World Transactions on Engineering and Technology Education
Vol.6, No.1, 2007

The economic performance of transportation infrastructure: an empirical study on the recent development of China

Jie Zhou†, Luyu Yang‡, Youquan Xu* & Chunlu Liu†

Deakin University, Geelong, Australia†
Tongji University, Shanghai, People's Republic of China‡
Shandong Jianzhu University, Jinan, People's Republic of China*

ABSTRACT: It has been widely recognised that infrastructure systems highly affect the economic development of a country or region. In particular, the quality and quantity of transportation infrastructure have a direct bearing on economic growth in developing countries. Therefore, it is challenging to allocate the infrastructure construction budget across a country so that economic growth as a whole will not be hampered by the lack of infrastructure construction in any local area. In this research, the authors focus on simulating the correlations between economic growth, capital investment and transportation infrastructure construction in China historically and comparing the production and investment indicators at the cross-region based on the statistical data reported from government agencies in China. These computed correlations and indicators are crucial for making financial decisions and investment policies on transportation infrastructure construction at a national level.

INTRODUCTION

The quality and quantity of transportation infrastructure systems have a direct bearing on economic growth, particularly in a developing country. Bottlenecks in the provision of transportation capacity can severely retard the growth in all economic sectors, including productivity, technology, resource, labour, capital investment and so on.

The importance of transportation infrastructure construction for regional economic performance has been extensively discussed in previous research [1-6]. Theoretical arguments and historical evidences have shown strong linkages between the stock of transportation infrastructure, its construction and maintenance investment, and the economic growth of a country. Notwithstanding, it was not until the late 1980s that economists started to develop quantitative measures of such linkages by building a macroeconomic model [7]. This pioneering paper employed aggregate time series data to investigate the relationship between public investment and economic growth by expanding the conventional production function to include public capital or its components. Since then, numerous authors have included infrastructure as an additional argument of the production function to declare that the public infrastructure can be taken as an input factor in the production process that contributes to output independently [8-15]. The widely used estimation method was ordinary least squares [2][7][12][13][16]. The two-stage least squares regression model was also used to estimate the relationships between transportation infrastructure and economic development from two directions [3][4][10]. Econometrics methods have drawn researchers' attention too [5][17].

The aggregate time series studies have been criticised by researchers [18][19]. One of the most frequently mentioned problems is the spurious correlation between economic growth and endogenous factors. This is because many macroeconomic time series demonstrate the characteristic of non-stationarity. In other words, the time series data may trend into similar directions over time in the long-term analysis. A common way to adjust the variables before estimating the relationship is to take the first difference using the change in a variable from one time period to the next rather than the absolute level of the variables [5][17-19]. Nevertheless, it is argued that first-differencing destroys any long-term relationships, which is the whole point of studying infrastructure and economic growth [20].

More recently, a cost function approach has also been employed by researchers and was suggested as being even better suited to this kind of analysis (eg refs [21][22]). The cost function framework yields input demand equations with endogenous dependent variables, in contrast to the estimating equations derived using the production function approach. However, this approach is more plausible for applications to individual firms with micro-data than to aggregate or even industry-level data [6]. In addition, constructing the social rate of return of public infrastructure capital is a very complicated issue [22].

China has been facing challenges of updating and expanding its infrastructure facilities so that the economic growth would not be affected due to the lack of the infrastructure. For the last two decades, infrastructure issues have risen to the forefront of the policy agenda of the central and local governments in China. Because the transportation infrastructure systems consist of systematic networks at different layers, relieving bottlenecks at certain points of the systems can produce very high returns on the economic growth. One striking example is that of China's intercity transportation system with its links to the supply of raw materials, coal and electricity, as mentioned in a World Bank Report [23]. Therefore, research efforts are needed to study in detail the economic effects of transportation infrastructure in China in order to make rational financial decisions and investment policies on transportation infrastructure construction at the national or regional level.

