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Evaluation of Urban Infrastructure Investment Efficiency in Shandong Province

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***Abstract*—In the 13th five-year plan of Shandong Province, it is proposed that to follow the objective law of urbanization development and accelerate the construction of urban agglomeration, the investment efficiency of urban infrastructure is directly related to regional economic development and social progress, and plays an important role in the quality of residents' life. Based on the DEA (data envelopment analysis) and Malmquist index, this paper studies the investment efficiency of urban infrastructure in 17 prefecture-level cities in Shandong Province from 2006 to 2015. The results show that the investment efficiency of urban infrastructure investment in Shandong Province has been developing well in the past 10 years. The driving force of growth mainly comes from technological progress, while comprehensive technical efficiency and scale efficiency growth are small. Therefore, in order to improve the efficiency of urban infrastructure investment, the government should make scientific decisions and continue to improve the level of technological innovation of the infrastructure, enhance the management level and maintenance level of the infrastructure, allocate resources reasonably and realize the scale effect of infrastructure investment.**

Keywords—urban infrastructure; DEA; investment efficiency; Malmquist index

I. Introduction

Urban infrastructure is the general name of the engineering infrastructure and social infrastructure which the city must have in order to survive and develop, and is the general name of all kinds of equipment built for the smooth operation of various economic activities and other social activities in the city. Lin Senmu (1998) discusses the economic, political and administrative management of urban infrastructure in the book Urban Infrastructure Management. He thinks that urban infrastructure is the embodiment and systematization of the national economic infrastructure in the city, a public facility which provides general conditions for material production and people's life, and the foundation of the survival and development of the city. In the book, the urban infrastructure is outlined in six major systems: energy systems, water resources and water supply and drainage systems, transportation systems, post and telecommunications systems, environmental systems, and disaster prevention systems. This definition of urban infrastructure and the division of large systems have been widely recognized by academics and city administrators.

Urban infrastructure is the material basis for urban economic and social development and improvement of the residents' quality of life, an important carrier of local government functions and urban functions, and an indispensable part of ensuring the smooth operation of various economic activities and social activities in the city. Whether the construction of urban infrastructure is improved is an important factor to maintain the long-term sustainable economic development. In 2015, the State Council points in its "Opinions on Further Strengthening the Work of Urban Planning Construction and Management" that urban infrastructure is the material basis of normal operation and healthy development of the city, and plays an important role in improving the living environment, enhancing the comprehensive carrying capacity of the city, improving the efficiency of urban operation, steadily advancing the new type of urbanization, and ensuring the completion of a moderately prosperous society in all respects by 2020. At present, the urban infrastructure in China still has some problems, such as insufficient quantity, low standard and extensive operation management. Strengthening the construction of urban infrastructure will facilitate the transformation of economic structural adjustment and development mode, drive investment and consumption growth, expand employment, and promote energy conservation and emission reduction.

With the continuous improvement of science and technology and the continuous improvement of the quality of people's living standards, urban development has constantly

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put forward new requirements for urban infrastructure construction, therefore, the construction of urban infrastructure must keep pace with the development of cities and coordinate with each other. Suggestions on the formulation of the 13th five-year plan for national economic and social development in Shandong Province have been put forward to promote the development of urban and rural integration, improve the urban public service system, build the three-dimensional transportation network, improve municipal public facilities such as underground pipe rack, flood control and waterlogging prevention, and construct ecological city, sponge city. So it can be seen, in the 13th five-year plan of Shandong Province, urban development has been placed in an important position, and the level of urban infrastructure construction directly affects the level of urban development, so it is very important to focus on improving the level of infrastructure construction in Shandong Province. In recent years, scholars have paid more attention to the research on the investment efficiency of urban infrastructure in China, and have obtained rich research results. Wu Wenzhong (2011) analyses the efficiency of urban infrastructure investment in the provinces of China from 2001 to 2008 and comes to a conclusion that the infrastructure investment in Tianjin, Hebei, Shanxi, Jiangsu, Zhejiang, Anhui, Shandong, Henan, Hubei and Hunan is more efficient, the infrastructure investment efficiency of Beijing, Shanghai and Guangdong is lower, and the infrastructure investment in Yunnan, Ningxia, Xizang and Hainan is the least efficient. After studying the investment efficiency of China's urban infrastructure construction in 2012, Hu Zongyi, Lu Yaochun and Liu Chunxia (2014) find that the investment efficiency of urban infrastructure in the eastern region is significantly higher than that in the central and western regions, while the investment efficiency of urban infrastructure in the central region is higher than that in the western region, meanwhile, the investment efficiency of urban infrastructure construction in most provinces and cities has some room for improvement. Li Xiaoyuan (2015) analyses the efficiency of urban infrastructure investment in China from 2004 to 2013 and finds that China's urban infrastructure investment efficiency is not high overall, and there are major differences between the provinces, especially in Shanghai, Zhejiang, Jiangxi and Guangdong Province it is relatively high. Wei Wei and Kuang Xiong (2016) study the investment efficiency of urban infrastructure construction in 30 provinces, autonomous regions and municipalities in China in 2013, the results show that China's urban infrastructure investment efficiency is relatively high in 2013, which presents a pattern of low efficiency in western regions and high efficiency in coastal areas. From previous researches, it can be seen that the investment efficiency of urban infrastructure investment is mainly concentrated in 31 provinces and autonomous regions of China, and there are few studies focusing on one province or region. As an economic power and populous province in China, Shandong Province's urban infrastructure is directly related to the development of the city and the improvement of people's living standard. In view of this, 17 cities in Shandong Province are selected as the research objects in this paper, and the investment efficiency of urban infrastructure in the 10 years from 2006 to 2015 is analyzed using the DEA(data envelopment analysis)-Malmquist index.

