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The impact of transport development on construction land use efficiency of shrinking cities in China

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Abstract. With the development of China's urbanization process, vacant land has become a critical issue in shrinking cities. Based on the panel data of 28 shrinking cities in China from 2006 to 2018, the impact of transport development (including transport investment and transport mobility) on construction land use efficiency (CLUE) was analyzed in this study. The results show that transport mobility plays a greater role than transport investment in improving CLUE of shrinking cities. Specifically, the increase of transport investment and transport mobility per unit will increase CLUE of shrinking cities by 0.01 and 0.1, respectively. Then, the shrinking cities are divided into three types, which include resource-based cities, post-industrial cities and less-developed cities. We find that transport development has the most significant impact on CLUE of less-developed cities while having no significant impact on resource-based cities. Finally, the results based on the mediating effect model show that the change of land use structure is the main mediating variable through which transport development affected CLUE of shrinking cities.

1 Introduction

Urban shrinkage, mainly manifested in population loss and land vacancy, has become a major challenge for sustainable development in many developing countries [1]. As Liu et al. (2020) revealed, about 20% of the 269 prefecture-level cities in China experienced urban shrinkage in multiple dimensions between 2000 and 2010 [2]. Ma (2010) also found that 40% of China's urban construction land is in a state of inefficient use [3]. Hence, improving construction land use efficiency (CLUE) has become an important issue for the sustainable development of shrinking cities.

More importantly, increasing studies have pointed out that the demand for construction land may be reduced due to the loss of urban population [4]. Li et al. (2020) found that high-speed rail service can effectively promote labor mobility in the condition of a relatively high population density of a region [5]. As a result, for shrinking cities experiencing population loss, transport investment may cause a waste of resources to some extent, which is not conducive to the improvement of CLUE.

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The purpose of this study is to make an empirical evaluation on the impact of transport development on CLUE of shrinking cities. Firstly, the stochastic frontier production function was adopted to estimate CLUE of shrinking cities. Then, the impacts of transport development on CLUE were investigated. We also evaluate on the impact of transport development on CLUE for different types of shrinking cities. Finally, we explored the mechanism by which transport development affects CLUE of shrinking cities, with the mediation effect model for examination.

2 Literature review and theoretical mechanism

2.1 Literature review

Urban shrinkage refers to the phenomenon of urban population loss and land vacancy caused by some economic, political and social reasons, which has become an important topic in geography and urban studies [6]. Schilling & Logan (2008) defined a shrinking city as the old industrial city whose population decreased by more than 25% in the past 40 years [7]. More importantly, land vacancy has become the major challenge to the sustainable development of shrinking cities. Due to the loss of population, a large number of houses and factories have been abandoned. These vacant lands are called “non-productive space” by Newman & Kim (2017) [8].

In order to solve the problem of inefficiency of land use in shrinking cities, some scholars have put forward various strategies. As suggested by Schilling & Logan (2008), the vacant land in shrinking cities can be utilized in many ways, which includes the improvement of road system and the expansion of cyclist routes [7]. Pallagst et al. (2017) emphasized the role of right-sizing and urban agriculture [9].

However, few scholars have examined the impact of transport development on CLUE of shrinking cities. In terms of shrinking cities, the demand for construction land reduces with the loss of population. The development of transportation can not only enhance labor mobility but also promote industrial agglomeration and improve urban attraction [10]. In addition, transportation infrastructure plays a significant role in promoting urban land use structure change [11].

2.2 Theoretical mechanism

To better identify the relationship between transport development and CLUE of shrinking cities, a conceptual framework is proposed based on the study of Chen et al. (2020) [11], as shown in Figure 1. Transport is embodied as visible infrastructure (including roads, railways and waterways), which depends on transport investment and transport mobility [12]. On one hand, transport investment is an important part of public financial expenditure. On the other hand, transport mobility is the basic condition for production factors to move from one location to another.

The impacts of transport development on CLUE of shrinking cities are explored mainly through two channels: (1) Direct land use effect. The increase of transport lines and stations will promote urban construction land use. (2) Indirect land use effect. Transport development will also bring about some changes in urban land use structure, including real estate development, increase in commercial and industrial land uses, and increase in land use for other purposes, such as logistics storage land, public facilities land, green space and square land [11].