In this research, the authors focus on simulating the correlations between economic development in terms of the Gross Domestic Product (GDP), and the transportation infrastructure construction historically and comparing the production and investment indicators at the cross-region based on the statistical data reported from Chinese government agencies.

ROLES OF TRANSPORTATION INFRASTRUCTURE IN ECONOMIC DEVELOPMENT

A controversial issue for many years has been that either infrastructure construction causes the economic development or the economic development leads infrastructure investment. Notwithstanding, much research has been given to study the role of infrastructure investment in economic development. When a transportation infrastructure project is undertaken, various economic impacts will be generated in the direct or indirect manner. Figure 1 is a conceptual framework of representing the influence of infrastructure construction on economic development via improving its various endogenous dominant parameters including the capital, labour, resource, facility and technology. These elements are detailed below:

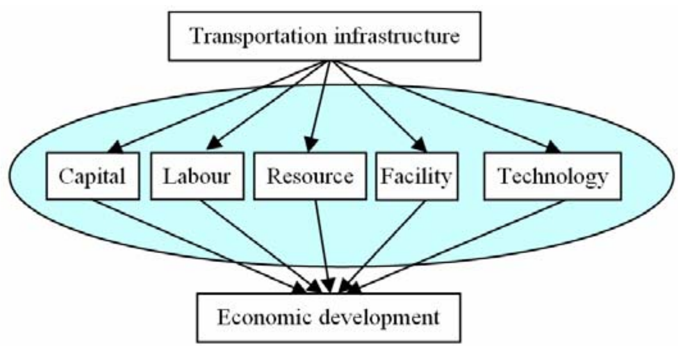


Figure 1: Influence flow of transportation infrastructure on economic growth.

- *Capital*: better transportation infrastructure may increase a region's capacity to attract investment from both home and abroad. The latter has proved an important stimulus to the economy and foreign trade in developing countries. For instance, various manufacturing factories financially supported by foreign investors could be established in rural areas with the improvement of infrastructure;
- *Labour*: with the improvement of transportation infra-structure, the availability and movement of the labour force for a region will increase and the time consumption of users will be reduced generally. On the other hand, the costs of users to infrastructure will be decreased in the long-term because of the improved infrastructure;
- *Resource*: the improved infrastructure systems are able to facilitate the formation and integration of the domestic market, and hence lead to the long-term effect of expanding the productive capacity of a region by increasing resources and enhancing the productivity of existing resources. Transportation shortage also has adverse affects on raw materials and energy supply, which is also vital to economic growth. In such a circumstance, improvement in the provision of transportation services should have a large marginal effect on output. As an important component of resources, the values of the land of a region will increase with the construction of new transportation infrastructure;
- *Facility*: the impact of infrastructure development on economic growth is usually more significant when a bottleneck exists in the economy as a result of an under-developed infrastructure. Although there has been rapid infrastructure development in recent years in China, it has not been able to adequately meet its economic growth;
- *Technology*: as the transportation infrastructure improves in the developing regions, it will become possible to raise productive technologies relatively quickly by either transferring from the industrial regions or developing in that area.

Additional endogenous components can further be identified, such as marketing, trading, legislation, social environment and so on.

INVESTMENT IN TRANSPORT INFRASTRUCTURE

As the economy in China grows and population mobility increases, the pattern of investment of constructing various transportation infrastructure modes also changes. Figure 2 shows the percentages of capital investment in the four main transportation modes, including railways, highways, waterways and airways, in China from 1995 to 2004 according to each version of the China Statistical Yearbook [24]. The total percentages at each year are 1.

