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The Impact of Government Integrity on Investment Efficiency in Regional Transportation Infrastructure in China

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Abstract: This paper examines the efficiency of China's transportation infrastructure investment to explain regional differences in efficiency on the basis of government integrity. First, we used a three-stage DEA (Data Envelopment Analysis) model to eliminate the influence of environmental factors and statistical noise and measured the investment efficiency of transportation infrastructure in 31 provinces of China from 2007 to 2017. In addition, we used a truncated regression to calculate the efficiency of infrastructure investment in relation to government integrity to explain the regional differences in investment efficiency. The research results show that, (1) after excluding the environmental and random factors, the adjusted sample investment efficiency value is significantly improved in comparison to the traditional DEA. This shows that environmental factors in various provinces reduce government investment efficiency, which suggests that a traditional DEA model would underestimate investment efficiency. (2) The provinces with higher efficiency in transportation infrastructure investment include, among others, Guangdong, Hebei, Henan, Jiangsu, Liaoning, and Tianjin; all are located at the efficiency frontier, while regions with better economic development, such as Beijing and Shanghai, exhibit rather low investment efficiency values. This may be due to the fact that transportation infrastructure investment in these regions has become saturated, resulting in an inevitable decrease in efficiency when investment continues to flow. (3) Low degree of government integrity significantly reduces the efficiency of infrastructure investment. On average, reduction of 1% in government integrity would lead to a decrease of 0.16 percentage points of the technical efficiency of government transportation infrastructure investment.

Keywords: efficiency of investment; government integrity; corruption; three-stage DEA model

1. Introduction

Numerous studies have demonstrated the positive contribution of transportation infrastructure investment to economic growth. In recent years, Chinese governments have increased investment in infrastructure, particularly in transportation infrastructure, to an unprecedented scale, thus shaping a unique miracle in Chinese infrastructure development.

However, after all kinds of resources have been accumulated in the infrastructure sector, it becomes evident that significant changes have occurred in the dynamics and potential of domestic economic development. With the continuous development of infrastructure, problems arise regarding infrastructure investment. First, low investment efficiency causes fiscal risks locally. Under pressure from economic downturn and tax cuts, state investment in infrastructure appears to be experiencing difficulties. In the past, the government chose to replace fiscal expenditure efficiency with higher levels of fiscal expenditure. This incurring inefficiency triggered local debt increase and local fiscal risks [1]. Second, low efficiency distorted resource allocation and economic growth. Because of intergovernmental competition, local governments may invest substantial funds in inefficient areas, where infrastructure investment has been saturated and thus renders a large number of investment projects inefficient. From a social perspective, the inefficiency of investment not only will distort economic resource allocation but also will hinder economic growth [2]. However, great importance should be attached to the improvement of government investment efficiency when it comes to restricted public budget and its fiscal sustainability as well as the sustainability of economic growth of economies.

Hence, the issue of transportation infrastructure efficiency is of particular importance, especially in the context of "One Belt, One Road", where infrastructure interconnection is a priority and the investment in transportation infrastructure is the primary challenge. High-efficiency investments can enable governments to achieve their goals with a lower level of transport infrastructure investment or to maximize output at a stable level of transport infrastructure investment. At the same time, since the 18th National Congress of the Communist Party of China (NCCPC), the government has put forward higher requirements for "anti-corruption and promoting government integrity", which renders the issue of government integrity even more significant. Liu Yongzheng and Feng Haibo pointed out that corruption can indirectly impact economic growth by affecting the efficiency of public expenditure [3]. Transportation infrastructure investment has more rent-seeking space than other public expenditure fields. The rent-seeking behavior of government officials is more likely to influence transportation infrastructure investment, thus affecting the sustainable development of the economy. Therefore, this paper evaluates the efficiency of China's transportation infrastructure investment and explains the regional differences in investment efficiency with integrity.

The difference in investment efficiency of transportation infrastructure from the perspective of government integrity have received limited scholarly attention and the study of government investment efficiency mostly uses nonparametric Data Envelopment Analysis (DEA) models [4–6]. However, due to environmental factors and the impact of random shocks, traditional DEA models cannot accurately measure the efficiency of government investment. In addition, due to different selections of input and output indicators, the measurement of investment efficiency often returns different results. Hitherto, research on the effect of government integrity on infrastructure investment mainly focused on how corruption distorted government spending structure [7–9] as well as on how corruption reduced the infrastructure quality [10,11]. However, the degree of government integrity has less direct impact on government investment efficiency. In fact, current research suggests that corruption at first improved investment efficiency before it decreased it, and this aspect deserves further discussion [12,13].

