_2 = 1|Y_1, Z, X_1 X_2 \cdots\cdots X_n) = \Psi(\alpha_{21}Y_1 + \alpha_{22}Z + \beta_{21}X_1 + \beta_{22}X_2 + \cdots\cdots + \beta_{2k}X_n + \zeta) \quad (2)$$

$$Z = \beta_{31}X_1 + \beta_{32}X_2 + \cdots\cdots + \beta_{3k}X_k + \delta \quad (3)$$

Y denotes endogenous binary variables, including land development and land ownership conversion in our study. Z denotes another endogenous variable: benchmark price (BP). X denote exogenous variables such as biophysics, locational, and neighborhood factors. ξ, ζ, and δ denote error terms. α denotes the coefficients of endogenous variables, while β denotes the coefficients of exogenous variables. Finally, P is the possibility constrained by particular conditions and Ψ is the probit link function. Detailed descriptions of all variables and data sources are provided in the following section.

4.2. Variables and data sources

The dataset is based on the National Land Use Survey and Land Use Survey of Collective Cooperative Stock Companies in Shenzhen in 1996 and 2010. The data from the National Land Use Survey contains information about the parcel division, land use type of each parcel, parcel attributes, and other information. The Land Use Survey of Collective Cooperative Stock Companies provides land-ownership information. By using ArcMap 10.2, we extracted the information that we needed and excluded the area retained for natural conservation, i.e., which will not