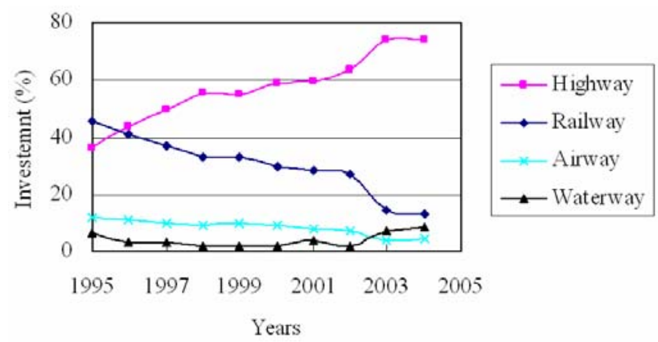


Figure 2: Capital investment in four transport modes in China.

In these 10 years, the shares of investment in highway construction stably increased from 36% in 1995 to 74% in 2004 and those in railway construction were completely reverse. It was not until 1996 that the construction investment on highway surpassed that on railway. In fact, the same trends of investment in highway and railway had appeared for many years until 1995, the starting point of this figure [1]. It should also be noted that the total capital investment in all four transportation modes in China has continuously increased. The investment in highways has also increased from one year to the next but those in railway, waterway or airway might decrease in some years.

As a result of capital investment, the lengths of railway, waterways and airways increased about 15%, 12% and 82%, respectively, from 1995 to 2004. Over this period, the highway length of the country increased by 62% and the length of expressway in 2004 is 16 times that in 2005. Although statistical data are not available, it is believed that the majority of the above capital investment in highways was spent for the construction of expressways.

Based on the allocations of capital investment over these 10 years, it may be predicted that the highway construction will be the dominant investment area for a long time period to improve the transportation capacity in China. In other words, the development priority of transportation systems in China will continue to shift from the traditional means of railway to highways. Therefore, there is a special need to research the highway construction and its effects on the national economic growth. Therefore, the remainder of this article will specifically focus on highways only.

HISTORICAL CORRELATION ANALYSES

The effects of highway construction on China's economic development are analysed from the historical perspective in the framework of the above-mentioned productivity function model based on the data available at various versions of the China Statistical Yearbook. economic performance is measured in terms of GDP in each year. In addition to the capital investment and length of highway, traditional productive factors, including labour, energy and export of the whole country, are also taken into consideration. The assessment period is from 1980 to 2004.

A correlation analysis is used to describe the strength and direction of the linear relationship between two selected variables. Pearson product-moment correlation coefficients are computed using a commercial statistical software package. Based on the coefficients and significances (also called *p*-value) shown in Table 1, it can be found that all of these parameters are significantly correlated. Interestingly enough, the correlation coefficient between GDP and highway length is the largest value among the coefficients between GDP and other parameters. This supports the general conclusion in previous research that highway construction has significant and positive effects on economic growth. As China's economy is highly pushed by its exports, it is not surprising that export has high correlation coefficients with GDP and length and investment of highway than labour and energy do [25]. These findings may also provide another explanation of that the labour and energy resources in China are not the critical barriers in developing its economy and their marginal products for GDP are relatively smaller than those of capital investment and infrastructure.

CROSS-REGION ANALYSIS

This article's researchers further conducted an investigation into the role of regional highways in determining productive and investment performance. Two comparable indicators are formulated to measure the regional economic productions and capital investments per unit of length of highway. Let p_i, c_i and l_i be GDP, capital investment and length of highway in region i at a year, respectively. Their sums in the whole country are represented by the symbols P, C and L. The production rate of highway in region i, representing the regional economic growth per unit of length of highway, is defined as follows:

$$\text{Production rate } (i) = \frac{p_i / P}{l_i / L} \tag{1}$$

Similarly, the capital investment rate is used to define the investment attraction per unit length of highway at certain a year and is given by the following:

$$\text{Investment rate } (i) = \frac{c_i / C}{l_i / L} \tag{2}$$

The production rate reflects the ratio of the weight of a region's GDP in the country's GDP to its weight of highway length. The value of production rate is 1 if these two weights are equal. Similarly, the investment rate is the ratio of the weight of a region's capital investment in the nation to its weight of highway length and is equal to 1 when these two weights are same.

