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Telecoupling mechanism of urban land expansion based on transportation accessibility: A case study of transitional Yangtze River economic Belt, China

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ABSTRACT

Several studies have explored the drivers of urban land expansion (ULE), but disregarded the influence of distant spatial effect on ULE at a large regional scale. This study contributed to a tele-coupling relationship framework between spatial spillover of ULE and transportation accessibility to find the influence of distance spatial effect on ULE. Drawing upon land-use remote sensing data from 1990–2015 and transportation network data, this study assessed the relationship between transportation accessibility and ULE, and developed a second-order spatial autoregressive model (SO-SAR) to explore the spatial spillover mechanism of ULE in the Yangtze River Economic Belt (YREB). The results find that ULE exhibits a significantly positive spatial correlation when the connection criterion of accessibility is $2\,h \le hour \le 3\,h$. The SO-SAR model results show that ULE is affected by the historical ULE, which presents a significant path-dependence effect. Moreover, the ULE in most local cities has a weak inhibition on the ULE of the surrounding cities where the connection criterion of accessibility is 1 h. However, the spillover effects of remote city's ULE have a slight positive impact on local ULE due to the improvement of traffic accessibility from 2005 to 2015. In addition, openness, labor flows, institutional hierarchy, and economic structure had a significantly positive effect on ULE during the period 1990–2015 in the YREB. Policy reforms are suggested to encourage the development of integrated transportation and urban land use at a large regional scale in China. Moreover, there is a need for a mindset shift from cities competing competition over land to co-operation between the cities in YREB.

1. Introduction

China has undergone a rapid process of urbanization since implementing the policy of reform and opening-up. The urbanization level has increased from 17.9 % in 1978 to 57.35 % in 2016 and is expected to reach 60 % by 2020 (Xia et al., 2019). This unprecedented urbanization is one of the major causes of land uses and land cover changes (Liu, 2018). Like in many countries, urbanization-meaning industrial, commercial, and residential land use and transportation infrastructures-is the main responsible of urban land use. In China, urban land expansion has outpaced urban population growth in a number of regions with excessive land resource consumption (Wei et al., 2017). Urban land expansion (ULE) is considered to be a direct performance of urbanization. Numerous increased urban population could demand more jobs, housing, and infrastructure construction, which result in extremely urban sprawl (Wei and Ewing, 2018). In this sense, sustainable urban land use is an effective way to promote equitable urbanization and mitigate urban expansion (Liu et al., 2018b; Liu et al., 2014; Wang et al., 2018b). The urban and transport planning strategy of Transit-Oriented Development (TOD) become one of key modes of intensive land use and urban sustainability (Ma et al., 2018; Zhao and Shen, 2018; Li et al., 2019a). The rational spatial distribution of transportation infrastructures, such as transportation network and public facilities, not only reform the urban spatial structure to improve land use efficiency, but also strengthen the spatial spillovers of land use by enhancing transportation accessibility to promote the flows of capital, labor, and knowledge (Huang et al., 2019; Wu et al., 2017). Exploring the spatial interactions of urban land expansion in adjacent cities is important for land use decision makers to launch sustainable land use policy.

The Chinses central government has implemented a serious of land use policies and territorial spatial regulations to achieve urban sustainable development. Whether it is the policies of strict urban construction land quota management or strategic spatial planning, these

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measurements are actively migrating the process of urban expansion. As such, the “increasing versus decreasing balance” land use policy and “muti-plan combinations” spatial regulation has been implemented to promote the integration of balance of urban-rural construction land, protection of ecological environment, and even the alleviation poverty (Long et al., 2012; Zhou et al., 2019; Wu et al., 2018a). However, these policies ignored the impact of externalities generated by economic agglomeration on urban land expansion. The indirect (spillover) effects and spatial patterns of urban landscape from the neighboring areas could influence the land conversion activities and land use decision making (Hui and Liang, 2016; Huang et al., 2019; Wu et al., 2017; Jiao et al., 2018). There is relatively limited studies that have examined the spillover effect and mechanisms of ULE and their implications on sustainable urban land development (Hertel, 2018). Moreover, existing literatures investigated the spatial spillover effect of urban land focusing on traditional econometric analysis (Li and Xiong, 2017; Guastella et al., 2017). Therefore, our study contributes to explore spillovers of ULE from the perspective of spatial econometric based on transportation accessibility. Land use change and spillover effects related to land use leakage may be a new perspective to coordinate the urban expansion and protect farmland, ecological environment, build new quota transaction of construction land among distance cities (Irwin and Bockstael, 2002; Carrion-Flores and Irwin, 2010; Meyfroidt et al., 2013; Lambin and Meyfroidt, 2011).

The sustainable mode of integrating transportation and land-use is the major tool to conduct intensive urban land in order to alleviate ULE. Many studies have been conducted the linkage between transit and land development in many cities in North America and Europe (Ratner and Goetz, 2013; Hurst and West, 2014; Lee and Sener, 2017; Loo and Chen, 2010). Moreover, these studies focused on developed cities where the public transit has been systematically developed. Recently, some literatures engaged on the interaction between TOD and urban expansion, population growth have been conducted in Asian countries (Sung and Oh, 2011; Dzizuddin et al., 2015). However, western-style TOD mode could not necessarily apply to China. Chinese scholars examined the interactions between transport and land use policies in many cities, such as Beijing, Shanghai, Shenzhen, and Urumqi. They mainly focused on urban activity impacts of the urban land-use policies, land use of TOD and urban mobility, impacts of transport network on land conversion (Niu and Li, 2018; Mu and Jong, 2016; Li et al., 2019a; Wang et al., 2019). These previous studies examined the influence of transport on urban land use at the rail station level and specific rail road in a city. A Few studies focused on the role of regional spatial planning for integrated TOD and sustainable land-use at the metropolitan region scale (Ustaoglu et al., 2018; Staricco and Brovarone, 2018; Taki and Maatouk, 2018). Furthermore, the impact of improved accessibility of the systemic transport network on urban land-use is still rare (Moniruzzaman et al., 2017).

Therefore, this research is attempt to build a new spatial econometric model to examine the spillover effect of ULE through considering the impacts of transport accessibility in the Yangtze River Economic Belt (YREB) area. The goals of this study are to (1) establish a conceptual framework to theoretically explain the relationship between transport accessibility, spillovers and urban land expansion after systematically review of related literatures, (2) capture the historical spatial temporal evolution features of urban land and examine the spatial dependence between transport accessibility and ULE, and (3) explore the spillover mechanisms of ULE and some of the major policy implications of the sustainable urban land-use in large regional areas.

2. Analytical framework

2.1. Land use, urban land expansion and transportation development

2.1.1. The mechanism of ULE and spatial spillover effect of land use

In the past, when the related issues of ULE were examined, three mainstreams have been raised which were spatial evolution features of ULE, negative influences of ULE, as well as the mechanism of ULE. First, the spatio-temporal evolution characteristics have been examined by using remote sensing data and Geographic Information System (GIS) technology at the national, regional, and city levels in previous studies (Ye et al., 2013; Xu and Min, 2013; Ji et al., 2001; Liu et al., 2012; Liu and Chen, 2017; Sun and Zhao, 2018). Secondly, negative influences of ULE have been widely accepted as major contradictions in promoting the sustainable land use and socio-economic development, such as cultivated land occupied by ULE, high-quality farmland loss (Wu et al., 2013; Jiang et al., 2012; Zhong et al., 2018; Liu et al., 2015; Song et al., 2015). Thirdly, the underlying determinants of ULE have been examined. It found that urbanization, institutional structures, economic transition, economic growth, population density, neighborhood factor and proximity were the main drivers of ULE (Bai et al., 2012; He et al., 2013; Wei et al., 2017; Li et al., 2015; Li et al., 2018c). Furthermore, there has been substantial spatial heterogeneity in driving forces among different regions and spatial scales. Regionally, economic development and the local government’s strategy for urban economy as the dominant factors for ULE at provincial and regional levels (Zhang et al., 2013; Tan et al., 2014; Sun and Zhao, 2018). At the city level, different cities present different significant potential drives due to local geospatial heterogeneity, such as accessibility (Shu et al., 2014), land fiscal revenue (Shu et al., 2018), planning preparations and profit-seeking (Han, 2010), population density (Xu et al., 2018), and rapid development of infrastructure, intensive industrial parks, and development of urban and rural settlements (Wu and Zhang, 2012). All these previous literatures focused on exploring the mechanism of ULE at the level of single city or macro urban agglomeration. However, regional integration and increasing technological innovation have led to a new flow characteristics at multi-level and multi-scale, including capital flows, resource flows, population flows, and information flow (Steffen et al., 2015; Bai et al., 2016). Taking the national, regional, and urban spatial scales as research objects in isolation, it will be difficult to adapt to the theoretical and practical needs of the study of the interaction between human activities and ULE in the context of rapid cross-level flow of information and materials.