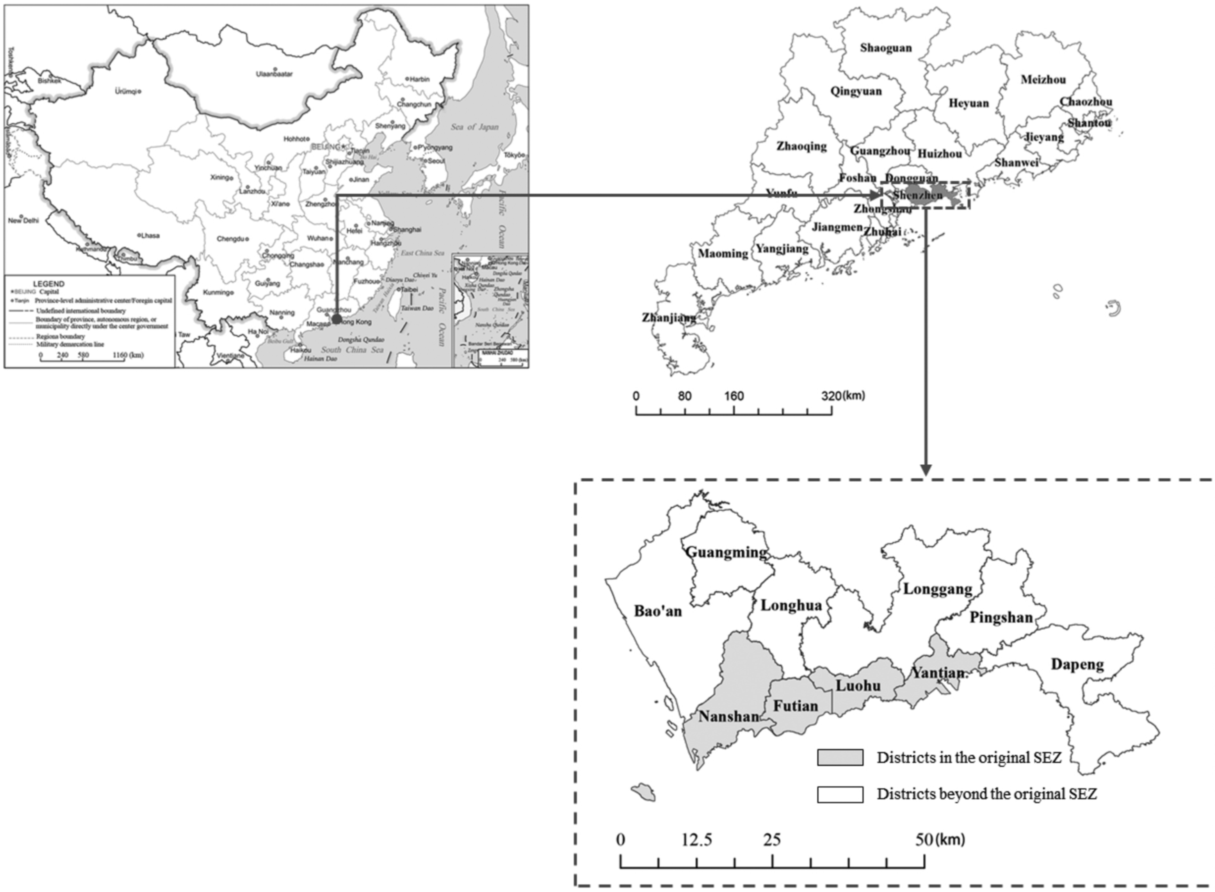

Fig. 2. Administrative Districts and Special Economic Zone in Shenzhen.

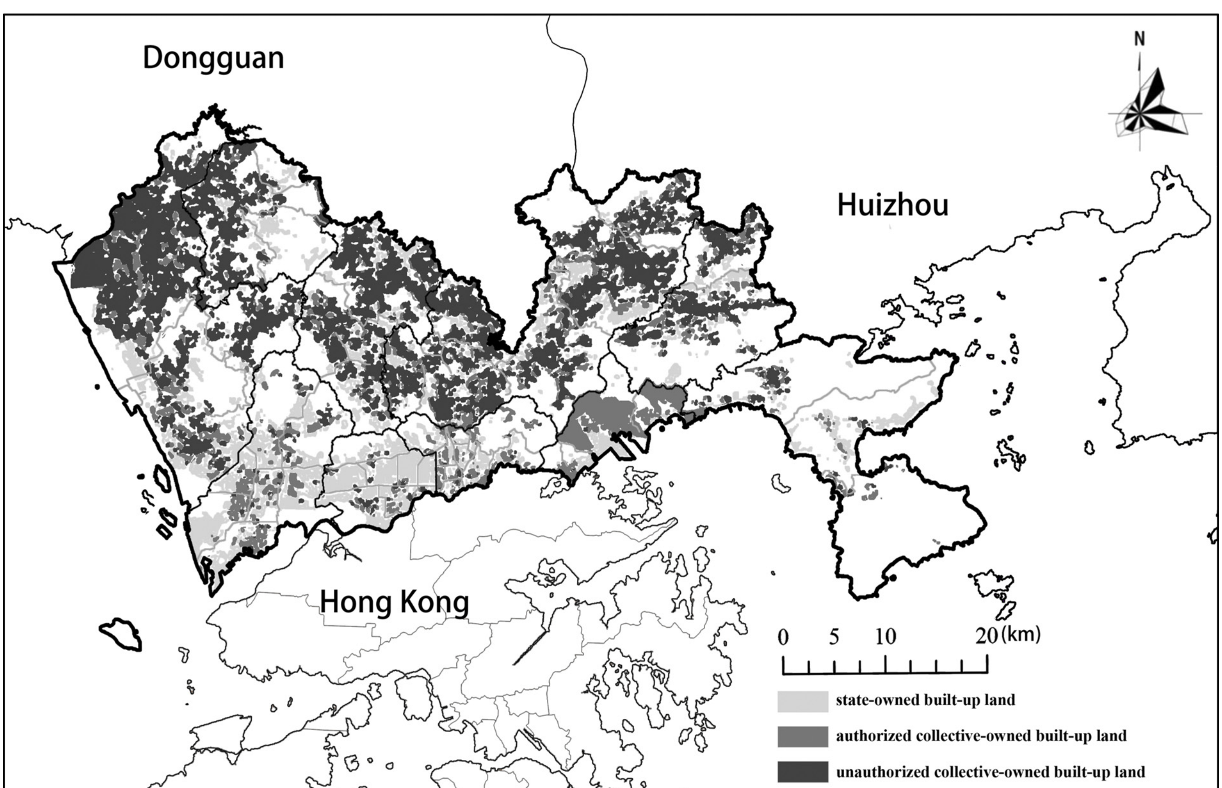

Fig. 3. Collective-owned developed lands in Shenzhen in 2010. (Data is drawn from the Urban Planning, Land and Resource Commission of Shenzhen Municipality).