Low investment efficiency is an important problem in infrastructure investment in China, especially in transportation infrastructure investment, which is prone to corruption and rent seeking. The reduction of investment efficiency will inevitably lead to sustainability problems: On the one hand, it affects the sustainable development of the economy. Transportation infrastructure investment directly drives the economy and promotes employment, but low efficiency caused by corruption will inevitably hinder the sustainable development of the economy. On the other hand, it affects fiscal sustainability and debt sustainability. The government faces serious fiscal and debt risks. This is not only because of the tax reduction policy but also because of the excessive government expenditure, especially some inefficient government investments. Integrity improves the efficiency of public investment, alleviates financial risks, and maintains financial sustainability [14,15].

Therefore, this paper tackles two questions: what is the efficiency of China's transportation infrastructure investment and how will the declaration for enhanced government integrity affect it? First, we establish an input–output indicator system, including more indicators to measure the quantity and quality of transportation infrastructure. Second, we use a three-stage DEA model to measure the investment efficiency of transportation infrastructure in 31 provinces in China from 2007 to 2017, and then, use SFA (Stochastic Frontier Approach) to eliminate environmental factors as well as the impact of random noise on the results. Finally, by using the truncated regression, we examine regional differences in transportation infrastructure investment efficiency in relation to government integrity.

2. Literature Review

2.1. Measurement of the Efficiency of Government Investment

Before studying the relationship between investment efficiency of transportation infrastructure and government integrity, an important step is to measure first the efficiency of infrastructure investment. Scholars measure government investment efficiency either by parametric methods or nonparametric methods. Parameter methods include OLS, COLS, and Stochastic Frontier Analysis (SFA) models. The nonparametric method comprises mainstream data envelopment analysis (DEA, Data Envelopment Analysis) and FDH models. In order to improve the accuracy of the calculations, scholars usually combine the DEA model with the parametric method. Accordingly, the initial efficiency value is estimated by the DEA model, and the parameter method is used to eliminate the influence of environmental variables and random errors.

Recently, many scholars have been using the DEA model to measure the efficiency of government investment, yet some scholars use the traditional DEA mode [4–6]. To be more specific, Wang Jing used the traditional DEA model to measure the government investment efficiency and the Tobit model to explain regional differences in government investment efficiency. The study found that educational level, population density, and openness of the region are positively related to government investment efficiency while the scale of government departments is negatively related to government investment efficiency [5]. Andreas P. Kyriacou used government quality to explain the differences in infrastructure investment efficiency between countries [6], while other scholars have recognized the limitations of traditional DEA models and excluded the effects of environmental variable and random noise through the application of multi-stage DEA models, such as Gong Feng's Bootstrapped DEA model and Liu Zimin's three-stage DEA model [16,17]. Others have considered the factor of time when using the S-SBM mode [18].

2.2. The Effect of Government Integrity on Government Infrastructure Investment

Non-market mechanisms inherent in infrastructure investment may lead to the failure of certain aspects of market economy. Many scholars think that corruption has a negative impact on the efficiency of government investment and reduces the impact of public investment because corruption distorts resource allocation, increases social development costs, and compromises public expenditure structure [11]. They argue that corruption affects the structure of government spending; it leads to distortions in resource allocation in investment decisions and to the implementation of large and unnecessary public investment projects; and it shifts public investment away from the fields of cultural promotion, education, and public health and towards the infrastructure sector [7,19–21]. Chinese scholars have reached similar conclusions. For example, by creating an endogenous growth model that includes corruption index and public expenditure, Wu Junpei and Yao Lianfang were able to show that corruption affects the structure of public expenditure and reduces the proportion of social and cultural expenditures in China [8]. Liu Changzhi and He Qi pointed out that corruption has stimulated the expansion of fiscal expenditure, distorted the expenditure structure, and increased the proportion of economic construction expenditure [9].

On the other hand, however, research has shown that government integrity can reduce the quality of infrastructure. Kenny, Gillander, and Huang Shoufeng, among others, have pointed out that the degree of government integrity is negatively correlated with the quality of infrastructure to a significant extent. This may indicate that low levels of government integrity can actually undermine the improvement of infrastructure quality [10,11,22]. Liu Yongzheng and Feng Haibo formed a general equilibrium model by introducing corrupt elements into the traditional, endogenous growth model of public expenditure and studied the relationship between corruption, public expenditure efficiency, and economic growth. They suggested that, while the role that corruption could play in China's economic growth remains uncertain, it is clear that corruption in general plays a significantly negative role in economic growth because it undermines the efficiency of public expenditure [3].