Therefore, scholars introduced urban land teleconnections (ULT) as a conceptual framework that illustrated the process of flows of population, goods and services between remote area and local place, which resulted in changes in local land use (Seto et al., 2012). Subsequently, the concept of ‘Telecoupling’ developed from teleconnections was used in the field of land use change (Friis et al., 2016). Using the concept of telecoupling and sustainable development, scholars examined the evolution process and mechanism of land systems at different spatial scales, such as global urban and rural areas under the telecoupling control of goods supply networks (Friis and Nielsen, 2017; Kastner et al., 2014; Tsai et al., 2018; Meyfroidt et al., 2013; Lambin and Meyfroidt, 2011). They mainly focused on the different single land types, such as agricultural land (Bruckner et al., 2012), grassland and forest (Liu, 2014). However, the impact of telecoupling concept on ULE has rarely been studied. The concept of ULT is only a conceptual framework for classifying and organizing land change related to urban process. Further quantitative study is needed on the extent to which ULE in local place is affected by the ULE in remote-distance areas.

2.1.2. Spatial spillover effect of ULE and transportation development

The relationship between transportation and land use is interactive. Scholars have deemed that land use changes can impact patterns of travel behavior and further influence the spatial distributions of transportation systems. Conversely, transportation system evolution may affect the changes of land use patterns through improving accessibility levels (Shaw and Xin, 2003; Handy, 2005; Yang and Gakenheimer, 2007). However, accessibility measured by the integrated level between land use and transportation, smart growth, sustainable urban expansion and transportation, and urban form

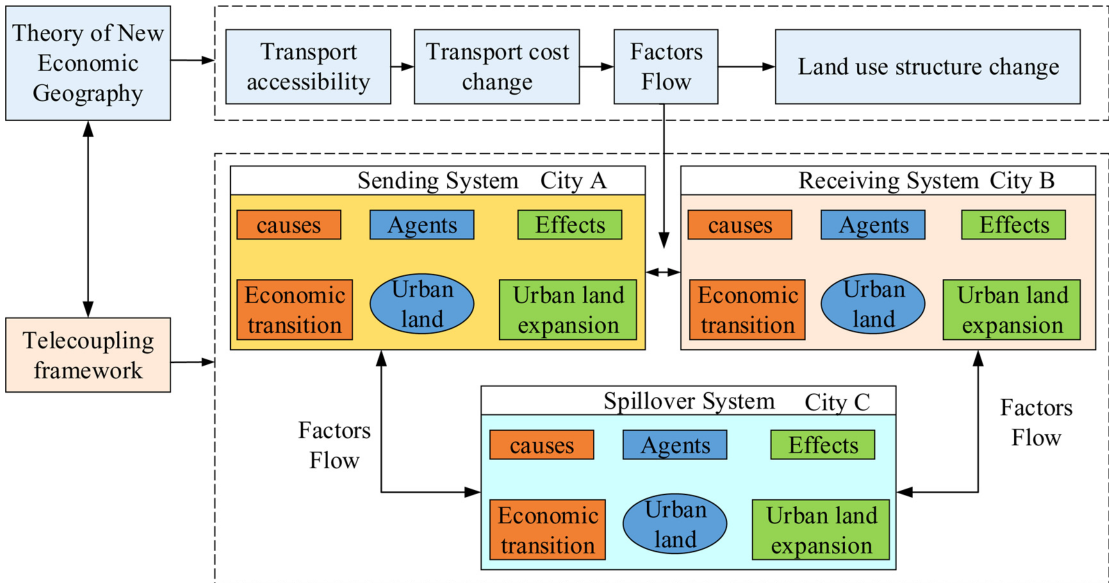

Fig. 1. The framework of telecoupling of urban land expansion.

affected by transportation are an important aspect of land use (Straatemeier, 2008; Zhao, 2011).

In this study, the term of spatial spillover effect of ULE, including the concept of telecoupling of ULE, means the ULE in local place is affected by the ULE of remote-distance cities. Exactly, transportation systems provide mobility for people and goods and is considered one of the main causes of urban growth (Aljoufie et al., 2013). Several studies revealed the relationship between the development of high-speed roads, transportation corridors, subway and population growth and urban expansion (Priemus et al., 2001; Fan et al., 2009; Calvo et al., 2013; Zhao, 2010). These studies have focused on the causes and effects of the relationship between transportation and urban growth, while there is a lack of research on the spatial spillover of ULE of the relationship. Moreover, the object of these existed studies mainly concentrated on single city level. Only a few studies involved the impact of spatial spillover of transportation on urban land efficiency (Cui et al., 2019; Wu et al., 2017). How transportation affects the spillover effects of ULE needs to be further studied.

Spillover effects is one of the main dynamics of transportation accessibility on ULE at regional level with regional integration. With the improvement of transportation accessibility, labors, capital, and technology could freely flow among neighboring regions, resulting in a restructuring of the form of the city-region and the agglomeration economy (Lopez et al., 2009; Carrion-Flores and Irwin, 2010). Recently, few studies considered spatial effects of ULE by embedding transportation accessibility (Wu et al., 2017; Calvo et al., 2013; Chen et al., 2016; Deng and Srinivasan, 2016). The relationship between urban sprawl and proximity explanatory driving factors at regional level is important in understanding the spatial and temporal dynamics of urban sprawl. Regional transportation, such as in the YREB, have been planned to improve the regional coordinated development, which failed to account for the fact that these transportation networks might induce urban sprawl and increase ULE. Scholars measured the sprawl in large cities along the YREB (Yue et al., 2016), but it was insufficient to demonstrate the effects of regional transportation on ULE. In our study, it is assumed that transportation accessibility can influence ULE under the guidance of telecoupling framework. At the same time, we examine the spatial spillover of ULE in YREB through embedding transportation accessibility into telecoupling framework.

2.2. *Theoretical framework*

The telecoupling framework consists of five major interrelated components, i.e., couled human and natural systems, flows, agents, causes, and effects (Liu et al., 2013).

In our framework, sending system (city A) represents a local city, such as the cities in lower reaches in YREB, which export of goods, information, and capital in the process of trade, e.g., regional cooperation and integration, industrial transfer, while receiving system (city B) refers to the remote city, such as the cities in middle reaches in YREB, where it receive the factors from sending system. Causes refer to the reasons that mainly aggravate ULE, e.g., economic transition. The threefold process of economic transition has widely been used to explain land use expansion in China (Li et al., 2015; Wei et al., 2017; Wu et al., 2017; He et al., 2013; Wei, 2001), including marketization (Ho and Lin, 2003; Long et al., 2007; Chen, 2012; Gao et al., 2014), globalization, and administrative decentralization (Lin and Ho, 2005; Long et al., 2012; Xie et al., 2005). Urbanization as another driver of the ULE has been explained by scholars to the economic transition (Lambin and Meyfroidt, 2011; Li et al., 2015). On one hand, increase of non-agricultural land resulted in a boom in township enterprises in rural area due to the land system reforms (Long et al., 2009; Zhu and Guo, 2014; Du et al., 2016). On the other hand, a large proportion of rural population migrated to cities, which accelerated urban growth and industrialization (Deng et al., 2008; Liu et al., 2014).

Effects refer to ULE resulted from social economic transition and telecoupling in our framework. They can be manifested in sending, receiving and spillover systems. The agents are nested within the systems that facilitate or hinder the flows of factors among the systems. The sending or receiving systems contain different agents, including local governments and individuals. These agents amplify or weaken ULE through the interaction across sending, receiving, and spillover systems. Flows are movements of factors, such as information, capital, population, between the different systems in telecoupling. These flows can be intensified by reducing transportation cost (Fig. 1).