Table 1
Description of Variables.

Categories	Factors	Variables in detail	Variable code	Data source
Biophysical variables	Size	Areal size of the parcel	Size (km^2)	The second national land survey in 2010
	Topography	Elevation	Elevation(m)	1:10,000 topographic map of Shenzhen
		Slope	SLOPE(°)	
	Land use	Land use types (dummies)	Farm (Yes = 1)	The first national land survey in 1996 and the second national land survey in 2010
			Orchard (Yes = 1)	
			Forest (Yes = 1)	
			Grass (Yes = 1)	
			Water (Yes = 1)	
			Unused (Yes = 1)	
Locational variables	Regional locations	Distance to the nearest city center, district center, or neighborhood center	Dis_city(km)	The first national land survey in 1996 and the second national land survey in 2010
			Dis_distr(km)	
			Dis_neigh(km)	
	Proximity to roads	Distance to the nearest city road	Dis_road(km)	
	Proximity to scenery	Distance to the nearest river, green area, famous scenic site, or forest	Dis_green(km)	
Neighborhood variables	The proportion of adjacent developed area	The proportion of constructed area within a 200 m buffer in 1996	BZ_96(%)	Shenzhen administrative division map
		The proportion of newly constructed area within a 200 m buffer from 1996 to 2010	BZ_New(%)	
Compound variables	Benchmark price	An official referenced standard land price	BP (1000 yuan/m^2)	Benchmark land price of Shenzhen in 2008
Ownership conversion	Land-ownership conversion	Remained collective-owned (0) or changed to state-owned by 2010 (1)	LO	Land use survey of collective cooperative stock companies
Development status	Land-development status	Remained undeveloped (0) or developed by 2010 (1)	LD	First national land survey in 1996 and second national land survey in 2010

be built up. Our study focuses on land parcels that were undeveloped and owned by collectives in 1996; we aim to examine land development and ownership conversion of these parcels. For each parcel, we calculated variables that measure its land-development outcome and land ownership conversion. We also created variables that are known to influence land development, land ownership, or both. Each of the variables is explained below (as shown in Table 1).

As shown in Table 1, biophysical variables describe the physical characteristics of a land parcel. Size is included in the study based on the hypothesis that larger parcels might be more likely to be developed because greater land development size usually means greater profit (Clauretie and Li, 2019). Topographic variables are included, too, as parcels with lower elevation and less slope are easier to develop and provide better construction conditions. Different land-use types may be associated with different levels of compensation and construction cost. There are six land use types in total. We use unused land – land parcels that are not used for either agriculture or urban construction – as the reference group.

Among locational variables, distance to the nearest city center, district center, neighborhood center, city road, and green scenic site are respectively represented by Dis_city, Dis_distr, Dis_neigh, Dis_road, and Dis_green. City centers are defined as the vital commercial centers of Shenzhen, including Shenzhen Citizen Center, Diwang Tower, Coastal City, and Qianhai Authority. District centers are based on the locations of the ten district governments in Shenzhen. Neighborhood centers are represented by Street Offices, which are subunits of district governments. Better accessibility to centers implies higher land value and a higher likelihood of land development. At the same time, places closer to centers may also be associated with more urban uses and higher potential land leasing revenue for the local government and hence a higher likelihood of state ownership. Better proximity to roads and green scenic sites might also increase land value and promote land development and land ownership conversion.

Neighborhood variables are measured to capture the characteristics of the area surrounding a land parcel. We assume that a parcel is more likely to be developed if surrounding parcels are developed. The neighbors of a land parcel are defined as all parcels located within 200 m of the parcel. To measure the land development level of the neighbors, we calculated the proportion of built-up land within a 200-meter buffer around land parcels in 1996 (BZ_96) and also the proportion of newly developed land within the same buffer between 1996 and 2010 (BZ_New).