This study introduces the term “efficiency” to measure the output benefit per unit land area, which reflects the input-output relationship between production factors and economic output. In the case of constant input factors, the greater the output per unit land area, the higher the land use efficiency. The improvement of transportation infrastructure can reduce transportation costs and promote the reallocation of land resources. As a result, the CLUE of shrinking cities may be affected.

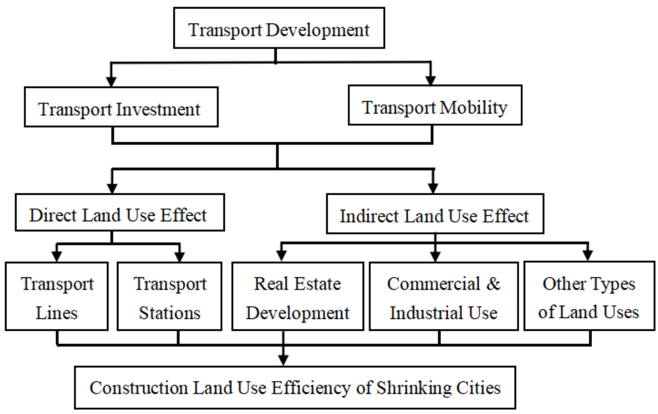

Fig. 1. Theoretical framework for evaluating the relationship between transport development and CLUE of shrinking cities.

3 Shrinking cities in China

3.1 Types of shrinking cities

Population loss is a typical feature of shrinking cities [1]. In this study, the data of permanent population in the urban district is used to measure the population change of a city. According to the National Bureau of Statistics of China, the total urban population of China had increased by 138.8 million from 2006 to 2018, while 28 out of 285 prefecture-level cities had experienced some degree of permanent population loss during this period. Then, we divided these shrinking cities in China into three types and conducted a case study to support our opinion.

3.1.1 Resource-based cities

Historically, many shrinking cities were located in industrial and mining areas. Due to the overexploitation of coal, oil and other resources, the local ecological environment was seriously damaged. These factors caused the continuous outflow of the labor force, thus forming a shrinking city. Pingxiang was one of the largest coal producers in China in the 1950s. According to Bureau of Statistics of Pingxiang, the coal industry here provided 120,000 jobs in 1995 and only 26,000 jobs in 2007. Overall, the depletion of coal resources has led to a decline in employment.

3.1.2 Post-industrial cities

The concept of “shrinking city” was originally proposed by Häußermann & Siebel (1988) [13], mainly referring to the cities with population loss and economic decline caused by deindustrialization in Germany. In addition, in the process of manufacturing transformation and upgrading, the use of automatic machines greatly reduces labor input. A typical example is Benxi city. The iron and steel industry was once the pillar industry of Benxi and occupied a dominant position in economic development. Due to industrial transformation, the permanent population in the urban district of Benxi has gradually declined.

3.1.3 Less-developed cities

In the context of China, the phenomenon of population loss often occurred in the less-developed cities [2]. Due to the improvement of the transportation network and business environment, the attraction of core cities to labor is increasing. In order to increase income, some residents who live in the less-developed regions prefer to migrate to the developed regions [10]. Zhanjiang, as a less-developed city in southern China. Owing to its disadvantaged living conditions, Zhanjiang has been experienced a huge loss of population.

3.2 CLUE of shrinking cities

The stochastic frontier production function is adopted to estimate CLUE of shrinking cities. The formula is as follows:

$$Y_{\mathrm{it}} = f(x_{it}, t)e^{v_{it} - \mu_{it}} \tag{1}$$

where Y_{it} represents the output factor, which is the output value of secondary and tertiary industries. x_{it} represents the input factors, which includes capital, labor and land. v_{it} is the random error term, and μ_{it} is the technical inefficiency term.

$$x_{it} = K_{it}^{\alpha_1} L_{it}^{\alpha_2} S_{it}^{\alpha_3} \tag{2}$$

where K_{it} represents capital input, which is the capital stock of city i. L_{it} represents labor input, which is the number of employees in the secondary and tertiary industries of city i. S_{it} represents land input, which is expressed by the construction land area of city i. $\alpha_1, \alpha_2, \alpha_3$ represent the elasticity coefficient of the output of capital, labor and land, respectively.