Other scholars argue that the impact of corruption on investment efficiency must be examined in different stages. Haque and Kneller pointed out that countries with low levels of government corruption can enjoy the benefits of economic growth due to public investment while, in countries with highly corrupt governments, public investment efficiency appears reduced [23]. Yang Feihu suggested that there is a Kuznets-curve effect on the relationship between corruption and economic growth in the public investment field. Specifically, after economic development reaches a certain level, the negative effects of corruption will dominate state investment [13].

2.3. Results of Literature Review

Our review of recent scholarship has shown that, (1) in terms of methods of measuring efficiency, many studies are still limited to the traditional DEA model. However, due to environmental factors and random noise, efficiency results are often underestimated. To correct the error, we introduced SFA regression on the basis of traditional DEA model to eliminate the influence of those factors and to improve the accuracy of the calculations. (2) It is mostly international researchers who study the impact of government integrity on investment, whereas Chinese scholars have been much less preoccupied with the issue. Government integrity makes an impact on the economy by indirectly altering the structure of government expenditures, and yet, it directly affects the efficiency of government investment. This is particularly the case when it comes to the construction of transportation infrastructure, a field with an important role in stimulating the economy. Therefore, would the consideration of the efficiency of China's transportation infrastructure investment in relation to government integrity shed light on the improvement of government investment efficiency? In our opinion, this is an important question that demands investigation.

3. Data

The sample includes data from 31 provinces, autonomous regions, and municipalities (excluding Taiwan, Hong Kong, and Macau) between 2007 and 2017. The specific input indicators, output indicators, and environmental variables are selected as follows:

3.1. Input and Output Variables

In order to use the three-stage DEA model to measure the investment efficiency, we first need to establish the input and output variable system of the transportation infrastructure: (1) The fiscal expenditure of the provincial transportation infrastructure is used as the input variable. (2) The output indicators are constructed as output variables, as in Wu Wenzhong and Kyriacou [4,6]. The output indicators selected in this paper include the quantity scale of transportation infrastructure and the following quality measurement indicators: per capita urban real roads, per capita highway mileage, and per capita railway operating mileage, which are all used to measure the per capita road and railway conditions. Graded highway proportion is used to measure road quality. Road freight turnover volume and railway freight turnover volume are used to measure the quantity of cargo transported. The highway passenger transportation turnover and the railway passenger transportation turnover are used to measure the average passenger turnover volume. In fact, the cargo and passenger turnover volume can indicate the actual use and capacity of the transportation infrastructure. Due to the availability of data, the output variables do not include air and sea transportation indicators; for the purposes of this paper, transportation infrastructure mainly comprises roads and railways. In addition, accessibility can measure the level of transportation infrastructure development. Referring to Faber and Liu Chong, a feasible measurement method is to calculate the geographical center location of each region based on the national electronic map containing traffic information combined with the boundary of administrative divisions and to calculate the shortest distance from the geographical center to each traffic line with the geographic information system software (ArcGIS) [24,25]. This variable is more microscopic and convincing than other macro variables mentioned before, but data collection and estimation are more complex. In order to focus on efficiency and integrity and to simplify research, we decided not to include accessibility in the output variables. The input and output measurement indicators for the construction of China's transportation infrastructure are shown in Table 1.

Table 1. Measurement indicators of input and output of transportation infrastructure.

Types	Indicators	Descriptions
Input variable	Public expenditure for transportation	100 million yuan, to measure local government's expenditure in the transportation sector
Output variables	Per capita urban real road	Km/10,000 people, ratio of the length of the road at the end of the year to the total population
	Per capita highway mileage	Km/10,000 people, the ratio of the number of highways maintained by local authorities to the total population
	Graded highway proportion	The ratio of graded roads to total highway mileage, measuring road quality
	Per capita railway operating mileage	Km/10,000 people, ratio of the number of railways maintained by local authorities to the total population
	Road freight turnover volume	100 million tons/km, measuring the actual usage of the road and road capacity
	Highway passenger turnover volume	100 million people/km, measuring the actual passenger turnover volume and capacity of the highway
	Railway freight turnover volume	100 million tons/km, measuring the actual usage and capacity of the railway
	Railway passenger turnover volume	100 million people/km, measuring the actual passenger turnover volume and capacity of the railway
Environmental variables	Per capita GDP	Measuring the economic development of the region
	Population density	Measure regional population density
	Openness level	Measuring regional openness

Source: China Statistical Yearbook, Provincial Statistical Yearbook.