We also included a benchmark price (BP) of land parcels in our model. BP is provided by the local government as guidance in assessing the land price. Local governments compute BP based on a formula considering the cost of reclaiming the parcel and its land development potential. BP is a very important reference for the local government to gauge the leasing price of state-owned land; it is also important for land users to gauge the price for trading. High BP usually implies high potential for land development and high cost to claim the land. As a result, BP can implicitly influence the occurrence of land development as well as land ownership conversion. Because BP can be influenced by market-oriented factors, we treat it as a "compound" variable influenced by both location and neighborhood variables. According to studies examining spatial patterns of BP in different cities in China (Wang, 2009), BP closely follows the Alonso model: the closer to the city center the parcel is, the higher will be the land price of the parcel. Thus, we consider BP as a compound index that reflects mostly market factors.

Two dependent variables (endogenous variables), the land ownership conversion variable and the land development status variable, are included as dummy variables. We only extracted data on land that was undeveloped and collective-owned in 1996. "Undeveloped land" in this study means land not developed for urban uses, which includes land for agriculture use or no use. "Developed land" in this study means land that has been developed for urban uses. The land ownership conversion variable equals 1 if the parcel was transferred from collective ownership to state ownership between 1996 and 2010 and equals 0 if it remained in collective ownership. Land development status is equal to 1 if the parcel was converted from undeveloped land to developed land between 1996 and 2010 and 0 if the parcel remained undeveloped. The statistics for each variable are shown in Table 2.

4.3. Sampling and modeling tools

To avoid spatial autocorrelation issues, we implemented a stratified spatial sampling approach. We separated land parcels into two groups: parcels remaining under collective ownership and parcels converted to state ownership by 2010. For each group, we performed a simple spatial sampling. We applied a minimum 200-meter separation distance between samples and randomly sampled 20 % of the data. After these processes, the statistical characteristics of the sample and population were sufficiently comparable to avoid loss of information. Moran's I index[1] showed that our stratified spatial sampling approach reduced spatial autocorrelation in the residuals. The final dataset included 14,875 samples. After performing a collinearity test, we found that the variance inflation factors (VIFs) of all variables were below 4, indicating an absence of severe collinearity problems. Thus, we included all the variables in our model.

The SEM model was implemented in AMOS 24 with the Bayesian method. The Bayesian method assigns a prior distribution to the model and then produces a posterior distribution of the model through the data that reflects a combination of prior beliefs and empirical evidence (Bolstad, 2004). During the estimation, in addition to the original data, AMOS will generate additional samples via Markov chain Monte Carlo estimation to make the posterior distribution converge and produce estimates of the parameters. More samples usually indicate more variability and independence of samples, and as a result, the posterior distribution will be more stable (Arbuckle, 2016). In our model, we assigned a uniform distribution to every parameter so that the data can provide the most information. When the total number of samples reached 35,000, the global convergence statistic was stable at 1.0013, which is lower than the criterion of 1.002. Additionally, as we had standard errors for all coefficients, we performed a z-test for each coefficient and found that all test values were considerably over 1.96 (criterion of normal distribution at $\alpha = 0.05$), indicating that all coefficients were significant.

5. Regression results

5.1. The reciprocal relationships between land development and land ownership

The most important finding of our study is evidence supporting the reciprocal relationship between land development and land ownership. As shown in Fig. 4, land ownership (LO) has a direct impact on land development (LD), which, in turn, influences land ownership. The absolute values of the direct effect between LO and LD are similar to the absolute values of the total effect between the two; thus, we focus on interpreting the direct effect. As shown in Fig. 4 and Table 3, the direct effect from LO to LD is −0.689. The negative direct effect indicates that land parcels that retain their collective ownership, compared to parcels converted to state ownership, are more likely to have been developed. Lower transaction costs and a shorter development cycle may contribute to ease of development in the bottom-up development track.

In addition to confirming the influence of land ownership on land development, our results contribute other new insights. According to our model results, the direct effect from land development (LD) to land ownership (LO) is 0.352. The positive direct effect indicates that if a land parcel remains undeveloped, it is more likely to have remained in the hands of collectives, while if the land underwent land development during our study period, it is more likely that ownership transfer occurred, with the local government acquiring the land. The result supports our hypothesis that collectives are inclined to hold on to their undeveloped land, possibly with the intended purpose of future bottom-up development. However, another possibility that may be propelling the results is that local governments might have shifted away from expropriating undeveloped rural land in favor of acquiring insufficiently developed land for the purpose of redevelopment.

