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Analyzing the coordinated development level of decomposed effects of transportation infrastructure economic benefit: case study of Shanghai, China

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Abstract:
The economic benefit of transportation infrastructure is the positive influence on economy system generated by the use of transportation infrastructure. This paper decomposes transportation infrastructure economic benefit into four effects which are consumption effect, investment effect, government purchase effect and external demand effect of it for the first time and introduces an integrated approach to analyze their coordinated development level taking Shanghai for example. The results showed that the coordinated development of decomposed effects of transportation infrastructure economic benefit of Shanghai was at the lower level and had certain improvement space. The external demand effect has the largest influence to the coupling coordination degree among four decomposed effects. All of these four effects have the positive significant impacts on the coupling coordination degree.
Keywords: *transportation infrastructure; economic benefit; decomposed effects; entropy method; coupling coordination degree model; multi-regression model*

1. Introduction

In recent years, China has built transportation infrastructure continually with the rapid development of national economy. There is an evident strong interaction between transportation infrastructure and economic development in China. The function of transportation infrastructure in the process of Chinese economy development has been emphasized highly. Many scholars have explored the relationship between Chinese transportation infrastructure and its economic growth (Demurger[1], 2001; Hong[2], 2007; Zou et al.[3], 2008; Hong et al.[4], 2011; Yu et al.[5], 2012). However, the relationship among the impacts of Chinese transportation infrastructure on different economic activities has been neglected before. This shortcoming motivated this research to further study the transportation infrastructure economic benefit. This paper takes Shanghai as an example to analyze the transportation infrastructure economic benefit using panel data. It is the biggest city in China. The investment and construction scale of transportation infrastructure in Shanghai are giant and increasing quickly year by year. But the basic function of transportation infrastructure in the process of economic development has not been fully played in Shanghai. This paper tries to divide economy system into four parts which are investment, consumption, government purchase and external demand according to the national economic identity in macroeconomics theory. Although these four parts are influenced by transportation infrastructure, to what extent transportation infrastructure has an impact on them is unclear. Therefore, this paper evaluates the impacts of transportation infrastructure of Shanghai on its four parts at first. Then whether the impacts of transportation infrastructure on different parts have been developed in harmony or not is analyzed by constructing coupling coordination model which is a useful approach for measuring interactive effects. The influence of the coupling coordination degree among the impacts of transportation infrastructure on different parts to the level of transportation infrastructure economic benefit will be studied at last.

The remaining part of this paper is organized as follows. Section 2 introduces the evaluation indicator system and empirical model. The main results are revealed in Section 3. And Section 4 concludes this paper.

2. Methodology

2.1. Content of transportation infrastructure economic benefit

As important public goods, transportation infrastructure has the obvious characteristic of external effect and spillover effect (Kollias and Paleologou[6], 2013; Lee and Yoo[7], 2016). It provides the basic condition to the operation and development of regional economy system and creates economic benefit through offering convenience for economic activities (Pradhan and Bagchi[8], 2013; Agbelie[9], 2014; Beyzatlar et al.[10], 2014; Achour and Belloum[11], 2016). Thus, the scope of transportation infrastructure economic benefit in this paper refers to the impact of transportation infrastructure on regional economy system. Here this paper divides economy system into four parts according to the theory of macroeconomics. The national economic identity shows that the economy system contains four kinds of activities which are consumption, investment, government purchase and external demand. The impacts of transportation infrastructure on these four activities are named as consumption effect, investment effect, government purchase effect and external demand effect of it respectively. And this effect is the variation of each economic activity when the amount of transportation infrastructure changed. It is calculated using formula (1):

$$Effect_{i,t} = \frac{\frac{\Delta Y_i}{Y_{i,0}}}{\frac{\Delta X}{X_0}} = \frac{\frac{Y_{i,t} - Y_{i,0}}{Y_{i,0}}}{\frac{X_t - X_0}{X_0}} \tag{1}$$

where $Y_{i,0}$ represents the observed value of the i th economic activity in initial year and $Y_{i,t}$ represents it in year t; X_0 represents the amount of transportation infrastructure in initial year and X_t represents it in year t; $Effect_{i,t}$ is the impact of transportation infrastructure on the i th economic activity in year t. As the amount of transportation infrastructure changes, the economic benefit will also undergo change. The value of effect should show its change degree along with the change of transportation infrastructure which will reflect how significantly transportation infrastructure impacts each economic activity. Consequently, according to the elastic calculation formula in economics, the calculation method of each effect is revealed in formula (1). It indicates how much the change percentage of each economic activity is when the transportation infrastructure changes 1%. In other words, it means the impact of transportation infrastructure on each economic activity.