3.2. Degree of Government Integrity

The degree of government integrity is based on the indicators used by Chen Gang, Shi Qing, and Huang Shoufeng [11,26,27]. The ratio of the number of cases of malpractice (pieces) to the number of public officials (per 10,000 people) is used to measure government integrity (government integrity 1). The number of cases of government malpractice refers to the number of cases investigated by the People's Procuratorate for investigating corruption, bribery, and dereliction of duty; the number of public officials refers to the number of officials who are employed at various levels in state administration and state-owned social organizations. In addition, Chinese literature also measures the degree of government integrity in terms of the ratio of the number of local government malpractice cases filed to the People's Procuratorate to the local population (government integrity 2). The higher the value of government integrity indicators is, the lower the degree of government integrity and the larger the number of corrupt government officials. On the contrary, the lower the value of government integrity indicators is, the higher the degree of government integrity and the smaller the number of the government officials. The number of government malpractice cases filed is collected from the China Procuratorate Yearbook and the individual procuratorate's annual report of each province. Since data available to this study only include the number of government malpractice cases filed in 2007–2016, additional data come from provincial statistical yearbooks.

3.3. Environmental Variables

Following the methodology of Andreas Kyriacou, Gong Feng, and Liu Zimin, the environmental variables selected in the three-stage DEA model are per capita GDP, population density, and openness level [6,14,15]. Similar to the selection of indicators in Andreas Kyriaccu, Tang Qiming, and Wang Biao, the environmental variables in the truncated regression include per capita GDP, openness, fiscal decentralisation, fiscal competition, urbanisation, and population density [6,28]. Among them, population density is represented by the population per square kilometer; the openness level is measured by the proportion of imports and exports to GDP. Total import and export volume are converted into RMB by the annual average exchange rate of RMB to the US dollar in the past years. The degree of fiscal decentralisation draws on Chen Shuo's measurement standard. Local financial autonomy equals local fiscal net income/(local fiscal net income + central government transfer payment), where local fiscal net income equals local government's fiscal revenue minus the central government expenditure. The higher the autonomy is, the greater the degree of financial decentralisation. Financial competition draws on that of Xi Xiaoying to use the proportion of fiscal revenue to GDP, and the fiscal revenue is the local fiscal net income. Urbanisation is represented by the proportion of urban population in the region to the total population of the region [29]. The above data are drawn from the China Statistical Yearbook, the provincial statistical yearbook, the Ministry of Finance of China, and the State Administration of Taxation of China. The statistical description of each of the variables above is shown in the Table 2 below.

Table 2. Statistical description.

	Variable	Obs	Mean	Std. Dev.	Min	Max
Output variables	Per capita urban real road	341	2.35	1.082	0.591	5.868
	Per capita highway mileage	341	41.262	38.571	5.149	265.114
	Graded highway proportion	341	0.849	0.137	0.401	1
	Per capita railway operating mileage	341	1.032	0.876	0.136	5.012
	Road freight turnover volume	341	1578.513	1707.523	25.404	7899.32
	Highway passenger turnover volume	341	415.878	360.199	18.952	2470.106
	Railway freight turnover volume	341	849.546	795.315	4.108	4278.355
	Railway passenger turnover volume	341	326.269	252.881	0.931	1042.717
Input variable	Public expenditure for transportation	341	215.991	182.746	8.478	1982.63
Integrities	Integrity1	310	24.027	8.048	2.65	55.594
	Integrity2	310	0.565	0.197	0.147	1.321
Controls	Per capita GDP	310	40,065.83	22,606.06	6915	118,000
	Openness level	310	0.302	0.364	0.032	1.721
	Fiscal decentralization	310	0.503	0.199	0.06	0.9
	Fiscal competition	310	0.102	0.031	0.054	0.221
	Urbanization	310	52.569	14.295	22.61	89.6
	Population density	310	2737.216	1231.019	515	5967

Source: China Statistical Yearbook, Provincial Statistical Yearbook, China PR curatorial Yearbook, Annual Report of Provincial Procuratorates.

4. Models

4.1. Measurement of Transportation Infrastructure Investment Efficiency: Three-Stage DEA Model

The traditional DEA model was originally proposed by Cooper and Rhodes [30]. The DEA model is used to evaluate the relative effectiveness of the same sector, especially for the relative effectiveness of the production sector with multiple inputs and outputs. However, DUM cannot reach the efficiency frontier, which may be caused because of the three factors in management: inefficiency, external environment factors, and random error. Therefore, the traditional efficiency score is inaccurate. As a result, Fried proposed a three-stage DEA model and introduced the Tobit method to exclude the influence of environmental factors. However, the Tobit method could not discern and exclude environmental factors or statistical noise. Therefore, Fried used the SFA model to exclude environmental factors and statistical noise to reach more accurate results [31,32]. The DEA model is divided into input orientation and output orientation. In general, the three-stage DEA model adopts the input-oriented BCC (variable returns to scale) model. Therefore, our research was designed according to the three-stage efficiency model of Fried as follows [28]:

In the first stage, the input-oriented BCC model was used for the original input–output data of each province:

$$\min\theta - \varepsilon\left(\hat{e}^T s^- + e^T s^+\right), \tag{1}$$

$$s.t.\begin{cases} \sum_{i=1}^{n} X_i\lambda_i + S^- = \theta X_0 \\ \sum_{i=1}^{n} Y_i\lambda_i - S^+ = Y_0 \\ \sum_{i=1}^{n} \lambda_i = 1 \\ \lambda_i \geq 0,\ S^-,\ S^+ \geq 0 \end{cases}, \tag{2}$$

where i is the decision-making unit, indicating different provinces (i = 1, ... , I); X_i is the input vector of i province to the transportation infrastructure; Y_i is the transportation infrastructure output vector of i province; and θ is the efficiency value of infrastructure investment. When $\theta = 1,\ S^+ = S^- = 0$, the decision unit weak DEA is valid; when θ = 1, S+ ≠ 0, or S- ≠ 0, the decision unit weak DEA is valid. When weak $\theta < 1$, then the weak decision unit is not DEA effective. Equations (2) and (3) respectively represent input constraints and output constraints, and quadratic equations are convex constraints, constructing a convex hull composed of intersecting faces so as to ensure that invalid individuals are only compared with similar-scale "baseline" individuals, but there is no such convex constraint in the CRS model.

In the second stage, the SFA regression is performed on the slack variables to eliminate the influence of environmental factors and random noise on the efficiency evaluation of decision-making units. The slack variable reflects the initial inefficiency, consisting of environmental factors, management inefficiency, and statistical noise. The SFA regression is used to regress the first-stage slack variable onto the environmental variables and the mixed error term to separate the three effects. The SFA regression function is as follows:

$$S_{\mathrm{ni}} = f(z_i;\beta_n) + v_{ni} + \mu_{ni}; i = 1,\ldots I; n = 1,\ldots,N, \tag{3}$$

where S_{ni} is the slack value of the nth input of the ith province; Z_i is the environmental variable; β_n is the coefficient of the environmental variable; and $v_{\mathrm{ni}} + \mu_{ni}$ is the mixed error term, where v_{ni} is the random interference term and μ_{ni} is the management inefficiency term. If v ~ N(0, σ_v^2), $\mu \sim N^+\left(0,\sigma_\mu^2\right)$. In addition, according to the SFA regression results, the infrastructure investment of all provinces is adjusted to the same external environment, and the adjustment formula is as follows:

$$X^A_{\mathrm{ni}} = X_{ni} + [max(f(Z_i;\hat{\beta}_n)) - f(Z_i;\hat{\beta}_n)] + [max(v_{ni}) - v_{ni}], i = 1,\ldots I, n = 1,\ldots,N \tag{4}$$

where X^A_{ni} is the adjusted input; X_{ni} is the pre-adjustment input; the first term $[max(f(Z_i;\hat{\beta}_n)) - f(Z_i;\hat{\beta}_n)]$ indicates the adjustment of external environmental factors; and the second term $[max(v_{ni}) - v_{ni}]$ indicates that all provinces are under the same level of luck, eliminating random interference.

In the third stage, the adjusted investment variables are used to measure again the investment efficiency of each province's transportation infrastructure. The remeasured efficiency rates have eliminated the influences of environmental factors and random factors and are more realistic and reliable.

4.2. The Impact of Government Integrity on Investment Efficiency: Truncated Regression

We have measured the investment efficiency of the transportation infrastructure in each province with the use of the three-stage DEA model. By comparison, we found that the investment efficiency of each province's transportation infrastructure differed significantly from each other. In order to further explore the reasons for the differences in investment efficiency between the provinces, we examined the degree of government integrity to regress the efficiency of transportation infrastructure investment of each region. Since the DEA efficiency score is cut off at one point, the method of Kyriacou (2018) is used to choose the truncated regression. The model is as follows:

$$\hat{\theta}_{\text{it}} = \alpha + \beta_t + \lambda honesty_{it} + \phi Z_{it} + \varepsilon_{it} \quad (5)$$

where i and t represent the provinces and the time in the sample, respectively; $\hat{\theta}_{it}$ is the technical efficiency value obtained in the first stage; α is the constant, and β_t is the time fixed effect, while $honesty_{it}$ is the degree of the government integrity; and λ is the coefficient of investment efficiency reflected on the degree of government integrity, while ϕ is the reaction coefficient of the control variable Z_{it} to $\hat{\theta}_{it}$. In addition, because the DEA technical efficiency value is obtained by the intrinsic data generation process, the efficiency value is tested by the Bootstrap method.