Assuming that the scale return of the factors remains unchanged and $\alpha_1 + \alpha_2 + \alpha_3 = 1$, then, the stochastic frontier production function in the form of unit construction land area can be expressed as:

$$y_{\mathrm{it}} = f(k_{it}^{\alpha_1} l_{it}^{\alpha_2}, t)e^{v_{it} - \mu_{it}} \tag{3}$$

Taking the natural logarithms on both sides of the equation (3), the result is as follows:

$$\ln y_{it} = \alpha_0 + \alpha_1 \ln k_{it} + \alpha_2 \ln l_{it} + \alpha_4 t - \mu_{it} + v_{it} \tag{4}$$

where y_{it} represents the economic output of unit construction land. k_{it} represents the capital investment of unit construction land. l_{it} represents the labor input of unit construction land.

Using Frontier 4.1 software, the estimated coefficients of equation (4) were obtained. Next, the CLUE can be obtained by the following formula:

$$TE_{it} = \exp(-u_{it}) \tag{5}$$

$$CLUE_{it} = TE_{it} \exp(\alpha_0 + \alpha_3 t) \tag{6}$$

In Equation (5), TE_{it} is the ratio of actual output to frontier output [5]. In Equation (6), $CLUE_{it}$ represents the construction land use efficiency of city i in year t.

4 Model, variable and data

4.1 Model specification

Based on the panel data of 28 shrinking cities in China from 2006 to 2018, the basic model is set as follows:

$$\ln CLUE_{it} = \beta_0 + \beta_1 \ln Transport_{it} + \delta_1 Z_{it} + \mu_i + \varepsilon_{it} \tag{7}$$

Where $CLUE_{it}$ denotes construction land use efficiency of the shrinking city i in year t. $Transport_{it}$ denotes the transport development of shrinking city i in year t, including transport investment (TRI_{it}) and transport mobility (TRM_{it}). Parameter β_1 reflects the impact of transport development on CLUE. Z_{it} represents control variables. μ_i represents urban fixed effect, ε_{it} represents a random error term.

Furthermore, the impact mechanism of transport development on CLUE of shrinking cities is investigated. Based on the mediation effect model proposed by Baron & Kenny (1986) [14], the sequential recursive model can be specified as follows:

$$\begin{cases} \ln CLUE_{it} = \beta_0 + \beta_1 \ln Transport_{it} + \delta_1 Z_{it} + \mu_i + \varepsilon_{it} \\ \ln Equilibrium_{it} = c_0 + c_1 \ln Transport_{it} + \delta_2 Z_{it} + \mu_i + \varepsilon_{it} \\ \ln CLUE_{it} = d_0 + d_1 \ln Transport_{it} + d_2 \ln Equilibrium_{it} + \delta_3 Z_{it} + \mu_i + \varepsilon_{it} \end{cases} \tag{8}$$

The first step is to examine the total impact of transport development on CLUE of shrinking cities, where the coefficient β_1 denotes the value of total impact. The second step is to examine the impact of explanatory variables on mediating variables, $Equilibrium_{it}$ represents the mediating variable. If the coefficient c_1 is statistically significant, it means that transport development has explained the variation of $Equilibrium_{it}$. The third step is to examine the impact of the mediating variable on CLUE of shrinking cities. If coefficients d_1 and d_2 are statistically significant and the value of d_1 is lower than β_1, it indicates that there exists a certain degree of mediating effect, i.e., transport development has both direct and indirect effects on CLUE of shrinking cities. If d_1 is statistically insignificant, while β_1 is still significant, it indicates that $Equilibrium_{it}$ plays a full mediating role in the impact mechanism of transport development on CLUE of shrinking cities.