These four effects are interrelated and affect each other which constitute transportation infrastructure economic benefit. Each effect has different importance in the whole structure of transportation infrastructure economic benefit. Therefore, the calculation of transportation infrastructure economic benefit adopts formula (2):

$$E_t = \sum_{i=1}^{n} w_i Effect_{i,t} \quad (2)$$

where w_i is the weight of the i th effect, and E_t is the level of transportation infrastructure economic benefit in year t.

2.2. Construction of indicator system

This paper designed an indicator system which comprised 16 indicators to evaluate the transportation infrastructure economic benefit of Shanghai. Each indicator reflected the impact of transportation infrastructure on one kind of economic activity so that it contains two parts which are transportation infrastructure and economic activity. Transportation infrastructure contains internal transportation infrastructure and external one. The urban internal transportation mainly refers to urban bus and rail transit whose scale can be reflected by their operating mileage and operation vehicle. Here the urban public traffic operating mileage is the sum of the mileages of urban bus and rail transit and urban public traffic operation vehicle is the sum of operation vehicles of them. These two variables stand for the level of urban internal transportation. The urban external transportation includes railway, highway, river, seaport, air, and so on. Here we selected the railway operating mileage and the highway operating mileage as the variables of urban external transportation. Firstly, these two transport modes are the major ways of external transportation. Secondly, other transport modes were not chosen in consideration of the availability of data. So the railway operating mileage and the highway operating mileage were chosen as the indicators of urban external transportation.

The variables of four economic activities would be chosen in the following section. Firstly, the household final consumption expenditure was chosen as the indicator of consumption activity. This indicator reflected the final consumption demand of urban residents which is helpful to promote the urban economic increase. Secondly, the level of investment activity was expressed through the gross capital formation. This indicator showed the total amount of capital which could form investment capability. Thirdly, the government purchasing power was the basis of government consumption. The excellent urban transportation infrastructure is beneficial to raise the government revenue which could lead to the increase of the government consumption expenditure. It increased the output of the whole economy system. Finally, this paper chose the net export of goods and services as the indicator of external demand.

Table 1. An evaluation indicator system for transportation infrastructure economic benefit

Level 1	Level 2	Level 3
Transportation infrastructure economic benefit (U)	Consumption effect (U_1)	Consumption effect of urban public traffic operating mileage (U_{11})
		Consumption effect of urban public traffic operation vehicle (U_{12})
		Consumption effect of railway operating mileage (U_{13})
		Consumption effect of highway operating mileage (U_{14})
	Investment effect (U_2)	Investment effect of urban public traffic operating mileage (U_{21})
		Investment effect of urban public traffic operation vehicle (U_{22})
		Investment effect of railway operating mileage (U_{23})
		Investment effect of highway operating mileage (U_{24})
	Government purchase effect (U_3)	Government purchase effect of urban public traffic operating mileage (U_{31})
		Government purchase effect of urban public traffic operation vehicle (U_{32})
		Government purchase effect of railway operating mileage (U_{33})
		Government purchase effect of highway operating mileage (U_{34})

	External demand effect (U_4)	External demand effect of urban public traffic operating mileage (U_{41})
		External demand effect of urban public traffic operation vehicle (U_{42})
		External demand effect of railway operating mileage (U_{43})
		External demand effect of highway operating mileage (U_{44})

2.3. Calculation of weight of each indicator of transportation infrastructure economic benefit

Before evaluating the level of transportation infrastructure economic benefit, the weights of all of the indicators should be determined. This paper adopts the entropy method to calculate the weight of each indicator. Generally speaking, the entropy which is used in the field of economy and management refers to the information entropy and is the measure of the system's disorder state. Its mathematical implication equals to the thermodynamics entropy in physics. It is commonly believed that the value of information entropy which means the variation degree of each indicator is proportional to the equilibrium degree of the system structure. The higher the variation degree is, the greater the weight of the indicator is (Ai et al.[12], 2015). Therefore, the weight of each indicator is calculated according to the value of entropy. The detailed step is showed as follow.