3. Materials and methodology

3.1. *Study area*

The YREB in this study includes nine provinces, including Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Sichuan, Yunnan, and

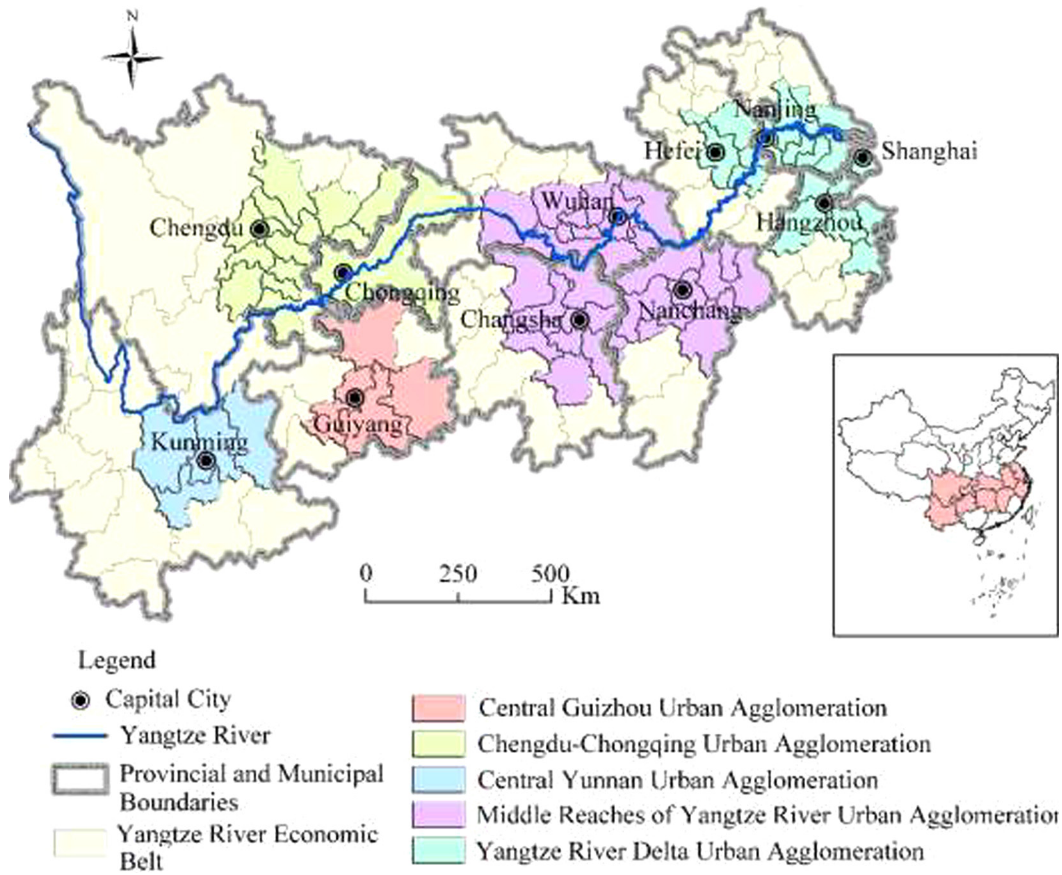

Fig. 2. Location of Yangtze River Economic Belt.

Guizhou, and two municipalities of Shanghai and Chongqing (Fig. 2). This region covers a total area of almost 2.05 million km^2, and holds more than 40 % of the total population and GDP in China. As an important growth pole of the new normal period of China's economy, the YREB also includes the five urban agglomerations, such as Yangtze River Delta (YRD), urban agglomeration in the middle reaches of the Yangtze River and urban agglomeration in the upper reaches of the Yangtze River (including Chengdu-Chongqing urban agglomeration, urban agglomeration in central Guizhou, urban agglomeration in central Yunnan). In order to build a high-quality development belt, the development strategy of YREB must adhere to the coordination of the upper, middle and lower reaches, strengthen the ecological protection and restoration and the construction of an integrated transportation system. However, there are differences in the land development intensity among the upper, middle and lower Yangtze River reaches in YREB. With the process of strengthening regional integration, how to improve the utilization efficiency of urban land and avoid disorderly urban land expansion, which may damage the ecological environment, become one of the challenges in YREB. Therefore, the YREB is selected as a case study to find the spatio-temporal features and mechanisms of urban land expansion when transport accessibility is improved.

3.2. Data collection

This study utilizes three types of data, including land-use remote sensing data, transportation networks data, and social and economic development data for the YREB.

Land-use maps are provided by the Institution of Remote Sensing Applications, Chinese Academy of Science (30-m resolution). This study uses land-use maps from 1990, 2005, and 2015, which were produced by Landsat Thematic Mapper (TM) with the visualization interpretation method. Specifically, Landsat TM data and Landsat 8 were used for the periods of 1990, 2005, and 2015, respectively (Liu et al., 2003). ArcMap GIS version 10.0 (ESRI, Redlands, CA) is used to analyze the land use data. A transition matrix is obtained using this method which represented the quantitative transition between different land use types.

Social and economic development data is derived from The Statistic Book of every province and municipality in the YREB. In addition, some transportation data are also used for accessibility calculation. We revise the traditional weighted matrix with the commuting time cost matrix, which is created with the method of cost-weighting grid algorithm that is defined as a minimum weighted distance of each grid to other grid. The pass speed of different landscape types are needed before calculating the commuting time cost. We classify the study area into land, road, and water areas due to different landscape types with different commuting times. Specifically, the road embracing national road (80 km/h), provincial road (60 km/h), country road (30 km/m), railway (100 km/h) and highway data (120 km/h). These speeds of different types of transportation road are defined according to the criterion of Technical Standard for Highway Engineering of the People's Republic of China (JTGB-2003). In addition, 'land' represents that there is not any transport across the whole region. These transportation road data are collected from the Road Traffic Atlas of China (1990, 2005, 2015), and then digitized using ArcGIS version 10.0.

3.3. Model specification

Several methods have been proposed to explore the determinants of ULE. A majority of the studies have adopted the linear regression model, logistic regression model, unique panel model, and spatial probit model to find the main drivers of ULE (Luo and Wei, 2009; Li et al., 2018c; Deng et al., 2010; Liu and Zhang et al., 2018a). In order to identify the coupling relationship between ULE and migrants, a decoupling model has been used (Liu et al., 2018d). In addition, structural equation model has been employed to examine the impacts of floating population on urban land (Luo et al., 2018). Although all these models could effectively explore the determinants of ULE, spatial neighborhood effect was possibly ignored.

Subsequently, scholars have employed the traditional spatial autoregressive (SAR) model that was autoregressive model of first order, to identify the geographic determinants of the urban landscape changes (Zhang et al., 2013). The autoregressive model of first order only consists a spatial weighted matrix, which is measured by the traditional physical distance (Xu and Lee, 2015). However, with the improvement of transportation network, the actual physical spatial distance is compressed. The commuting time cost is used instead of the traditional weighted matrix. A relevance research is previous work that used an autoregressive model of first order to investigate the effect of accessibility on the urban land efficiency in Yangtze River Delta (Wu et al., 2017). Although traditional SAR models could explain spatial geographic factors, different period effects and spatio-temporal characteristics are ignored. Therefore, scholars developed a second order spatial autoregressive model (SO-SAR) that contained two spatial weighted matrix of spatial lag, e.g., effects of changes of periods, and changes of spatial distance (Ribeiro et al., 2010). Exactly, 'effects' in our telecoupling framework of ULE contains different types of complex effects, including indirect effects, sometimes called 'second-order effects', nonlinearities, time lag, and so on (Liu, et al., 2013). Specifically, the ULE in a local place is not only affected by the direct growth of urban land of itself, but also by the indirect influence from growth of urban land of remote places around it. Thereafter, a second-order SAR (SO-SAR) model was produced based on the first order SAR model through embedding different periods and different spatial units to explore the spatio-temporal mechanism of ULE.

To explore the spatial spillover effects of ULE, spatial-temporal autocorrelation analysis is used to calculate Moran's I index and LISA index. A SO-SAR model is used to investigate the spatio-temporal mechanisms of ULE in the YREB.

3.4. Accessibility

Accessibility is defined as the potential for interaction between geographic locations. The basic transportation accessibility of any location i is defined as follows:

$$A_i = \sum_j g(W_j) f(c_{ij}) \tag{1}$$

where $g(W_j)$ represents the weight W_j of location j and $f(c_{ij})$ is a cost function based on cost c_{ij}, the value of movement from location i to location j. The accessibility indicators have different index measurements based on the different function. Different accessibility indicators, such as Hansen-type accessibility indicator, economic potential indicator, and daily accessibility indicator, can be used to measure accessibility, based on target locations (Ribeiro et al., 2010; Gutiérrez, 2001). In this study, the economic potential which is a gravity-based measure is adopted as the indicator of accessibility. It was widely used in previous accessibility studies (Moyano et al., 2018; Gutiérrez et al., 2010; Kotavaara et al., 2011). The formular is as follows:

$$A_i = \sum_{j=1}^{n} W_j T_{ij}^{-a} \tag{2}$$

where A_i represents the economic potential of location i; a is a parameter reflecting the rate of increase of the friction of distance, which is defined as 1; W_j represents opportunities for social interaction; and T_{ij} is a cost variable which indicates the connectivity criterion between location pair i–j.