According to Fig. 4, given that the absolute direct effect from LO to LD (−0.689) is larger than the absolute direct effect from LD to LO (0.352), it can be concluded that the negative influence from LO to LD is the dominant force in Shenzhen. Collective ownership has a strong promotional effect on land development, which is slightly offset by the opposite effect of land development on collective ownership.

5.2. The effect of the control variables on LO and LD

In addition to the key variables mentioned above, other interesting findings emerged in relation to control variables, which are discussed below.

5.2.1. The effect of biophysical variables on LD

According to our conceptual framework (shown in Fig. 1), biophysical variables such as land use types, parcel size, and slope should have effects on LD, and our results confirmed such connections. As shown in Table 3, the coefficients for all five land use types are negative, indicating that unused land (the reference group) is more likely to be developed, which could be due to low land development cost and restricted regulations controlling the transfer of agriculture land to construction land. The coefficient of land size is 2.04, indicating that larger parcels are more likely to be developed, which is in line with the current land development trend in China. This is the result of the merging of land parcels with scattered patches; additionally, larger land parcels often have reduced transaction costs by area (Li et al., 2017; Xie et al., 2019). The coefficient of slope (−0.014) is consistent with our expectation: greater slope is associated with lower likelihood of land development. The coefficient for elevation is positive (0.081), which is counterintuitive. Our interpretation is that, in our study area, lands with low elevation are more likely to be swales or coastal lands, which tends to increase construction costs.

5.2.2. The effect of locational variables on LO and LD

Locational variables have effects on both LO and LD that are consistent with our expectations (as illustrated in Fig. 1). The coefficients for Dis_road, Dis_distr, and Dis_neigh are negative, which is consistent with traditional locational theories that better accessibility to roads, green space, district centers, and neighborhood centers corresponds to higher likelihood that land will be developed. However, the Dis_city coefficient for LD is positive. The reason may be that lands close to city centers in Shenzhen were mostly already developed prior to our study period (1996–2010) given that Shenzhen was the first SEZ of China in the 1980s. After 1996, land parcels located at the urban fringe, away from city centers, became more attractive for land development.

Most of the locational variables follow the rule of distance decay,

[1] Moran's I is a statistical index developed by Moran in 1948, commonly used to measure the spatial autocorrelation of spatial data. The formula is as follows: $I = \frac{n * \sum_i^n \sum_j^n w_{ij} * (y_i - \bar{y})(y_i - \bar{y})}{\left(\sum_i^n \sum_j^n w_{ij}\right) * \sum_i^n (y_i - \bar{y})^2}$ .where I is Moran's I index, n is the number of regional units, $y_i$and y_i are the attributes of the i^{th} and j^{th} region, $\bar{y}$ is the average of the attributes of all regions, and W is the spatial weight matrix between the regional units, which is used to measure the neighbor relationship between the i^{th} and j^{th} regions. The value of Moran's I is generally between −1 and 1. Under the original assumption that there is no spatial autocorrelation, the expected value of Moran's I is $E(I) = -1/(n+1)$. Therefore, if Moran's I < E(I), then the spatial relationship is negative, while if Moran's I > E(I), then the spatial relationship is positive. If Moran's I is equal to E(I), then the space is not relevant.

Table 2
Variable Statistics.