Step1: standardize the indicators by the standardized method. Different data has different measurement and magnitude. In order to eliminate the influence of dimension and magnitude, the raw data need to be standardized using formulas (3) and (4).

$$Y_{ij} = \frac{X_{ij} - \min\{X_j\}}{\max\{X_j\} - \min\{X_j\}} \tag{3}$$

$$Y_{ij} = \frac{\max\{X_j\} - X_{ij}}{\max\{X_j\} - \min\{X_j\}} \tag{4}$$

Where X_{ij} is the observed value of the j th indicator in year i; $\max\{X_j\}$ is the maximum observed value; $\min\{X_j\}$ is the minimum observed value, Y_{ij} is the normalized value. When the increasing value of indicator is raise the level of transportation infrastructure economic benefit, the formula (3) is applied. When the decreasing value of indicator is raise the level of transportation infrastructure economic benefit, the formula (4) is applied. In this paper, the values of all of the indicators are calculated by formula (3).

step2: calculate the proportion of the j th indicator value in year i.

$$\varpi_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}} \tag{5}$$

step3: calculate the information entropy of each indicator and the redundancy degree of the information entropy.

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m}\left(\varpi_{ij} \times \ln \varpi_{ij}\right) \tag{6}$$

$$d_j = 1 - e_j \tag{7}$$

Where e_j is defined as the information entropy of the j th indicator, $0 \le e_j \le 1$, d_j is the redundancy degree of the information entropy.

step4: calculate the weight.

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{8}$$

Where w_j is the weight of the j th indicator.

2.4. Coupling coordination degree model

This paper introduces the concept of coupling in physics to calculate the coupling degree of four decomposed effects of transportation infrastructure economic benefit of Shanghai (Tang[13], 2016). Coupling refers to the dynamic relationship which is mutual influenced between two or more systems. Coupling degree reflects the correlation degree between the systems. But in some cases it does not tell the synergies between the systems. Therefore, this paper will construct a coupling coordination degree model to analyze the coordinated development degree among four decomposed effects of transportation infrastructure economic benefit. The coupling coordination degree model is given by formulas (9) and (10) :

$$H = \sqrt{C \times S_{benefit}} \tag{9}$$

$$C = \left[\frac{U_1 \times U_2 \times U_3 \times U_4}{\left(U_1 + U_2 + U_3 + U_4\right)^4}\right]^{1/4} \tag{10}$$

Where H represents the coupling coordination degree, and $H \in (0,1)$; C represents the coupling degree among four decomposed effects; U_1, U_2, U_3 and U_4 represent the consumption effect, investment effect, government purchase effect and external demand effect respectively. According to the value of coupling coordination degree, the coordinated development of four decomposed effects of transportation infrastructure economic benefit was divided into ten classes (Table 2). It reflects the overall coordination result of four decomposed effects.

Table 2. Discriminating standard of the class of coupling coordination development

H	class
0.000-0.100	Extremely unbalanced development
0.101-0.200	Seriously unbalanced development
0.201-0.300	Moderately unbalanced development
0.301-0.400	Slightly unbalanced development
0.401-0.500	Barely unbalanced development
0.501-0.600	Barely balanced development
0.601-0.700	Slightly balanced development
0.701-0.800	Moderately balanced development
0.801-0.900	Favorably balanced development
0.901-1.000	Superiorly balanced development