Using the latest region level data in 2004, the importance of the stock of highways to regional economic growth and the capital investment per unit length of highway are measured for all 31 regions in mainland China. Figure 3 plots the regional production and investment rates according to the descending values of production rates from left to right. Among these 31 regions, Beijing, Shanghai, Tianjin and Chongqing are four municipality cities administrated directly under the Central Government of China. Chongqing, which was justly separated from Sichuan province in 1995, is much different from Beijing, Shanghai and Tianjin. Figure 3 indicates that most regions have a well-fitted balance between their production and investment rates. However, the capital investments per unit of length of highway in Beijing, Zhejiang, Chongqing, Ningxia and Inner Mongolia are obviously higher than the economic contributions of their highways. Shanghai, Guangdong, Hebei, Henan, Fujian and Helongjiang have the opposite situations.

There are 11 regions, plotted on the left side of Figure 3, whose production rates per unit of length of highway are greater than 1. Their investment rates are also greater than 1 except for Fujian. Notably, all these 11 regions are located in the east of China. On the right side, all regions are located in the west part of China except for Hainan, which is located in the east but is an island province. These comparisons clearly show that the economic production efficiencies and capital investment attraction in the east of China are greater than its west. This figure also gives the ranks of production rate, investment rate, GDP, capital investment and length of highway of each region among all 31 regions. The top four regions ranked by both GDP and investment are Zhengjiang, Shandong, Jiangsu and Guangdong, all of which are located at the eastern coast of China. It is surprising that Yunnan's highway is the longest.

Table 1: Correlation analyses between parameters.

		GDP	Labour	Energy	Export	Length	Investment
GDP	Pearson correlation	1	0.879(**)	0.802(**)	0.933(**)	0.960(**)	0.917 (**)
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
Labour	Pearson correlation	0.879(**)	1	0.652(**)	0.793(**)	0.806(**)	0.852(**)
	Sig. (2-tailed)	0.000		0.006	0.000	0.000	0.000
Energy	Pearson correlation	0.802(**)	0.652(**)	1	0.894(**)	0.765(**)	0.846(**)
	Sig. (2-tailed)	0.000	0.006		0.000	0.001	0.001
Export	Pearson correlation	0.933(**)	0.793(**)	0.894(**)	1	0.937(**)	0.989(**)
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000
Length	Pearson correlation	0.960(**)	0.806(**)	0.765(**)	0.937(**)	1	0.871(**)
	Sig. (2-tailed)	0.000	0.000	0.001	0.000		0.000
Investment	Pearson correlation	0.917 (**)	0.852(**)	0.846(**)	0.989(**)	0.871(**)	1
	Sig. (2-tailed)	0.000	0.000	0.001	0.000	0.000	

**Correlation is significant at the 0.01 level (2-tailed).

Further research has been carried out to study the trends of regional production and investment rates. Figure 4 show all regions' ranks of production rates over the period from 1997 to 2004. The order of these regions at the horizontal axis is same as their order in Figure 3, which is also the ascending order of production rates in 2004. Although the ranks of production rates of regions except for Shanghai and Tibet are not exactly same in these eight years, their changes are minor. This is because all three parameters, namely GDP, capital investment and length of highway, of each region are normally stable from one year to the next. Not only in 2004, the geographic split up between the east and west parts are also obvious in other years.