Variable	Number	Range	Minimum	Maximum	Mean		Standard Deviation	Skewness		Kurtosis	
					Statistic	Std. Error		Statistic	Std. Error	Statistic	Std. Error
LD	14,875	1.000	0.000	1.000	0.571	0.004	0.495	−0.288	0.020	−1.917	0.040
LO	14,875	1.000	0.000	1.000	0.139	0.003	0.346	2.090	0.020	2.369	0.040
Size	14,875	0.850	0.000	0.850	0.006	0.000	0.015	16.762	0.020	688.020	0.040
Elevation	14,875	407.000	0.000	407.000	35.157	0.215	26.243	1.056	0.020	3.550	0.040
Slope	14,875	41.601	0.000	41.601	3.220	0.027	3.279	3.554	0.020	19.233	0.040
Farm	14,875	1.000	0.000	1.000	0.143	0.003	0.350	2.044	0.020	2.177	0.040
Orchard	14,875	1.000	0.000	1.000	0.193	0.003	0.394	1.559	0.020	0.429	0.040
Forest	14,875	1.000	0.000	1.000	0.192	0.003	0.394	1.562	0.020	0.441	0.040
Grass	14,875	1.000	0.000	1.000	0.009	0.001	0.093	10.557	0.020	109.469	0.040
Water	14,875	1.000	0.000	1.000	0.205	0.003	0.404	1.463	0.020	0.140	0.040
Dis_city	14,875	49.747	1.900	51.647	23.442	0.077	9.416	0.300	0.020	−0.467	0.040
Dis_distr	14,875	33.628	0.055	33.682	8.462	0.044	5.405	1.302	0.020	2.289	0.040
Dis_neigh	14,875	14.108	0.050	14.158	3.279	0.014	1.673	0.880	0.020	1.615	0.040
Dis_road	14,875	5.760	0.000	5.760	0.113	0.002	0.252	11.329	0.020	182.369	0.040
Dis_green	14,875	2.672	0.000	2.672	0.452	0.003	0.385	1.190	0.020	1.642	0.040
BZ_96	14,875	0.995	0.000	0.995	0.192	0.002	0.227	1.219	0.020	0.708	0.040
BZ_New	14,875	1.000	0.000	1.000	0.302	0.002	0.273	0.702	0.020	−0.515	0.040
BP	14,875	1.691	0.839	2.530	1.277	0.002	0.265	1.064	0.020	1.322	0.040

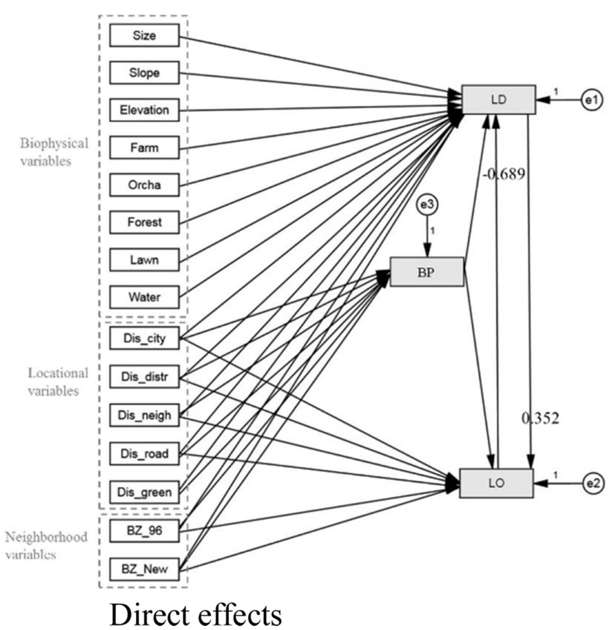

Fig. 4. Diagram of direct effects and total effects among variables.

which indicates that locations closer to centers usually have better accessibility. Lands in these locations are more likely to be developed. However, more centralized lands also have a greater possibility of being developed for urban uses, which indicates that ownership of lands closer to centers is more likely to shift from collectives to the government. The results for most of the locational variables are in agreement with our speculations, with the exception of the results for Dis_city. Thus, land on the "urban fringe," which is far from the city centers, underwent more land development and more land ownership conversion due to the prior government-led land development before 1996. This effect may be more prominent on the city level rather than on the sub-city level, which makes Dis_city an exception.

5.2.3. The effect of neighborhood variables on LO and LD

The level of land development in the neighborhood of the considered land parcels in 1996 and the ratio of newly added land development in the neighborhood between 1996 and 2010 are captured in variable BZ_96 and BZ_new, respectively. The coefficient for BZ_96 is positive, while the coefficient for BZ_new is negative. The results indicate that greater levels of land development in neighborhoods in 1996 (higher ratio of developed land) tended to promote additional land development, while a greater number of land parcels were developed in less developed areas with less competition (lower ratio of newly added development land). The direct effects of BZ_96 and BZ_New on LO (0.023 and 0.010) are consistent with our expectations that neighborhoods that were more developed in 1996 or neighborhoods that saw greater levels of land development during the study period were more likely to be converted to state ownership.