3.5. Spatial-temporal proximity autocorrelation analysis

Traditional spatial autocorrelation, sometimes called 'spatial proximity' spatial autocorrelation, refers to correlation of one or two variables across the geographic space, and is known to influence both the coefficients of regression and the inferences made during statistical analyses (Cheng, 2016). In our study, we develop this traditional 'spatial proximity' spatial autocorrelation model to 'spatial-temporal proximity' spatial autocorrelation model through considering commuting time into the concept of proximity. The interdependence of spatial units measured by time distance is not limited to the fact that spatial units must be adjacent or less than a given Manhattan spatial distance. For the calculation of time distance, we intends to use accessibility to represent the shortest time of space access between two places in the traffic network composed of different levels of various transportation modes. We mainly examine the spatial-temporal autocorrelation of ULE between location i and location j. The model of spatial-temporal autocorrelation includes the global Moran's I index which describes the overall spatial interactions among cities in the entire study area. The local LISA cluster map is another index of spatial autocorrelation to test the local spatial heterogeneity existed in variables. The global Moran's I equation is expressed as follows:

$$\mathrm{I}= \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i-\overline{X})(X_j-\overline{X})}{(\sum i \sum_j W_{ij})\sum_i (X_i-\overline{X})^2} \tag{3}$$

where I represents the global Moran's I of ULE. Moran's I ∈(-1,1), when I = 0 and no spatial correlation exists; when -1 < I < 0, areas with different ULE levels are grouped together; when 0 < I < 1, areas with the similar ULE are grouped together; n represents the total amount of study areas; and X_i and X_j represent ULE in location i and j, respectively. W_{ij} represents the spatial weighted matrix. The commuting time cost matrix T_{ij}^* of transportation accessibility was used to replace spatial weighted matrix W_{ij}.

3.6. Construction of second-order spatial autoregressive model (SO-SAR)

The effect of accessibility on a variable of interest can be formulated in Eq. (4). Drawing upon this concept, it is assumed that the determinants of ULE is not only related to its own factors, but also related to the factors in a neighboring area with certain accessibility.

$$\Delta P_i^{0-1} = f(\Delta w_j^{0-1}, \Delta c_{ij}^{0-1}, X_i) \tag{4}$$

Where P is the dependent variable in the unit of analysis i. In this study, this equation corresponds to the temporal evolution of the urban land changes, and therefore, ΔP_i^{0-1} is the changes of urban land between periods 0 and 1; Δw_j^{0-1} is the changes of urban land in location j where location i is linked through the connectivity from periods 0–1; Δc_{ij}^{0-1} represents the cost changes due to the transportation network improvement between location i and j from periods 0–1. X_i is other variables of location i These variables, including urbanization, decentralization, marketization and globalization could affect ULE.

Operationally, a set of concepts can be used as an input into an accessibility model (2) according to the interpretations in formulating (4).

$$\Delta A_i^{0-1} = \theta_1 \Delta w_j^{0-1} c_{ij}^0 + \theta_2 \Delta c_{ij}^{0-1} w_j^1 \tag{5}$$

where ΔA_i^{0-1} is the change in accessibility between the periods 0 and 1. Combining the Eqs. (4) and (5), a new equation is prepared, which demonstrates the impact of accessibility on ULE. P represents the variable W of urban land, as shown below:

$$\Delta P_i^{0-1} = \theta_1 \Delta P_j^{0-1} c_{ij}^0 + \theta_2 \Delta c_{ij}^{0-1} P_j^1 + \beta X_i + \varepsilon_i \tag{6}$$

Since $\Delta P_i^{0-1} = P_i^1 - P_i^0$, formula (6) can be rewritten, as shown below:

$$P_i^1 = \alpha P_i^0 + \theta_1 \Delta P_j^{0-1} c_{ij}^0 + \theta_2 \Delta c_{ij}^{0-1} P_j^1 + \beta X_i + \varepsilon_i \tag{7}$$

In Eq. (7), α, θ_1, θ_2, and β represent the parameters of the model, respectively. ε_i is the random term. P_i^1 and P_i^0 represent the amount of urban land area in location i between periods 1 and 0, respectively. The formula (7) means that ULE in period 1 (P_i^1) not only relates to the scale of ULE in period 0 (P_i^0) and other variables in X_i, but also relates to changes in accessibility due to changes in urban land in locations j linked to i ($\Delta P_j^{0-1} c_{ij}^0$), and accessibility changes because of improved transportation network ($\Delta c_{ij}^{0-1} P_j^1$). This equation can be rewritten in a matrix form, as follows:

$$\mathbf{P}^1 = \alpha \mathbf{P}^0 + \theta_1 \Delta \mathbf{P} \mathbf{T}^0 + \theta_2 \Delta \mathbf{T} \mathbf{P}^1 + \beta \mathbf{X} + \varepsilon \tag{8}$$

Since $\Delta \boldsymbol{P} = \mathbf{P}^1 - \mathbf{P}^0$, and $\Delta \boldsymbol{T} = \mathbf{T}^1 - \mathbf{T}^0$, the Eq. (8) can be reorganized as below:

$$\mathbf{P}^1 = \sigma \mathbf{P}^0 + \theta_1 (\mathbf{P}^1 - \mathbf{P}^0) \mathbf{T}^0 + \theta_2 (\mathbf{T}^1 - \mathbf{T}^0) \mathbf{P}^1 + \beta \mathbf{X} + \varepsilon \tag{9}$$

Further reorganizing the Eq. (9) obtained the final model as below:

$$\mathbf{P}^1 = \rho_1 \mathbf{T}^0 \mathbf{P}^1 + \rho_2 (\mathbf{T}^1 - \mathbf{T}^0) \mathbf{P}^1 + \alpha_1 \mathbf{P}^0 - \alpha_2 \mathbf{T}^0 \mathbf{P}^0 + \beta \mathbf{X} + \varepsilon \tag{10}$$

Eq. (10) is an SO-SAR, including a connectivity matrix of first order T^0 and a matrix $T^1 - T^0$ of second order that reveals the impact of changes in surrounding areas on ULE through accessibility. The formula (10) contains two parts of influences on ULE, on one hand, the ULE is affected by the historical changes of ULE in the past, including the matrix of P^0 and T^0P^0; on the other hand, the ULE also affected by the present changes of ULE under the different accessibility level, including the matrix of $(T^1 - T^0)P^1$, T^0P^1, and other influence factors matrix X. An advantage of this model is that it provides a more dynamic determinant of ULE. Although the SAR has been widely used in several studies that looked at spatial analysis, lesser attention has been paid on the SAR with second order (Ribeiro et al., 2010). T is a spatial weight matrix with the indicator of commuting time cost in accessibility. The details of methods for creating T can be found in our previous work Wu et al. (2017).

3.7. Variables

Table 1 shows the specific meanings and abbreviations of independent and depend variables used in this study. Generally, ULE is measured by the changes of urban land areas, which contains the growth rate (GR) for urban land use (Gao et al., 2014). Following Gao et al. (2014), the rates can be calculated as follows:

$$\mathbf{GR} = \frac{\frac{A_t - A_{t-1}}{A_{t-1}}}{\boldsymbol{T}} \times 100\% \tag{11}$$

where GR represents the urban land change rate (percent); A_t and A_{t-1} are areas of the urban land at the beginning and end of a period; and T is the time interval (years).

Table 1
The variables and its meaning.

Variable	Category	Definition	Abbreviation
Dependent variable	Urban land expansion	Growth rate of urban land	GR
Independent variable	Accessibility	Time accessibility	
Control variable	Globalization	Openness	OPENNESS
		The proportion of foreign direct investment (%)	FDI
	Marketization	Capital flow	CF
		Labor mobility	LM
	Decentralization	Land finance	LF
		Hiarchcy	AH
	Urbanization	Economic structure	ES
		Urbanization rate	UR

In our SO-SAR model (Eq. (10)), other variables X are arranged by economic transition variables in the YREB. We use OPENNESS and foreign direct investment (FDI) to measure globalization. OPENNESS is calculated by the change of rate between export value and gross domestic production (GDP). FDI also is measured by the change of ratio between FDI and GDP. The unit of FDI is converted from USD to RMB to get the comparable ratio.

As for marketization, both capital flows (CF) calculated by the changes of proportion between fixed asset investment and GDP and labor mobility (LM) weighed by the changes of proportion in employees divided by the total population are used to measure marketization.