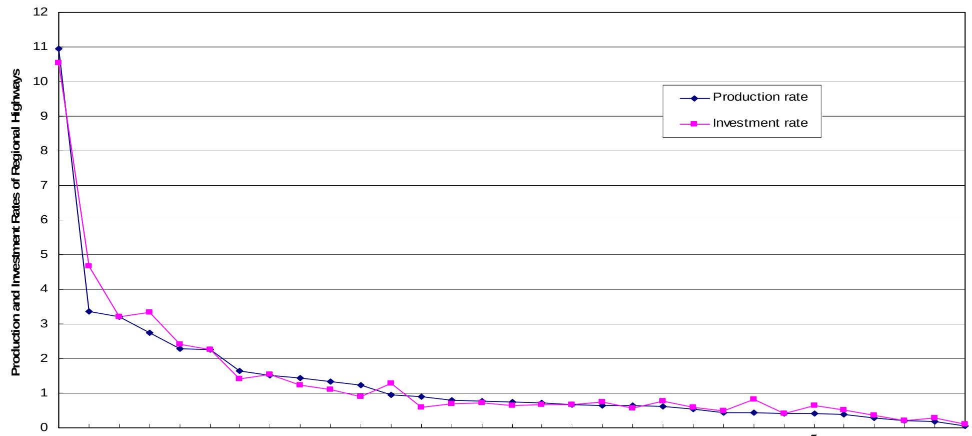
Similarly, the ranks of investment rates of all the regions from 1997 to 2004 have been studied and plotted in Figure 5, in which the horizontal axis is the same as that for Figures 3 and 4. The ranks of some regions may be considered as fluctuating compared to the ranks of production rates. Among all west regions, only Chongqing's investment rate was ranked within the top 10 regions, but only once in 1999.

CONCLUSIONS

This authors aim to identify the correlations between economic development in terms of GDP, capital investment and the transportation infrastructure construction historically and cross-regionally given the statistical data reported from government agencies in China. A conceptual framework was presented and described in order to reflect the effects of transportation infrastructure construction on GDP via improving its endogenous variables.

Considering the possibility of future investment, and potential demand and supply in four transportation modes, it was concluded that highways are the dominant investment area for improving the transportation capacity in China and the development priority of transportation systems in China has shifted from the traditional means of railways to highways.

Statistical analysis based on the historical data indicated that the correlation coefficient between GDP and highway length is the largest among coefficients between GDP and all selected parameters. This means that highway construction has significant and positive effects on China's economic growth. In addition, export has high correlation coefficients with GDP and length and investment of highway than labour and energy do. These findings provide another explanation that the labour and energy resources in China are sufficient and their marginal products for GDP are relatively smaller than those of capital investment and infrastructure.



	Shanghai	Beijing	Tianjin	Zhejiang	Shandong	Jiangsu	Guangdong	Liaoning	Hebei	Henan	Fujian	Chongqing	Heilongjiang	Hubei	Anhui	Hunan
Production rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Investment rate	1	2	4	3	5	6	8	7	10	11	12	9	23	17	16	20
GDP	7	15	21	4	2	3	1	8	6	5	11	24	13	10	14	12
Investment	7	10	22	4	1	2	3	8	5	6	14	17	20	11	13	12
Length	31	28	30	20	8	7	3	19	12	10	17	25	13	4	11	5

	Jilin	Sichuan	Jiangxi	Guangxi	Shaanxi	Shanxi	Gansu	Ningxia	Hainan	Inner Mongolia	Guizhou	Xinjiang	Yunnan	Qinghai	Tibet
Production rate	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Investment rate	18	19	15	24	14	22	26	13	27	21	25	28	30	29	31
GDP	20	9	16	17	22	18	27	30	28	23	26	25	19	29	31
Investment	24	9	16	23	18	19	27	28	29	15	26	25	21	30	31
Length	21	2	15	16	18	14	24	29	27	9	22	6	1	26	23

Figure 3: Regional production and investment rates per unit of length of highway in China in 2004.