Finally, the benchmark price (BP) is positive for LD (0.240), which indicates that higher land values lead to more active land development. The negative effect from BP to LO (−0.099) reflects that land of lower value tends to be converted to state ownership, possibly due to the lower transaction costs for such land. It also might be because collectives are more likely to retain high-value land compared to low-value land to capture the greater added value of future land development.

Table 3
Estimated Direct Effects and Total Effects.

Coefficients	Direct effect coefficients	S.E.	S.D.	*P*-value	Total effect coefficients	S.E.	S.D.	*P*-value
LO < — > LD								
LO < —LD	0.352	0.001	0.060	< 0.001	0.280	0.001	0.030	< 0.001
LD < —LO	−0.689	0.002	0.110	< 0.001	−0.549	0.001	0.054	< 0.001
LD < —Other variables								
Biophysical variable								
LD < —Size	2.040	0.005	0.330	< 0.001	1.631	0.002	0.133	< 0.001
LD < —Slope	−0.014	0.000	0.002	< 0.001	−0.011	0.000	0.001	< 0.001
LD < —Elevation	0.002	0.000	0.000	< 0.001	0.001	0.000	0.000	< 0.001
LD < —Farm	−0.120	0.000	0.014	< 0.001	−0.096	0.000	0.006	< 0.001
LD < —Orchard	−0.111	0.000	0.013	< 0.001	−0.089	0.000	0.005	< 0.001
LD < —Forest	−0.113	0.000	0.013	< 0.001	−0.091	0.000	0.005	< 0.001
LD < —Water	−0.139	0.000	0.014	< 0.001	−0.111	0.000	0.007	< 0.001
LD < —Lawn	−0.133	0.001	0.048	< 0.001	−0.107	0.000	0.015	< 0.001
Locational variable								
LD < —Dis_road	−0.315	0.000	0.021	< 0.001	−0.268	0.000	0.012	< 0.001
LD < — Dis_green	−0.083	0.000	0.012	< 0.001	−0.081	0.000	0.005	< 0.001
LD < —Dis_city	0.001	0.000	0.001	< 0.001	−0.005	0.000	0.000	< 0.001
LD < —Dis_distr	−0.002	0.000	0.001	< 0.001	0.000	0.000	0.001	< 0.001
LD < —Dis_neigh	−0.028	0.000	0.003	< 0.001	−0.033	0.000	0.002	< 0.001
Neighborhood variable								
LD < —BZ_96	0.009	0.000	0.020	< 0.001	−0.005	0.000	0.013	< 0.001
LD < —BZ_New	−0.023	0.000	0.016	< 0.001	−0.020	0.000	0.011	< 0.001
Compound variable								
LD < —BP	0.240	0.000	0.027	< 0.001	0.248	0.000	0.017	< 0.001
LO < —Other variables								
Locational variable								
LO < —Dis_road	0.041	0.000	0.021	< 0.001	−0.056	0.000	0.012	< 0.001
LO < —Dis_distr	0.000	0.000	0.001	< 0.001	0.001	0.000	0.000	< 0.001
LO < —Dis_city	−0.001	0.000	0.001	< 0.001	−0.001	0.000	0.001	< 0.001
LO < —Dis_neigh	0.003	0.000	0.003	< 0.001	−0.006	0.000	0.002	< 0.001
Neighborhood variable								
LO < —BZ_96	0.023	0.000	0.014	< 0.001	0.021	0.000	0.013	< 0.001
LO < —BZ_New	0.010	0.000	0.012	< 0.001	0.002	0.000	0.011	< 0.001
Compound variable								
LO < —BP	−0.099	0.000	0.023	< 0.001	−0.012	0.000	0.017	< 0.001

6. Discussion and conclusions

The relationship between land ownership and land development is attracting more academic attention. However, relevant quantitative studies are few, and the reciprocal relationship between land ownership and land development is often neglected. Capitalizing on land parcel data from Shenzhen, China, and applying structural equation modeling (SEM), this paper exposes a deeper glimpse of the inherent mechanisms underlying China's land development than can be had with traditional multivariate regressions. Our study adds to existing studies by providing a more comprehensive framework and a new tool for studying the interactive relationship between land ownership and land development, especially within China's unique institutional context. Our results paint a fuller picture of these coupled relationships.