2.5. Empirical model

The coupling coordination degree among four decomposed effects of transportation infrastructure economic benefit shows the coordinated development level among four decomposed effects. Therefore, the coupling coordination degree is influenced by the level of these four decomposed effects. In order to analyze the impact of four decomposed effects on their coupling coordination degree, we establish the regression model as follows:

$$H_t = \alpha_0 + \beta_1 \mathrm{Consume}_t + \beta_2 Invest_t + \beta_3 Gonvern_t + \beta_4 Export_t + \varepsilon_t$$

(11)

where H_t is the coupling coordination degree at year t; $Consume$, $Invest$, $Gonvern$ and $Export$ stands for the consumption effect, investment effect, government purchase effect and external demand effect respectively; α_0 represents constant term; the parameters β_1, β_2, β_3 and β_4 are the coefficients to be estimated and ε is the error term.

3. Results

3.1. Changes in transportation infrastructure economic benefit value

The required data cover the period from 1999 to 2014 which came mainly from Shanghai Statistics Yearbook 1999-2015. Here this paper takes the data of year 1998 as the base when calculating the change rate of each variable. Doing like this makes the index value of each year calculated under the same standard. It also can avoid the severe fluctuation of the indicator's value owing to the different base period data.

The level of transportation infrastructure economic benefit of Shanghai was calculated by formula (2). As illustrated in Fig. 1, Shanghai showed uncertain change trend of transportation infrastructure economic benefit from 1999 to 2014. The highest transportation infrastructure economic benefit value emerged in year 1999 and the lowest one in year 2000. The highest urban infrastructure economic benefit value of Shanghai was smaller than 0.6. The lowest urban infrastructure economic benefit value of Shanghai was near to 0.3. The research result indicated that the transportation infrastructure economic benefit of Shanghai was at the different level and had certain improvement space.

Beyond that, Fig. 1 revealed the change trends of four decomposed effects of transportation infrastructure environment benefit of Shanghai from 1999 to 2014. The external demand effects showed different change trend with that of transportation infrastructure economic benefit in some years. The change trends of other three effects mainly coincided with those of transportation infrastructure economic benefit. The value of consumption effect was between 0.3 and 0.6 besides 2000 and 2001. The change of government purchase effect of Shanghai was basically in the same trend of its consumption effect but the change of the investment effect of Shanghai was different with that of consumption effect in some years.

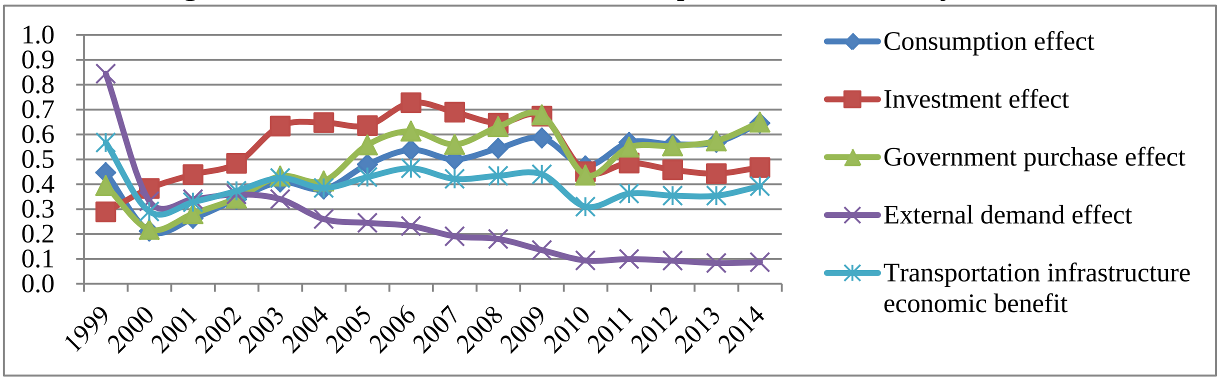

Fig. 1. Transportation infrastructure economic benefits of Shanghai

3.2. Coupling coordination degree among four decomposed effects of Shanghai

The change trend of the coupling coordination degree among four decomposed effects of transportation infrastructure economic benefit of Shanghai from 1999 to 2014 was illustrated in Fig. 2. The highest value of coupling coordination degree among four decomposed effects occurred in 1999. The values of coupling coordination degree of Shanghai changed around 0.3 after 1999. The values of coupling coordination degree among four decomposed effects of Shanghai were lower than 0.4 from 1999 to 2014.