The land finance (LF), calculated by the proportion of tax revenue that accounts for the budget expenditure, is used as a proxy for decentralization. The greater the proportion, the smaller the demand for LF. In addition, top down administrative allocation of urban land (quotas) has been a special phenomenon in China (Du et al., 2016). Consequently, institutional hierarchy has a significant influence on ULE (Li et al., 2015). Thus, hierarchy (HIERARCHY) is selected as a dummy variable, and is assigned different values for different administrative levels. Specifically, 0 meant that the city is a centrally administered municipality; 1 meant that the city is a capital prefectural city; and 2 represents a generally prefectural city.

Therefore, the urbanization rate (UR), calculated by the proportion of non-agricultural population to the total population, is used as one of indicators to measure urbanization. Economic structure (ES), measured by the ratio between industrial productivity and GDP, is another urbanization's index, reflecting the impact of industrialization on ULE.

4. Results

4.1. Historical changes of ULE in YREB from 1990–2015

During the period from 1990–2015, the urban land area showed an increasing trend in the YREB, increasing by 86 % from 1990 with an area of $4.24 \times 10^4\,\text{km}^2$ to $7.89 \times 10^4\,\text{km}^2$ in 2015. In particular, this trend have accelerated since 2005 because many regional development policies have been issued by Chinese central government and local governments in YREB. In the period from 1990–2005, the average growth rate of built-up land was 27.83 % and subsequently increased to 45.57 % for the period from 2005 to 2015. The built-up land area increased by $36{,}500\,\text{km}^2$ for these two periods in the YREB. Complying with the development policy of YREB, rapid urbanization and mushrooming development zones have intensified the ULE. (Wei, 2015).

We develope two indicators, including changes of urban land areas (CUA) and growth rate of urban land areas (GR), to reflect the changes of ULE. In order to find the spatial heterogeneity of ULE, These two indices representing ULE are mapped (Figs. 3 and 4). In order to investigate the greatest sprawl regions, automatic grading technology in ArcGIS 10.0 is used to classified five degrees (I–V) of CUA. Also, those cities are selected where the GR exceeded 50 %.

Fig. 3 shows that during the period from 1990–2005, the cities of degree I were located at Shanghai, Suzhou, and Ningbo, which belong to the YRD. In addition, 11 cities at degree II were agglomerated in the YRD of the YREB, except for Chongqing and Chengdu, while 11 cities at degree III were situated to the east of the YREB, except Wuhan, Changsha, and Nanchang. The remaining cities with areas less than $127.73\,\text{km}^2$ of CUA were classified as degree IV and V. Thereby, most cities with GR more than 50 % were concentrated in the YRD of eastern YREB and Chengdu-Chongqing agglomeration of western YREB.

During this period, regions in the YRD have experienced a dramatic expansion in urban areas with the open reform policy. Businesses and enterprises enjoyed special privileges of land-use rights in special economic development zones (SEDZs) of coastal China. Accompanied by this change, land-use rights and land ownership were separated, which impacted the land resource allocations. In 1991, land users were

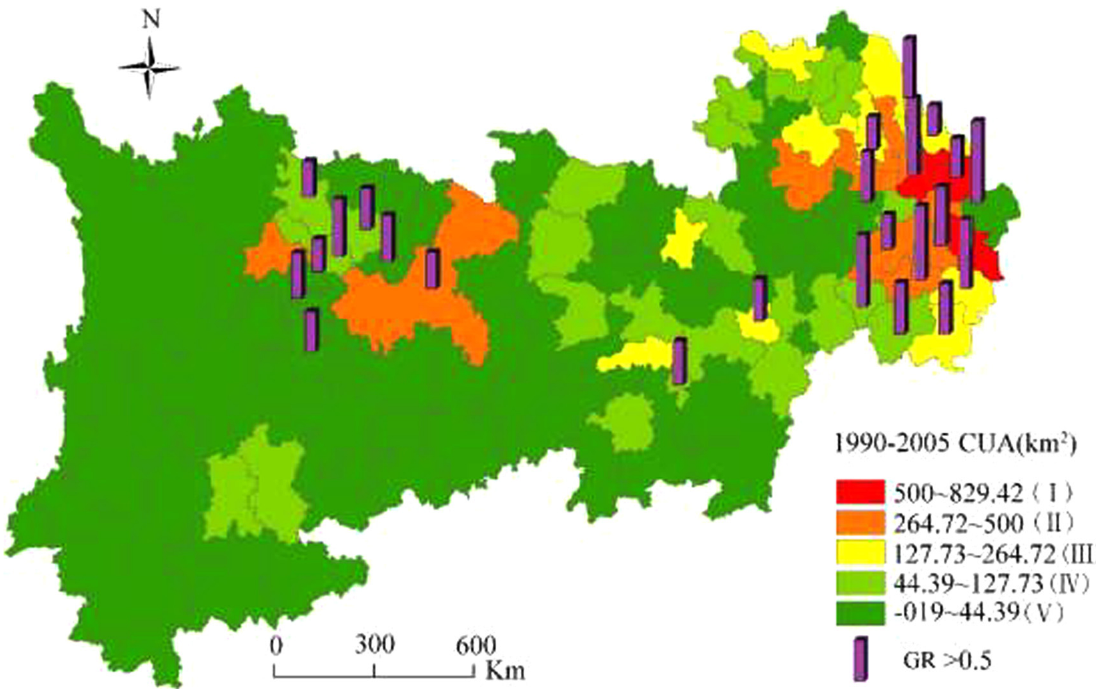

Fig. 3. Spatial distribution of urban land changes from 1990 to 2005.

allowed to let, transfer, rent, and mortgage land-use rights for state-owned land in cities and towns. Post 1991, land-use system policy reform became popular across the country (Ding, 2003; Deng, 2005; Koroso et al., 2013). Therefore, a large amount of foreign companies and private township enterprises rapidly increased in the YRD. Inevitably, urban sprawl has happed with this land marketization reform (Long et al., 2009; Lin and Yi, 2011).

Compared to 1990–2005, the amount of CUA of all cities increased and the patterns of spatial agglomeration of high values spread from east to central region in the YREB during the period 2005 to 2015. A majority of these cities were located in the central and western parts of the YREB, including provinces of Hubei, Hunan, Sichuan, Yunnan, and Guizhou. The GR has rapidly increased compared to the period of 1990–2005. The spatial distribution of these cities, where growth rate was greater than 50 %, showed dynamic characteristics. The GR of urban land has relatively decreased in the east of YREB, while it has drastically increased in the western region of the YREB. These features of ULE are closely related to the regional development strategy in China. In 2006, the state council promulgated several options of promoting the rise of central China, which accelerated the development of these cities along with the main transportation line and the Yangtze River in central China. Followed by this, several programs were

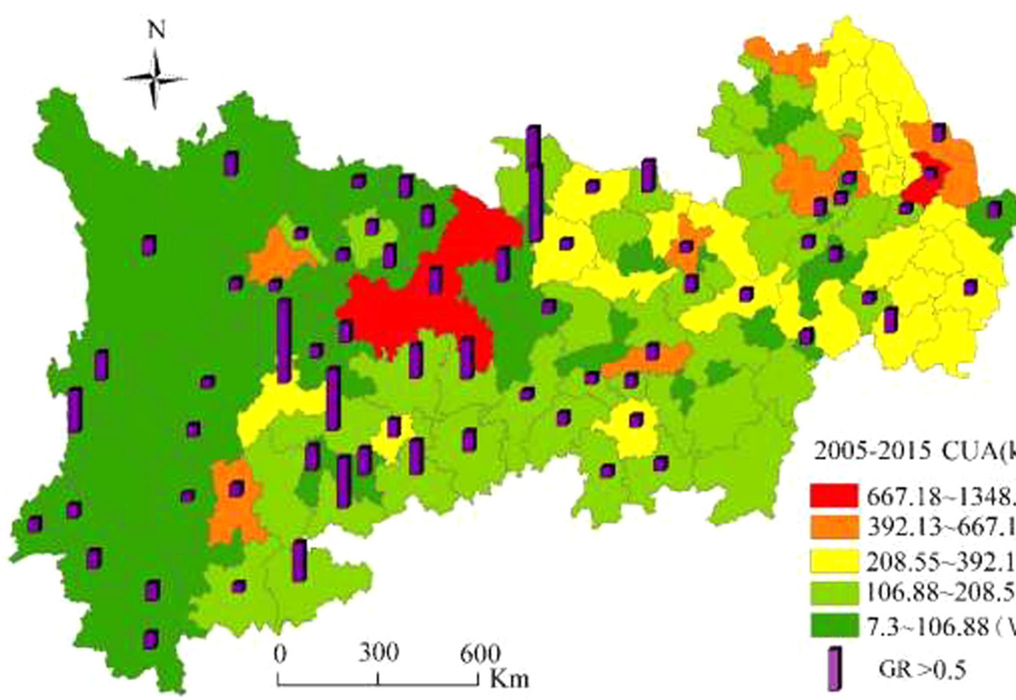

Fig. 4. Spatial distribution of urban land changes from 1990 to 2005.

launched by local governments to promote economic development in the YREB, including further construction of Wuhan agglomeration and Chang-Zhu-Tan agglomeration. Until 2013, China had attached great importance to the development of the YREB, and the regional development strategy of YREB was once again adopted as a national strategy. These economic transition policies have increased urbanization and economic growth, resulting in large-scale ULE.