5. Empirical Results

First, we used the three-stage DEA to measure investment efficiency of the transportation infrastructure in 31 provinces in China from 2007 to 2017; the results are shown in Table 3. We presented the measured efficiency scores of both traditional DEA (before adjustment) and the three-stage DEA (after adjustment), where Crste is technical efficiency and Vrste is pure technical efficiency. The results show that, (1) on average, the provinces with high levels of pure technical efficiency (Vrste) of transportation infrastructure investment in 2007−2016 were Guangdong, Hebei, Henan, Jiangsu, Liaoning, Inner Mongolia, Ningxia, Qinghai, Shandong, and Tianjin. In terms of Vrste, these provinces did not change much either before or after the adjustment, and the efficiency values both were 1, indicating that the transportation infrastructure investment efficiency in those provinces is relatively high. The bottom five provinces were Yunnan, Fujian, Sichuan, Guizhou, and Chongqing, indicating that these regions have low efficiency values, with the adjusted pure technical efficiency being only 0.44 and with Chongqing exhibiting the highest efficiency score, although only at 0.65. (2) Based on the results before and after the adjustment, after the exclusion of environmental and random factors, the adjusted sample investment efficiency value is significantly improved in comparison with the efficiency value through the traditional DEA measurement, which indicates that the environmental factors of the provinces reduced the government investment efficiency. Therefore, the use of traditional methods to estimate investment efficiency will underestimate investment efficiency. In addition, due to the specific characteristics of each province or region, the traditional DEA model will also reduce the accuracy of efficiency assessment. (3) Regions with higher efficiency distribution are not all located in the more developed, eastern part of the country. On the contrary, many regions with higher economic development, such as Beijing and Shanghai, have lower transportation infrastructure investment efficiency. This may be due to the fact that the transportation infrastructure investment in these areas has become more saturated and additional investment has decreased efficiency. In addition, the reason why Yunnan, Sichuan, Guizhou, Chongqing, and other regions have lower investment efficiency scores might lie with their characteristic mountainous geographical features, and the complicated geographical factors might increase the construction cost of transportation infrastructure, resulting in lower investment efficiency.

Table 3. The average value and ranking of infrastructure investment efficiency of each provincial government in 2007–2016.

	The Traditional DEA				The Three-Stage DEA			
Province	**Crste1**	**Ranking**	**Vrste1**	**Ranking**	**Crste2**	**Ranking**	**Vrste2**	**Ranking**
Anhui	0.89	8	0.91	17	0.96	7	0.98	15
Beijing	0.39	30	0.59	25	0.53	28	0.71	25
Fujian	0.45	28	0.47	29	0.51	30	0.53	30
Gansu	0.78	16	0.79	18	0.92	11	0.94	18
Guangdong	0.65	20	1.00	1	0.74	21	1.00	1
Guangxi	0.77	17	0.78	20	0.85	16	0.87	21
Guizhou	0.47	26	0.49	28	0.56	27	0.63	28
Hainan	0.86	10	0.92	16	0.94	9	0.97	17
Hebei	1.00	1	1.00	1	1.00	1	1.00	1
Henan	0.98	4	1.00	1	1.00	4	1.00	1
Heilongjiang	0.51	25	0.56	27	0.66	22	0.72	24
Hubei	0.79	15	0.93	14	0.84	17	0.97	16
Hunan	0.91	7	0.97	13	0.93	10	0.98	14
Jilin	0.68	18	0.74	22	0.75	19	0.81	22
Jiangsu	0.66	19	1.00	1	0.75	20	1.00	1
Jiangxi	0.92	6	0.93	15	0.99	6	0.99	13
Liaoning	0.88	9	1.00	1	0.91	12	1.00	1
Inner Mongoria	0.81	14	1.00	1	0.88	15	1.00	1
Ningxia	1.00	2	1.00	1	1.00	1	1.00	1
Qinghai	0.85	12	1.00	1	0.95	8	1.00	1
Shandong	0.86	11	1.00	1	0.88	14	1.00	1
Shanxi	0.85	13	0.98	12	0.90	13	0.99	12
Shaanxi	0.60	22	0.62	24	0.64	24	0.69	26
Shanghai	0.44	29	0.79	19	0.57	26	0.88	20
Sichuan	0.46	27	0.47	30	0.52	29	0.54	29
Tianjing	0.99	3	1.00	1	0.99	5	1.00	1
Tibet	0.94	5	1.00	11	1.00	1	1.00	1
Xinjiang	0.63	21	0.76	21	0.81	18	0.90	19
Yunnan	0.31	31	0.32	31	0.42	31	0.44	31
Zhejiang	0.58	23	0.68	23	0.65	23	0.72	23
Chongqing	0.57	24	0.59	26	0.63	25	0.65	27