Following Chen et al. (2020)'s approach [11], the entropy balance index ($Equilibrium_{it}$) was adopted to measure the structural changes of construction land use of shrinking cities, $Equilibrium_{it} \in [0,1]$. The higher the entropy balance index, the lower the difference of various land use areas and the more balanced the land use structure. The formula of the entropy balance index is as follows:

$$Equilibrium_{it} = H_{it} / H_{max} \tag{9}$$

$$H_{it} = -\sum_{i=1}^{m} P_{ijt} \ln P_{ijt} \tag{10}$$

$$H_{max} = \ln m \tag{11}$$

In Equation (10), H_{it} is the information entropy of city i in year t, which reflects the level of land diversification. P_{ijt} denotes the share of land use type j of city i in year t. In Equation (11), H_{max} is the maximum value of information entropy, m represents the number of land use types. In this study, construction land includes residential land, public facilities land, industrial land, storage land, road transport land, municipal public facilities land and green space and square land. Hence, m = 7.

4.2 Variable selection

Following He et al. (2019) [12], the transport development of a city can be divided into investment level and mobility level.

Transport Investment. Some scholars adopted the fixed asset investment of transport infrastructure to measure the level of transport investment [15]. In this study, the fixed asset investment of roads and bridges was used to reflect the transport investment level of shrinking cities.

Transport Mobility. Mobility is the basic characteristic of transportation, which has an important impact on regional economic development. Given that factor flow mainly depends on walking or mechanical transportation, the number of buses and trams per 10,000 people was used to reflect transport mobility level of shrinking cities.

In order to control for the influence of other factors on CLUE of shrinking cities, four control variables were adopted.

FDI reflects the impact of foreign direct investment on CLUE, which is measured by FDI per capita. **Gov** reflects the government service level, which is measured by the proportion of government fiscal expenditure in GDP. **Pop** represents the level of population agglomeration, which is measured by the number of people per unit land area. **Marketization** represents the marketization degree of land transfer, which is measured by the proportion of land transferred in the form of bidding, auction and listing in all transferred land[1]. The higher the value of Marketization, the higher the allocation efficiency of land resources [16].

4.3 Data source

Based on the panel data of 28 shrinking cities in China, the impacts of transport development on CLUE are discussed. The period of investigation is from 2006 to 2018, and the statistical analyses were performed using Stata software, version 16.0. The data of these variables were derived from the *China Urban Construction Statistical Yearbook* and the *China Urban Statistical Yearbook*. All non-percentile variables are converted in the logarithmic form to reduce the influence of heteroscedasticity. Table 1 presents the descriptive statistics of various variables.

5 Results and discussions

5.1 Baseline regression

Firstly, we estimate Equation 7 to test the impact of transport development on CLUE of shrinking cities. As shown in Table 2, Columns (1) and (2) are the estimation results based on total samples. It can be found that transport development has a positive impact on CLUE of shrinking cities. Specifically, Column (2) shows that the increase of transport mobility ($\ln TRM$) per unit will improve CLUE of shrinking cities by 0.1, which is much greater than the coefficient (0.011) of transport investment ($\ln TRI$).

Then, the impacts of transport development on different types of shrinking cities were investigated. According to Columns (3) and (4), the impact of transport investment on CLUE of resource-based cities is not statistically significant, and neither is the coefficient of

[1] Land transfer refers to the state that a government transfers the land use right to the land user within a certain period of time, and the land user must pay the land transfer fee to the government. In China, there are four forms of land transfer: bidding, auction, listing and agreement.

transport mobility. The results of Column (5) suggest that transport investment has no impact on CLUE of post-industrial cities. In contrast, Column (6) shows that every 1% increase in transport mobility is associated with an increase in the CLUE of post-industrial cities by 0.178%. In terms of less-developed cities, Columns (7) and (8) show that when the transport investment and transport mobility increase by 1%, the CLUE of less-developed cities increases by 0.017% and 0.092%, respectively. In short, the impacts of transport development on CLUE were found to vary among types of shrinking cities.

Table 1. Descriptive statistics.