In order to control ULE, built-up land allocation is strictly controlled by the central government. The policy of "increasing vs. decreasing balance of urban-rural built land" was implemented in a pilot city in 2006 (Liu et al., 2014), which optimized the contradiction between urban- rural land use. Consequently, these measures effectively decreased the amount of urban land, and increased the land use efficiency.

4.2. Spatial effects of urban land expansion based on transportation accessibility

According to the area of each administrative unit in YREB, the minimum value of commuting time is 1 hour (h), which is gradually increased to 5 h in order to observe its dynamic changes. We firstly calculate the spatial weighted matrix with different commuting time value, and then obtain the global Moran's I index and test value (Table 2). The Moran's I value in different periods experience a trend from increase to decrease, indicating that urban land expansion shows spatial agglomeration features. Specifically, the Moran's I value significantly increased from 1990–2015, and reached the maximum value when the accessibility was 2 h and 3 h. It illustrates that the spatial effect of ULE has significant positive spatial correlation between 2 h and 3 h. the ULE in a city is often influenced by the neighboring area's ULE through the improvement of transportation accessibility. Accessibility improvement could change the spatial pattern of urban land, which lead to flowing of the factors of production, for example, labors, capital, and technology. ULE has been intensified by the factors flow, especially adjacent area's formation of urban land and investment behavior. However, this influence weakens as the geographic distance increases. From Table 2, it can be seen that the spatial autocorrelation significantly decreases when accessibility is over 4 h. Because the Moran's I value reaches the peak between 2 h and 3 h, and we further draw the scatter plot to show the degree of spatial distribution of ULE. Fig. 5 shows that scatter plot gradually changes from agglomeration to dispersion along diagonal of the first quadrant, and then gradually agglomeration towards the X axis in the period from 1990–2015. This indicates that the closer the accessibility of the selected related units, the more concentrated the spatial agglomeration or the higher the degree of similarity

4.3. Transportation accessibility dynamics and driving forces of ULE

In this section, the SO-SAR model is employed to explore the underlying determinants in multivariate variables for the two periods. Tables 3 and 4 demonstrate the result of SO-SAR for five models of different accessibility for the two time periods. The spatial dependence value represents the degree of spatial correlation, while all the parameters of R^2 for spatial regressive model show that the model has a good explanation. The parameter ρ_1 represents the spillover influence of remote city's ULE in final year on local city's ULE under the controlling of accessibility in initial year, and parameter ρ_2 represents the spillover effect of remote city's ULE on local city's ULE due to accessibility changes, and parameter α_1 indicates the impact of ULE of local city in the initial year on the ULE in the final year, and parameter α_2 shows the spillover influence of remote city's ULE in the initial year on local city's ULE in the final year under the controlling of accessibility in the initial year. All the parameters of β indicates the effect of other transitional factors on ULE in the final year.

Table 3 shows the results of SO-SAR in the period from 1990–2005, we find that the parameter of the urban land in 1990 (α_1) is positively significant within 3 h, indicating that the ULE in 2005 is affected by ULE in 1990. This results evident that the historical ULE has a significant impact on ULE in the future of a city in YREB. It is partially consistent with the effects of "path dependence" of industries in the YREB (He et al., 2016), resulting in the effects of spatial locking in the ULE. In addition, the parameter of the access to urban land in 1990 (α_2) is positively significant within 5 h. It illustrates that the ULE of some cities of YREB in 2005 has been affected by the ULE of around cities where the accessibility is within 5 h in 1990. We find the spatial spillover effect of ULE existed within a certain space during the period from 1990–2005.

Table 4 shows the results of SO-SAR model in the period of 2005 to 2015. The variable of access growth of urban land (ρ_1) is significantly negative in model 1. Because the administrative units of the study area are large, the level of one hour commute in 2005 is still in the local city, so the results show that the ULE in most local cities has a weak inhibition on the ULE of the surrounding cities. Moreover, the parameter of access changes of travel time (ρ_2) is significantly positive in all models. It indicates that the spillover effects of remote city's ULE have a slight positive impact on local ULE due to the improvement of traffic accessibility from 2005 to 2015. The parameter of access to urban land in 2005 (α_2) is significantly negative for the period from 2005 to 2015. The significantly negative effect of access to urban land in 2005 become more evident as a diffusion feature of ULE became prominent with the improvement of the transportation network. Similarly, the parameter of urban land in 2005 (α_1) is significantly positive for the period from 2005 to 2015. The findings also indicate that the historical ULE in 2005 has an impact on ULE in 2015.

As can be seen in Tables 3 and 4, the determinants of ULE in the YREB are different across different study periods. The historical ULE has an impact on ULE in all period from 1990–2015, indicating the ULE existed path dependence in YREB. Since 2005, although the accessibility has slowed down the ULE in a proximity region, the remote city's ULE has a weak positive spillover effect on local city's ULE with the improvement of accessibility.

Except for the influence of accessibility on ULE, the economic transition process also has substantially affected ULE in the YREB. According to the SO-SAR results, we find that globalization, marketization, decentralization, and urbanization's effect on ULE varied for different time periods. Table 3 shows that globalization had a significantly positive effect on ULE from 1990–2005. Variables of openness levels and the degree of FDI positively influenced ULE at different accessibility connectivity criteria. However, only variable of openness associated with globalization was significantly positive for the period 2005–2015, as shown in Table 4. The results indicate that ULE is the result of a path-dependent process of economic development policy and the reform of land use system (Wang et al., 2018a). With the upsurge of development zones, much more inefficient and scattered industries have participated in new development zones, which strengthened the ULE.

As another important aspect of economic transition, marketization also has a positive significant influence on ULE. The results indicate that of the two variables that represent marketization, only labor flow was significant and only in the case where the connectivity criterion was $T \leq 2$ h for 1990–2005, but the significantly positive influence of

Table 2
The Moran's I value of the urban land use change in different time cost periods.

Moran's I		1h	2 h	3 h	4h	5 h
1990	M value	0.366	0.558	0.500	0.414	0.352
	P value	0.001	0.001	0.001	0.001	0.001
2005	M value	0.234	0.446	0.478	0.458	0.399
	P value	0.001	0.001	0.001	0.001	0.001
2015	M value	0.268	0.397	0.373	0.298	0.251
	P value	0.001	0.001	0.001	0.001	0.001

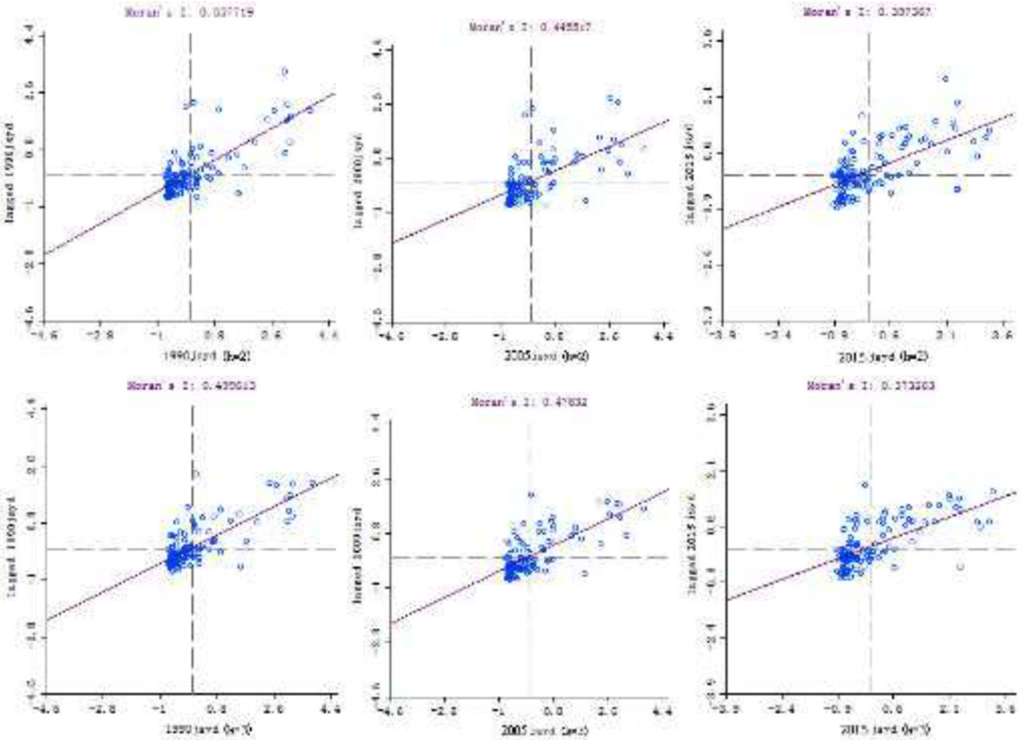

Fig. 5. The Scatter plot of Moran's I of different commuting time during the period from 1990 to 2015spatial effects of urban land use change in different time cost periods.