Secondly, in order to study the differences in investment efficiency between provinces in more depth, we examined the impact of government integrity on infrastructure investment efficiency. In view of the fact that the efficiency value is a restricted variable, we employed the truncated regression. Due to limited availability of data on government integrity, we were only able to collect and process data between 2007 and 2016. Similarly to previous studies, we chose per capita GDP, urbanization, openness level, fiscal decentralization, fiscal competition, and population density as control variables. The regression results are shown in Table 4: Columns (1)–(4) list the effects of government integrity on different efficiency indicators. Among them, columns (1) and (2) list adjusted pure technical efficiency and the reflection of pure technical efficiency on the degree of government integrity. The result is significantly negative at the 0.01 level, indicating that, with other variables remaining constant, the higher the degree of corruption, the lower the efficiency of infrastructure investment of the region. When the degree of corruption increased by 1%, on average, pure technical efficiency decreased by 0.191 percentage points, while technical efficiency decreased by 0.161 percentage points. Columns (3) and (4) show the relationship between the efficiency score and the degree of government integrity when environmental factors were not excluded. In this case, the pure technical efficiency is also significantly negative at the 0.01 level, while the technical efficiency is significantly negative at the 0.05 level, demonstrating the same results as before, although the degree of significance is smaller.

On average, when the degree of corruption is increased by 1%, pure technical efficiency will be reduced by 0.167 percentage points while technical efficiency will be reduced by 0.121 percentage points.

Table 4. Impact of government integrity on infrastructure investment efficiency in 2007–2016.

	(1)	(2)	(3)	(4)
	Vrste2	**Crste2**	**Vrste1**	**Crste1**
Integrity1	−0.191***	−0.161***	−0.167***	−0.121**
	(−2.83)	(−3.13)	(−3.30)	(−2.41)
Per capita GDP	0.080	0.061	0.173***	0.110*
	(1.41)	(1.14)	(3.16)	(1.93)
Urbanization	0.250*	0.344***	0.294**	0.331***
	(1.70)	(2.66)	(2.34)	(2.84)
Openness level	−0.091	−0.127	−0.275**	−0.295***
	(−0.86)	(−1.61)	(−2.41)	(−3.25)
Fiscal decentralization	−0.525***	−0.313*	−0.405**	−0.051
	(−2.78)	(−1.93)	(−2.19)	(−0.28)
Fiscal competition	−2.133**	−3.321***	−1.606***	−2.560***
	(−2.46)	(−6.15)	(−3.05)	(−4.35)
Population density	−0.000	−0.000	−0.000	−0.000
	(−0.82)	(−0.67)	(−0.75)	(−0.45)
Constant	0.161***	0.179***	0.172***	0.195***
	(16.38)	(18.50)	(20.48)	(19.07)
N	131	214	143	229

t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6. Robustness Tests

Finally, in order to eliminate the impact of the difference in indicator selection on the results, we replaced two indicators for the government infrastructure investment efficiency and government integrity and then conducted a re-regression. Government investment efficiency has different measures, including technical efficiency (Crste) and pure technical efficiency (Vrste) before and after adjustment. In addition to the ratio of the number of government malpractice cases filed to the number of state officials (government integrity 1), Chinese scholars measure the degree of government integrity (government integrity 2) by the ratio of the number of government malpractice cases filed to the local population. In order to ensure that the selection of the measurement indicators would not affect the research results, we conducted re-regression on the breakpoints with the ratio of the number of government malpractice cases filed to the local population (government integrity 2). The regression results are shown in columns (1)–(4) (shown in Table 5). Except for the technical efficiency before adjustment, the other regression results were significantly negative, as in the original results.

On the other hand, in the basic regression, we used the data from 2007 to 2016 for regression. In order to confirm that the regression results would not be affected by the length of the time period, we selected the data from 2012 to 2016 to conduct the regression on the sample to exclude the time factor. The regression results are listed in columns (5)–(7), and the results are also significantly negative, with the intensity of the effect even greater than the baseline regression, which indicates that the impact of government integrity on infrastructure investment efficiency is more apparent in the last five years.

Table 5. Robustness Test.