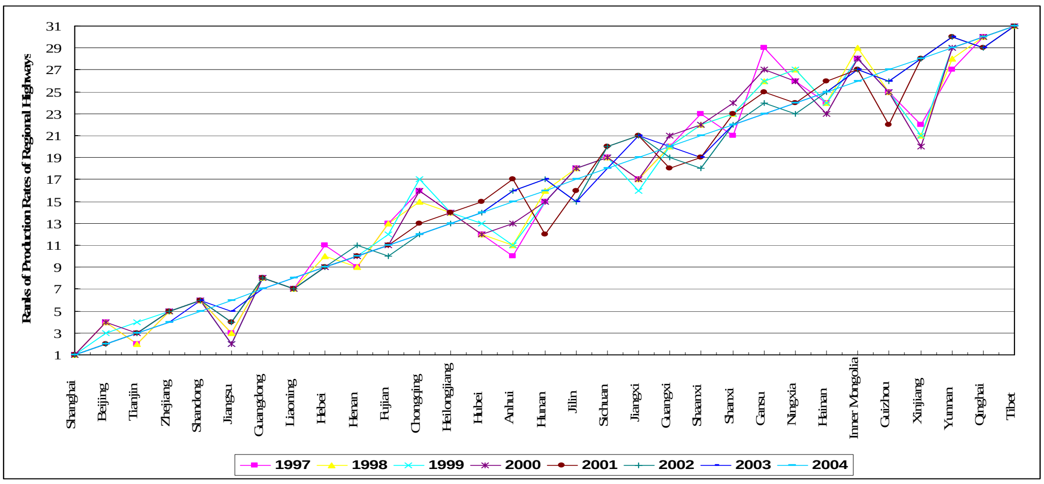


Figure 4: Ranks of production rates.

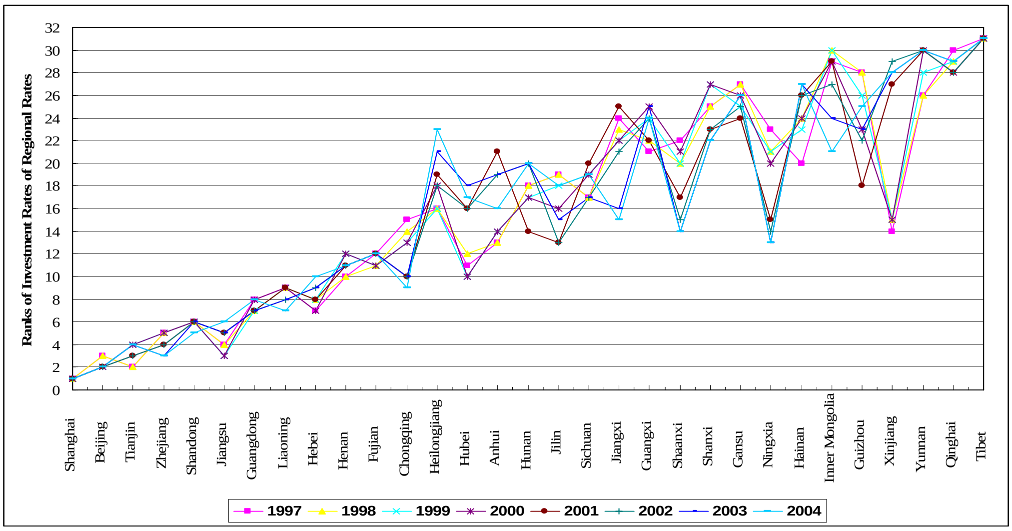


Figure 5: Ranks of investment rates.

Highways in most regions of China have a good balance between their economic contributions and capital investment attractions. However, the production and investment rates per unit length of highway in the eastern regions are obviously higher than those in the western part. This research may be further applied to investigate the optimal capital investment policy.