labor flow became more evident when the connectivity criterion was T ≤ 5 h for 2005–2015. These results illustrate that on one hand, with the rapid process of urbanization, more and more rural labors have migrated to urban areas, pursuing better educational resources and higher wages and benefits, resulting in rising of urban land demand. On the other hand, the Chinese central government has implemented a strategy of "rise of central China" since 2006, after which labors, capital, and advanced technology prospered in central region of the Yangtze River Basin. Thus, industries and urban agglomerations grew, leading to ULE.

Institutional decentralization also has significantly impacted ULE. The Hierarchy variable had positively influenced ULE where the connectivity criterion was T ≤ 5 h for the two periods in the YREB. Although China's economy has been facing transition from a centrally planned to a market economy, the land resource allocation still abides by a top-down control model. Higher ranking cities often have more opportunities to attract foreign investment and benefit from the national land use policy reform, which have enhanced ULE (Liu et al.,

Table 3
The test result of OR-SAR model in 1990-2005.

Variable			Accessibility and economic transition variables				
			1 h	2 h	3 h	4 h	5 h
			Model 1	Model 2	Model 3	Model 4	Model 5
Accessibility	Δ access growth of urban land	ρ_1	−0.013	−0.02	−0.011	−0.001	0.012
	Δ access changes of travel time	ρ_2	−0.001	−0.002	−0.001	−0.002	−0.002
	Access to urban land in 1990	α_2	**0.001****	**0.001****	**0.000****	**0.001****	**0.001****
	Urban land in 1990	α_1	**1.063*****	**1.062*****	**1.061*****	1.06	**1.058*****
Globalization	Δ openness	β_1	**0.014*****	**0.013*****	**0.015*****	**0.015*****	**0.014*****
	Δ Foreign investment	β_2	**0.098*****	**0.097*****	**0.099*****	**0.101*****	**0.104*****
Marketization	Δ capital flow	β_3	−0.001	−0.001	−0.001	−0.001	−0.002
	Δ labor flow	β_4	**0.001***	**0.001***	−0.001	−0.001	−0.001
Decentralization	Δ land finance	β_5	−0.001	−0.001	−0.001	−0.001	−0.001
	hierarchy	β_6	**0.004*****	**0.004*****	**0.005*****	**0.005*****	**0.005*****
Urbanization	Δ economic structure	β_7	**0.005****	**0.005*****	**0.005****	**0.005****	**0.005****
	Δ urbanization rate	β_8	0.003	0.004	0.004	0.003	0.003
	Log-likelihood		469.89	541.34	541.39	541.00	540.63
	R^2		0.99	0.99	0.99	0.99	0.99
	Spatial dependence		1.418	1.545	0.752	0.011	1.186

Note: *** P value < 0.01; ** p value < 0.05; * p value < 0.10.

Table 4
The test result of OR-SAR model in 2005-2015.

Variable			Accessibility and economic transition variables				
			1 h	2 h	3 h	4 h	5 h
			Model 1	Model 2	Model 3	Model 4	Model 5
Accessibility	Δaccess growth of urban land	ρ_1	**−0.09***	0.023	−0.03	−0.022	−0.014
	Δaccess changes of travel time	ρ_2	**0.001*****	**0.001*****	**0.001*****	**0.001*****	**0.001*****
	Access to urban land in 2005	α_2	**−0.001*****	**−0.001*****	**−0.004*****	**−0.001*****	**−0.004*****
	Urban land in 2005	α_1	**1.067*****	**1.053*****	**1.057*****	**1.054*****	**1.055*****
Globalization	Δopenness	β_1	**0.053*****	**0.054*****	**0.054*****	**0.055*****	**0.056*****
	Δ Foreign investment	β_2	−0.002	−0.002	−0.002	−0.002	−0.002
Marketization	Δ capital flow	β_3	−0.002	−0.004	−0.002	−0.002	−0.002
	Δ labor flow	β_4	**0.001***	**0.001***	**0.001*****	**0.001***	**0.001***
Decentralization	Δland finance	β_5	**0.038*****	**0.038*****	**0.041*****	**0.04*****	**0.039*****
	hierarchy	β_6	**0.021*****	**0.022*****	**0.021*****	**0.021*****	**0.021*****
Urbanization	Δeconomic structure	β_7	**0.006***	**0.007***	**0.007****	**0.006***	**0.006***
	Δurbanization rate	β_8	−0.007	−0.008	−0.008	−0.008	−0.008
	Log-likelihood		469.89	406.64	405.8	406.43	406.02
	R^2		0.99	0.97	0.97	0.97	0.97
	Spatial dependence		2.326	0.647	1.907	1.085	0.328

Note: *** P value < 0.01; ** p value < 0.05; * p value < 0.10.

2018c). Interestingly, it was found that the second study period (2005–2015) witnessed an impact of land finance on ULE at all connectivity criterions. As other scholars have argued, decentralization reform increased local governments' reliance on LF and improved the revenue dependence of land leasing (Chen et al., 2017).

In addition to decentralization, urbanization has been recognized as a significant impetus for ULE in the YREB. In our model results, economic structure measured by the proportion of industrial value to total GDP positively affected ULE in the case where the connectivity criteria was T ≤ 5 h between 1990–2005 and 2005 to 2015. The results implied that urbanization accompanied by economic transition upgraded industrial structure, which increased the process of land urbanization, and accelerated ULE. For instance, the cities in the YRD are experiencing ULE mainly characterized by the growth of industrial land (Gao et al., 2015).

5. Discussion

This section highlights the contribution of regional transportation accessibility to ULE, and discusses the implications of regional urban land use policy. The strengths and weaknesses of the proposed methods have also been discussed in this section.

5.1. Contribution of regional transportation accessibility to urban land expansion

The interactions between land use and transportation has been originally derived from studies on resisting urban sprawl in the United States and Europe (Shaw and Xin, 2003; Halden, 2002). Many theories and frameworks, including neo-classical location theory, new economic geography theory, and framework of integrated transportation and land use package (ITLUP), urbanism, modelo de uso de suelo de Santiago (MUSSA) have been used to study the interactions between land use and transportation (Alonso, 1964; Hunt et al., 2005; Huang and Wei, 2014; Krugman, 1991). However, these studies focused on the causes and effects of transportation on land use in urban transportation. With strong further urbanization and regional integration in China, urban land change is not restricted to the core city, but includes many urban regions. Spatial planning was used to try to regulate disorder ULE with the aim of developing sustainable regions (Hersperger et al., 2018). Transit-Oriented development in metropolitan areas has gained considerate priorities in spatial planning strategies towards urban region sustainability (Staricco and Brovarone, 2018; Li et al., 2019a).

The outline of YREB development planning emphasizes the regional guidance of a comprehensively three-dimensional traffic corridor. As a national development strategy in China, this plan will promote the further urbanization and regional cooperation (Liu et al., 2018c). Therefore, our telecoupling urban land conceptual framework assumed that regional transportation accessibility could impact ULE by dividing the effect of accessibility into time and space dimensions in the transitional YREB. This framework discloses the dynamics of ULE in YREB that differed considerably from those of the single cities in terms of the integrated transportation accessibility and land use system. This paper shed lights on how spatial spillover effect of ULE under the control of different regional traffic accessibility during transitional economy in the YREB by considering temporal evolution and geographic neighborhood effect of ULE. The existed urban land teleconnections framework is a process-based conceptualization that intertwines land use and urbanization by linking places through their processes (Seto et al., 2012). Our urban land telecoupling framework is a composite system that combines five components of telecoupling framework with transportation accessibility of new economic geography theory. Therefore, this study's framework contributes the theoretical implications of ULE as follows:

First, to distinguish the spatial spillover effects of ULE in YREB from the perspective of temporal evolution; second, to clarify the spatial agglomeration effects of ULE and show evidence of the significant effect of accessibility on ULE. Furthermore, previous studies on accessibility and urban land use used a statistical description. This study, however, provided new insights from spatio-temporal spatial dynamics. In addition to theoretical implications, our framework also has a practical significance. This framework is applicable in other large-scale urban agglomerations in China, as the construction of transportation infrastructure was widespread during the promotion of coordinated regional development.