The SEM results demonstrate that collective ownership might have a promotional effect on land development when controlling for other factors. Our theoretical and empirical results are consistent with some of the prior studies (Tong et al., 2018, 2019), but contradictory to others that have suggested collective ownership in China might prohibit or hinder land development due to the accompanying incomplete property rights and limited revenue opportunities of development activities (Deng, 2009; Huang et al., 2017; Lai et al., 2017a,2017b; Lai et al., 2014; Wang and Sun, 2014). We attribute the promotional effect of collective ownership to its lower transaction cost, shorter development cycle, easier negotiation, weaker planning, and looser regulation and supervisions (Lai et al., 2017a,2017b; Song et al., 2008; Zhang et al., 2003). The positive influence of collective ownership on land development facilitates the rapid growth of bottom-up development (Song et al., 2008; Zhang et al., 2003). Our SEM results also suggest state ownership is less active in promoting land development, which could be because the local government is more meticulous – and likewise more conservative – in its land development due to explicit and implicit economic considerations and societal, environmental, and security impacts.

More importantly and interestingly, the result of the paper confirms that the relationships between land ownership and land development are reciprocal: land ownership determines land development outcomes, while the land development status of a land parcel also influences its likelihood of ownership transition. Thus, while collective-owned land is more likely to be developed than state-owned land, developed land is more likely to be acquired by the local government, while on the reciprocal side, undeveloped land tends to remain in the ownership of collectives. This result is consistent with prior studies showing that collectives may be unwilling to transfer their undeveloped land to the local government due to the low compensation calculated based on the original agricultural use of the land (Ding, 2007; Hao et al., 2011; Hui et al., 2013; Qian, 2015); rather, they prefer to hold their undeveloped land for future bottom-up development. Another possible reason behind these results comes from a shift in local governments: as local governments face more obstacles in acquiring collective-owned undeveloped lands, they may shift away from expropriating undeveloped rural land in favor of acquiring insufficiently developed land for the purpose of redevelopment. Several studies have documented governments' new trend of stricter land protection policies and land use plans that move towards sustainable development (Li et al., 2018; Wu and Wang, 2017; Ma and Chiu, 2018).

China's unique dual land ownership system is often criticized for its negative effect on China's urbanization. However, our study highlights the potential positive impacts of this dual system on land development if we can recognize the complex reciprocal relationships and carefully tailor land use policies to the regulation of both top-down and bottom-up land development without jeopardizing the enthusiasm of either local governments or collectives. On the one hand, since collective-owned undeveloped land is much easier to develop than state-owned land when controlling for other conditions, planning and regulation should be emphasized to regulate low-quality bottom-up land development, instead of simply prohibiting such development or allowing unsupervised development. On the other hand, directed by our discovery of the reciprocal effect, albeit small, of land development on land ownership, there is hope that transferring and redeveloping collective-owned built-up land could become a dominant top-down land development method, improving land use efficiency and protecting agricultural and other undeveloped land. As China's land urbanization is happening at an unprecedented speed, our study calls for more scholarly attention on the effects of collective ownership and more tailored policies and strategies that target better management of collective-owned lands.

This study reveals that land development under different ownerships is driven by different dynamic mechanisms, but it does not thoroughly discuss the differences in land-development structures, dynamics, and magnitude of dynamics between the two types of land ownership. Although the experience in Shenzhen may have limitations in terms of its generalizability, the study highlights the complexity of the coupled relationships between land ownership and land development, which could have broader implications for cities in countries with diverse land ownerships and rapid land development. Other potential confounding variables such as urban planning, policies, and social capitals, which are difficult to quantify, are not included in our current study. Considering the complexity of these variables and their relationships with other variables, SEM remains an effective tool for revealing the mechanisms underlying these relationships, which may be the goal of our future work. Other aspects of future works may focus on comparing bottom-up and top-down land development or comparing the experience of Shenzhen with that of other cities, all of which would deepen our understanding of land development, especially in rapidly urbanizing areas.

CRediT authorship contribution statement

De Tong: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Yuxi Yuan:** Methodology, Formal analysis, Data curation, Investigation, Writing - original draft, Writing - review & editing. **Xiaoguang Wang:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing.

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Appendix A. Supplementary data

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