REFERENCES

1. Liu, C. and Itoh, Y., A study on the influence of transportation infrastructure construction on regional economic development. *J. of Construction Management*, 7, 111-118 (1999).
2. Lombard, P.C., Sinha, K.C. and Brown, D.J., Investigation of the relationship between highway infrastructure and economic development in Indiana. *Transportation Research Record*, 1359, 76-81 (1992).
3. Man, J.Y., Transportation infrastructure and regional economic development in China. *Inter. J. of Public Admin.*, 21, **9**, 1307-1321 (1998).
4. Mohamad, D., The relationships between road infrastructure investment and economic development. *Proc. Inter. Conf. on Transportation into the Next Millenium*. Singapore 261-270 (1998).
5. Pereira, A. and Andraz, J., Public investment in transportation infrastructure and economic performance in Portugal. *Review of Development Economics*, 9, **2**, 177-196 (2005).
6. Jiang, B., A Review of Studies on the Relationship between Transport Infrastructure Investment and Economic Growth. Vancouver: Canada Transportation Act Review (2001).
7. Aschauer, D.A., Highway capacity and economic growth. *Economic Perspectives*, 14, **5**, 14-24 (1990).
8. Aziz, A. and Russell, A., Generalized economic modelling for infrastructure and capital investment projects. *J. of Infrastructure Systems*, 12, **1**, 18-32 (2006).
9. Bhatta, S. and Drenna, M., The economic benefits of public investment in transportation a review of recent literature. *J. of Planning Educ. and Research*, 22, **2**, 288-296 (2003).
10. Canning, D., Fay, M. and Perotti, R., *Infrastructure and Growth*. In: Baldassarri, M., Paganetto, L. and Phelps, E.S. (Eds), International Differences in Growth Rates: Market Globalization and Economic Areas. New York: Macmillan Press, 113-147 (1994).
11. Kessides, C. and Ingram, G.K., Infrastructure's impact on development: lessons from WDR 1994. *J. of Infrastructure Systems*, 1, **1**, 16-32 (1995).
12. Lu, W., Public infrastructure and regional economic development: evidence from China. *Pacific Economic Paper No. 258*. Australian National University: Canberra (1996).
13. Munnel, A.H. and Cook, L.M., How does public infrastructure affect regional economic performance? *New England Economic Review*, 15, **5**, 11-32 (1990).
14. Perkins, P., Fedderke, J. and Luiz, J., An analysis of economic infrastructure investment in South Africa. *South African J. of Economics*, 73, **2**, 211-228 (2005).
15. Vickerman, R.W., *Infrastructure and Regional Development*. London: Pion (1991).
16. Batten, D.F. and Karlsson, C., *Infrastructure and the Complexity of Economic Development*. Berlin: Springer (1996).
17. Luo, Z., Liu, C. and Picken, D., Causal relationships between house prices and macroeconomic variables. *Proc. 31st Annual Meeting of Australian University Building Educ. Assoc.* (CD-ROM), Sydney, Australia (2006).
18. Evans, P. and Karras, G., Are government activities productive? Evidence from a panel of U.S. states. *Review of Economics and Statistics*, 76, **1**, 1-11 (1994).
19. Holtz-Eakin, D., Public-sector capital and the productivity puzzle. *Review of Economics and Statistics*, 76, **1**, 12-21 (1994).
20. Munnel, A.H., Policy watch: infrastructure investment and economic growth. *J. of Economic Perspectives*, 6, **4**, 189-198 (1992).
21. Nadiri, I. and Mamuneas, T.P., The effects of public infrastructure and R&D capital on the cost structure and performance of U.S. manufacturing industries. *Review of Economics and Statistics*, 76, **1**, 22-37 (1994).
22. Morrison, C.J. and Schwartz, A.E., State infrastructure and productive performance. *American Economic Review*, 86, **5**, 1095-1111 (1996).
23. Infrastructure Development. World development report, New York.: Oxford University Press (1994).
24. National Bureau of Statistics of China, *China Statistical Yearbook*. Beijing: China Statistics Press (1996-2005).
25. Buckley, P.J. and Meng, C., The strategy of foreign-invested manufacturing enterprises in China: export-orientated and market-orientated F revisited. *J. of Chinese Economic and Business Studies*, 3, **2**, 111-131 (2005).