The result demonstrated that the degree of coordinated development among four decomposed effects of Shanghai was in lower level from 1999 to 2014. According to the discriminating standard of the class of coupling coordination development in Table 2, the coordinated development among four decomposed effects of Shanghai was at the level of unbalanced development. It has the problem of uncoordinated development among four decomposed effects of transportation infrastructure economic benefit.

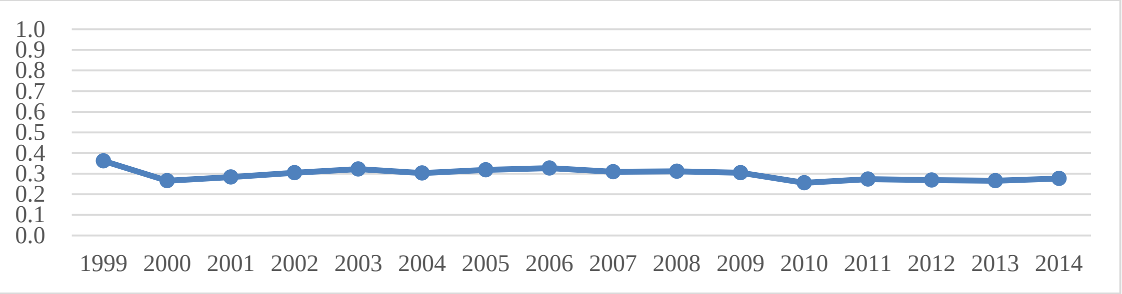

Fig. 2. Coupling coordination degree of four decomposed effects of transportation infrastructure economic benefits of Shanghai

3.3. Results of Panel Regression

The estimation results are shown in Table 3. According to the value of R^2, the fitness of this model is higher which explains the influences of all of independent variables to the dependent variable well. The elasticity of external demand effect is greatest (0.1766), indicating that a 1% increase in external demand effect would lead to 0.1766% increase in coupling coordination degree when other factors keep constant. The investment effect has the smallest impact on the coupling coordination degree. The results show that all of these four effects have significant influence to the coupling coordination degree but the impacts of four effects were obviously different.

Table 3. Regression model estimation results

Variables	
Constant	-7123.446^{***}
Consume	0.1036^{***}
Invest	0.0482^{***}
Gonvern	0.1413^{***}
Export	0.1766^{***}
R^2	0.9994
Adjusted R^2	0.9992
Sum squared residuals	7757.531
S. E. of regression	26.5562
F-Statistic	4855.784^{***}
LogL	-72.1737
D. W. stat	2.6608

Note: ***Means significant at confidence level 1%

4. Conclusions

According to the analysis results obtained above, the coordinated development of four decomposed effects of transportation infrastructure economic benefit of Shanghai was at the lower level and had certain improvement space. The external demand effect has the largest influence to the coupling coordination degree among four decomposed effects. All of these four effects have the positive significant impacts on the coupling coordination degree. Therefore, the increase of all of effects of transportation infrastructure economic benefit was greatly beneficial to raise the coordinated development level of them.

In order to raise the coordinated development level of decomposed effects of transportation infrastructure economic benefit, several steps should be put forward. Firstly, Shanghai should highly pay attention to the external demand effect of transportation infrastructure. The construction level of urban external transportation should be raised to boost the trade between Shanghai and other regions. It is helpful to increase the level of this effect. Secondly, the effects of transportation infrastructure on different economic activities should be developed simultaneously. Shanghai should keep the rough balance of the development speeds of different effects. Thirdly, Shanghai should attach importance to the proportion among different transportation infrastructures. Transportation infrastructure economic benefit emerges from a variety of transportation infrastructures. The inputs on them should roughly equal and fit the demand of urban development. Keeping the appropriate structure of transportation infrastructure system is also an important way of raising the level of transportation infrastructure economic benefit. In these ways, the coordinated development level of different decomposed effects of transportation infrastructure economic benefit can be increased.

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