	(1) Vrste2	(2) Crste2	(3) Vrste1	(4) Crste1	(5) Vrste2	(6) Crste2	(7) Vrste1	(8) Crste1
Integrity1	-	-	-	-	−0.227**	−0.323***	−0.227***	−0.261***
	-	-	-	-	(−2.16)	(−3.46)	(−2.62)	(−3.23)
Integrity2	−0.109*	−0.110*	−0.183**	−0.083	-	-	-	-
	(−1.67)	(−1.79)	(−2.57)	(−1.15)	-	-	-	-
Per capita GDP	0.088*	0.078	0.199***	0.141***	0.537***	0.076	0.438***	0.119
	(1.72)	(1.32)	(2.85)	(3.11)	(3.15)	(0.39)	(3.21)	(0.96)
Urbanization	0.238**	0.297**	0.232*	0.244**	0.142	0.236	0.048	0.096
	(2.04)	(2.20)	(1.81)	(2.07)	(0.78)	(0.81)	(0.22)	(0.73)
Openness level	−0.001	−0.115	−0.232**	−0.247***	0.274	−0.590	0.067	−0.429
	(−0.01)	(−1.44)	(−2.10)	(−2.67)	(0.87)	(−1.58)	(0.20)	(−1.40)
Fiscal decentralization	−0.758***	−0.500***	−0.713***	−0.270*	−1.597***	0.536	−0.748	0.565
	(−3.48)	(−2.84)	(−3.26)	(−1.85)	(−2.62)	(1.02)	(−1.64)	(1.53)
Fiscal competition	−1.265**	−2.702***	−1.081*	−2.186***	−1.329	−6.673***	−3.259*	−4.862**
	(−1.96)	(−5.42)	(−1.75)	(−3.04)	(−0.63)	(−2.83)	(−1.81)	(−2.54)
Population density	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000*	−0.000
	(−0.29)	(−0.87)	(−0.84)	(−0.72)	(−0.54)	(−1.06)	(−1.93)	(−1.20)
Constant	0.166***	0.183***	0.173***	0.197***	0.150***	0.185***	0.141***	0.158***
	(12.85)	(14.49)	(15.15)	(17.10)	(7.26)	(8.24)	(8.69)	(11.06)
N	131	214	143	229	49	69	51	69

t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

7. Conclusions and Implications

This paper examined the efficiency of China's transportation infrastructure investment and explained the differences in transportation infrastructure investment on the basis of government integrity. First, we established an input–output measurement index that includes the scale and quality of transportation infrastructure investment based on current literature. Secondly, using the three-stage DEA model, we applied the SFA method to eliminate the impact of environmental factors and random noise and to measure the efficiency of transportation infrastructure investment in 31 provinces from 2007 to 2017. Finally, based on the differences in infrastructure investment efficiency, we conducted a truncated regression to estimate the impact of government integrity on the efficiency of the local governments' investment in transportation infrastructure.

The results show that, (1) after the exclusion of environmental and random factors, the adjusted sample investment efficiency value is significantly higher than the efficiency value measured by traditional DEA models. This shows that environmental factors in various provinces reduce government investment efficiency and that traditional DEA models underestimate investment efficiency. (2) The provinces with higher efficiency in transportation infrastructure investment include Guangdong, Hebei, Henan, Jiangsu, Liaoning, and Tianjin. These provinces are located at the frontier of efficiency. In more developed areas, such as Beijing and Shanghai, the investment efficiency is comparatively lower. This may be because the transportation infrastructure investment in these areas has become saturated and additional investment actually reduces investment efficiency. (3) Low degree of government integrity (high degree of corruption) will significantly reduce the efficiency of infrastructure investment. On average, when the degree of government integrity would be reduced by 1%, the technical efficiency of government transportation infrastructure investment would be reduced by 0.161 percentage points.

Our findings show that, when the government invests in infrastructure, it needs to use the efficiency of fiscal expenditure instead of the scale of fiscal expenditure. With inefficiency, the mere expansion of the scale of expenditure does not necessarily generate higher returns. Therefore, the improvement of the efficiency of capital utilisation should be the first choice for the government. Furthermore, one way to improve government investment efficiency is to choose regions for investment carefully. For example, in areas where transportation infrastructure investment is saturated, such as Beijing and Shanghai, increased transportation infrastructure investment will only reduce government investment efficiency and distort resource allocation. However, areas such as Guangdong, Hebei, Tianjin, and other provinces with higher transportation infrastructure investment efficiency can continue to absorb funds and to preserve high levels of efficiency in infrastructure. Third, for less efficient provinces, such as Yunnan, Guizhou, and Sichuan, it is necessary to strengthen the control of government integrity, to further establish and improve various systems for punishing and preventing government corruption, to monitor closely the construction projects for transportation infrastructure, to clarify project responsibilities, and to strive to enhance the efficiency of government transportation infrastructure investment.

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