Variable	Definition	Mean	Std. Dev.	Min	Max
CLUE	Construction land use efficiency	7.12	3.06	1.13	22.89
TRI	Fixed-asset investment in roads and Bridges	1979.24	4345.96	0.18	49780.22
TRM	The number of buses, cars and trams per 10,000 people	7.86	6.84	0.32	110.52
Equilibrium	The entropy balance index of construction land use	0.84	0.06	0.16	0.95
FDI	FDI per capita	698.06	851.41	9.29	7056.28
Gov	Share of general fiscal expenditure in GDP	0.18	0.09	0.04	0.58
Pop	Population per unit of land area	318.53	272.60	35.06	903.95
Marketization	Marketization degree of land leasing	0.66	0.24	0.02	1

Table 2. Baseline regression results.

Variable	All shrinking cities		Resource-based cities		Post-industrial cities		Less-developed cities	
	1	2	3	4	5	6	7	8
lnTRI	0.011** (2.19)		-0.015 (-1.40)		0.007 (1.10)		0.017** (2.07)	
lnTRM		0.100*** (5.48)		0.005 (0.11)		0.178*** (6.99)		0.092*** (3.06)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.164 (-0.32)	-0.408 (-0.82)	3.558*** (2.71)	3.475** (2.39)	-0.416 (-0.59)	-0.883 (-1.44)	-0.783 (-1.12)	-0.494 (-0.74)
Hausman Test	55.10	44.38	19.50	20.51	66.96	71.22	55.39	56.61
Effect	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
No.of obs.	364	364	130	130	156	156	78	78
R-squared	0.656	0.680	0.790	0.786	0.691	0.769	0.664	0.687

Note: t statistics in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

5.2 Meditating effect regression

In this section, we explored the mechanism by which transport development affects CLUE of shrinking cities. Table 3 shows the results of meditating effect regression of Equations 8.

In Column (1), it can be found that when the transport investment increases by 1%, the entropy balance index of shrinking cities will increase by 0.005%. In Column (2), it can be found that the coefficient of transport investment is still significantly positive at the 5% significance level and its value is lower than the regression coefficient of Column (1) in Table

1 (0.008<0.011). Column (3) shows that the coefficient of transport mobility is significantly positive at the 5% level. Column (4) shows that coefficient of transport mobility is still statistically significant and its value is lower than the regression coefficient of Column (2) in Table 1 (0.072<0.1).

Hence, both transport investment and transport mobility have a positive impact on CLUE of shrinking cities, and the structural change of construction land use plays a certain mediation effect in these conduction mechanisms.

Table 3. Mediation regression results of land use equilibrium.

Variable	Equilibrium	CLUE	Equilibrium	CLUE
	1	2	3	4
lnTRI	0.005** (1.97)	0.008** (2.05)		
lnTRM			0.014** (2.01)	0.072*** (5.39)
Equilibrium		0.211** (1.98)		0.195** (1.97)
Control variables	Yes	Yes	Yes	Yes
Constant	0.675** (2.47)	-0.075 (-0.15)	0.692** (2.51)	-0.327 (-0.65)
No.of obs.	364	364	364	364
R-squared	0.221	0.658	0.245	0.682

Note: t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

6 Conclusions

Taking 28 shrinking cities in China as an example, we explored the impacts of transport development on CLUE in this study. Our study has the following four findings. Firstly, from 2006 to 2018, CLUE of non-shrinking cities showed an overall growth trend, while CLUE of shrinking cities showed a fluctuating and declining trend. Thus, low land use efficiency is the typical feature of shrinking cities in China. Secondly, both transport investment and transport mobility have a significant positive impact on CLUE of shrinking cities. Thirdly, the heterogeneity test results show that transport development has the most significant impact on CLUE of less-developed cities, followed by post-industrial cities, and has no significant impact on CLUE of resource-based cities. Finally, the meditating effect regression results show that a balanced land use structure caused by transport development is an important reason for the improvement of CLUE.

The contribution of this study is to explore the impact of transport development on CLUE and its impact path from the perspective of transport investment and transport mobility, which will provide some implications for policymakers to formulate reasonable strategies of land resource development.

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