Inevitably, there are certain limitations of the conceptual framework. ULE at regional levels is not only influenced by accessibility, but may also be impacted by local policies and local government administrative jurisdictions (Pagliarin, 2018). We hope to explore these issues in our future studies.

5.2. Implications of regional urban land use policy

We also explore the policy implications of our study results, including strengthening intraregional urban land coordination, improving balance between rural and urban built land, and adjustment of urban land use under the economic transition.

First, policy makers should promote complementarity of urban land through strengthening the role of transportation on interregional cooperation and accelerating regional integration development in the YREB. Our study find that ULE in YREB is not only related to the historical amount of urban land at a unit, but also related to the influences of ULE from some proximity areas. Moreover, the changes of transportation accessibility would slightly affect the ULE within a certain spatial range. Therefore, policy makers should focus on the Transit-Oriented Development (TOD) and public transportation accessibility in large regional scale for urban land sustainability (Papa and Bertolini, 2015; Zhao et al., 2018). Although the total amount of built-up land has been allocated according to top-down indicator's quota from the central to the local government, the urban expansion in China is uneven (Long et al., 2018; Wei and Ewing, 2018). Moreover, this quota system failed to prevent urban expansion from encroaching farmland and other land types (Yue et al., 2016; Zhong et al., 2017). However, the YREB region is the epitome of China, which includes various ranking cities with economic inequality and urban agglomeration with different land intensities. This region not only has a great potential for economic development, but also faces a big challenge of protecting the ecological environment (Luo et al., 2019; Liu et al., 2018a). This situation calls for innovative policies for regional land resource allocation. For example, cross-regional urban land quota trading between developed units and undeveloped areas. This approach requires further studies to examine the effect of regional integration on ULE.

Second, regional land management should also pay attention to controlling ULE due to rural land remediation during the process of urbanization. In order to prevent ULE, strict policies have been implemented for protecting arable land in China, such as 'increasing vs. decreasing balance of urban-rural built land' and 'requisition-compensation balance of arable land'(Zhou et al., 2019; Huang et al., 2014). In 2017, the 19th National Congress of the Communist Party of China proposed a strategy for rural revitalization in the 'new normal' China. At the same time, rural land system reform was comprehensively advanced to support rural revitalization (Li et al., 2018a; Liu, 2018; Li et al., 2018b). Correspondingly, rural land acquisition, marketization of profitable collective constructive land, and reform of rural homestead system were proposed again (Gao et al., 2020; Zhou et al., 2020), which would enhance urbanization and release potential of rural land circulation. However, in recent years, urbanization has attracted numerous rural migrants to work and live in urban areas, resulting in ULE (Wu et al., 2018b; Wu et al., 2018c). The results of this study have shown that improved transportation network accelerated labor flow between rural and urban in YREB. These findings show that improved management of urban-rural integration development, such as regulating residential land leasing and reforming household registration system, and promoting in-situ urbanization should be considered.

Third, urban land management policy should focus on the new situation and policy-oriented development strategy in the current transitional period. China has entered a transformational period of the 'new normal' of its economy, which refers to an economy that has adjusted economic structure, speed of economic growth, and entered an innovation-driven growth model (Yang et al., 2018; Liu et al., 2018b). As an important transitional policy, the structural reform of the supply side is issued to promote the adjustment of stocks (Woo, 2019; Li et al., 2019b). Therefore, the Ministry of Land and Resources (MLR) of China propose that the cities must control the total amount of built-up land and strictly control the scale at which built-up land is added in megacities (Liu et al., 2018a). Namely, it requires revitalizing the stock of built-up land and, in principle, not adding built-up land quotas and implementing zero growth in urban built-up land. For example, the Shanghai Urban Master Plan (2017–2035) proposes to maintain a negative growth in the total scale of planning and built-up land use. In these findings, openness to the outside world, FDI, and economic structure were significantly positive drivers of ULE in the YREB. Therefore, it is suggested that policy makers should strengthen the structural reform of supply side of urban land.

5.3. potential uses and limitations of the proposed method

Compared with the traditional SAR, the SO-SAR model offers new insights into the dynamics of ULE and yields an additional perspective of the relationship between regional transportation accessibility and ULE. Moreover, economic transition framework as an important control variable is embedded into our model to provide multidimensional measurements of ULE. Previous economic transition frameworks have explained the mechanism of ULE with econometric models that neglected temporal and spatial influences (Gao et al., 2014; Li et al., 2015). Considering that the method proposed in this study has been used for the first time in the field of ULE, the relationship between accessibility and economic development has also been examined by this method. With the advancement of economic globalization and economic integration, this method will be applied in similar research.

However, the proposed method has its own limitations. First, the raster data used in this study has been calculated using the administrative area boundary, which might lead to a reduction in grid volume. The urban land area expansion should be studied in the future at the grid level to improve the assessment. Second, the threshold of connectivity criterion was set according to the accessibility calculated by the daily accessibility in this study, which only considered the travel behavior in a day. However, the western part of YREB is situated far away from the eastern part, and this result may uncover the western region's influence on ULE. In future studies, the ULE features in different urban agglomeration in the YREB will be explored, considering the geographic heterogeneity. Third, in addition to the control variables of economic transition, there are other factors that may have an impact on ULE, such as terrain, cultural difference, and population. All these potential factors will be examined in future studies.

6. Conclusion

This study analyzes the mechanism of spatial spillover of ULE by proposing a telecoupling conceptual framework and developing a SO-SAR model from 1990–2015 in YREB. This study establishes indicator systems to investigate the changes of urban land among 127 cities in the YERB during different time periods. The results show that urban land increased rapidly from 1990–2015, and presented a characteristics of spatial heterogeneity. Specifically, the amount of built-up areas increased by 36,500 km^2 from 1990–2015 in the YREB. The average growth rate of built-up land was 27.83 % for the period 1990–2005; this rate rose to 45.57 % for the period of 2005 to 2015. However, the spatial distribution of ULE varied across the two periods. The cities with the fastest urban expansion were located in the YRD in 1990 and spreaded to the midwest with accelerated expansion during the period 2005 to 2015.

This study uses spatial-temporal autoregressive model to visualize and compare the spatial relationship between ULE and accessibility changes, and found that a close spatial relationship exists between ULE and accessibility. The results suggested that ULE had a spatial agglomeration features. Moreover, the spatial effect of ULE had a significantly positive spatial correlation when the connection criterion of accessibility was $2\,h \le h \le 3\,h$.

The SO-SAR model results suggest that the influence of traffic accessibility on ULE is significantly positive only for the period 2005–2015, and for the all accessibility connectivity criteria. It illustrates that the improvement of accessibility could slight accelerate ULE in some cities in YREB. These findings also indicate that the impact of accessibility on ULE not only exists in proximity areas, but also in a spatial remote cities. In addition, ULE has a spatial agglomeration effect, which shows an increasing trend at first but decreased when accessibility is improved. Furthermore, it is found that ULE has a significant path-dependence effect. The historical location of ULE is found to affect the orientation of ULE in a new location.

In addition, the economic transition factors have a significantly positive impact on ULE. Globalization, marketization, decentralization, and urbanization have significantly influence the ULE. However, only variables of openness, labor flows, hierarchy, and economic structure have a significantly positive effect on ULE during the period 1990–2015. FDI is an important positive driver of ULE from 1990–2005, but this variable become non-significant during the second time period. Interestingly, LF is significantly positive on ULE for period from 2005 to 2015. It is suggested that integrated transportation and urban land use at regional level should be focused during the future development in YREB. Policy makers and local governments should actively push forward regional integration and structural reform at the supply side to guide population migration and optimize land resources.

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CRediT authorship contribution statement

Changyan Wu: Conceptualization, Writing - original draft, Writing - review & editing, Data curation. **Xianjin Huang:** Project administration, Supervision. **Bowen Chen:** Methodology, Visualization, Investigation.

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