II. Study Design

A. Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) method provides a good idea to study the investment efficiency of infrastructure from multiple outputs. Data envelopment analysis refers to constructing effective production front surface with the use of existing data. The method was first proposed by Charnes, Cooper and Rhodes (1978), they assume that all decision-making bodies should be paid the same, then use linear programming to find the efficiency front of each decision subject, and finally give the relative efficiency of each decision subject. The basic idea of DEA method is to evaluate the relative availability of multiple inputs and multiple output units using the mathematical linear programming model. Data enveloping surface formed relatively effective production frontier, thus each decision unit is projected onto the relatively effective production front surface, the relative effectiveness is evaluated by comparing the degree of deviation of the front surface by the comparison decision unit. The production front surface is a generalization of the production function in economics to the multi-output situation, using DEA method and model can determine the structure of the front surface of production, so DEA method can be regarded as a non-parametric statistical estimation method. Therefore, judging whether DMU (decision making unit) is effective for DEA is essential to judge whether DMU is at the forefront of production possible set. Because it is a relatively efficient evaluation of efficiency, it does not require data dimensionless processing. Its weight is the dynamic weight generated by its linear programming system, so it requires no weight assumption, and DEA analysis is the most effective non-parametric method for evaluating efficiency.

B. Malmquist Index

The DEA model solves only the relative efficiency of multiple decision units at the same time; it does not analyze the efficiency of a decision unit over a period of time. In a certain period of time, because the efficiency and technical level of the decision unit cannot remain the same, the production front side can’t maintain the same front side, at this point, we need to evaluate the changes in efficiency and technology, it is not enough to evaluate the model with non-parametric original DEA. In order to solve this problem, in this paper, the Malmquist index method is introduced to analyze the efficiency of decision unit in a certain time period.

The Malmquist index was first proposed by StenMalmquist in 1953; RolfFare etc. combined the non-parametric linear programming method of this theory with data envelopment analysis (DEA) theory in 1994, making the Malmquist index widely used in the calculation of the efficiency of various departments. The Malmquist index analyses the efficiency changes due to the inability of the production frontier to maintain the same frontier in a certain period of time. In the BBC model, total factor productivity changes can be decomposed into changes in technological progress and integrated technical efficiency, and the change of integrated technical efficiency can be further decomposed into the change of pure technology efficiency and scale efficiency, that is, total factor productivity change = technological progress change × comprehensive technical efficiency change, integrated technical efficiency change = pure technical efficiency change ×scale efficiency change.

C. *Index Selection and Data Source*

Generally speaking, the selection of input-output indicators should consider the objectivity, representativeness, importance and accessibility of indicators. This paper borrows the selection method of indicators from scholars such as Li Qi (2016), Zhang Qi (2016) and Cheng Min(2017), then select the per capita water supply, the adoption rate, every 10,000 people having buses, per capita urban road area and per capita urban green area as input indicators, and adopts the per capita GDP and per capita disposable income as the output index. The input and output indicators adopt per capita data, which can exclude the interference factors caused by the population of 17 cities, so as to reflect the efficiency of urban infrastructure investment more accurately. The indicator system is shown in "Table I".

TABLE I. EVALUATION INDEX SYSTEM OF URBAN INFRASTRUCTURE INVESTMENT EFFICIENCY

	System	*Evaluation index*
Input indicators	Water resources system	Per capita water supply (ton)
	Living energy system	Adoption rate (%)
	Public transport system	Every 10,000 people having buses(car)
	Road traffic system	Per capita urban road area (m2)
	Urban ecosystem	Per capita urban green space (m2)
Output indicators	Economic level	GDP per capita (yuan)
	Residents live	Per capita disposable income (yuan)

III. EMPIRICAL ANALYSIS

A. *Analysis on Investment Efficiency of Urban Infrastructure in Shandong Province Based on DEA Method*

1) Overall characteristics of investment efficiency of urban infrastructure in Shandong Province: Using the DEAP2.1 software, this paper calculates the investment efficiency of urban infrastructure in 17 prefecture-level cities in Shandong Province from 2006 to 2015, and obtains comprehensive technical efficiency, pure technical efficiency and scale efficiency of urban infrastructure investment efficiency, the specific calculation results are shown in "Table II". As can be seen from "Table II", the comprehensive technical efficiency of investment efficiency of urban infrastructure investment in Shandong Province is 0.868, the lowest value is 0.813, and the maximum value is 0.938. It shows that the investment efficiency of urban infrastructure in Shandong Province is low. The total efficiency of 2015 was 0.938, meaning that if the current production elements were all played out, the output could be increased by 6.61% in the same input.

TABLE II. EFFICIENCY OF URBAN INFRASTRUCTURE INVESTMENT IN SHANDONG PROVINCE

Year	**Comprehensive technical efficiency**	**Pure technical efficiency**	**Scale efficiency**
2006	0.902	0.965	0.928
2007	0.903	0.971	0.925
2008	0.851	0.952	0.889
2009	0.822	0.947	0.862
2010	0.818	0.954	0.850
2011	0.813	0.946	0.848
2012	0.853	0.961	0.881
2013	0.864	0.966	0.889
2014	0.914	0.975	0.933
2015	0.938	0.971	0.965
Mean	0.868	0.961	0.897

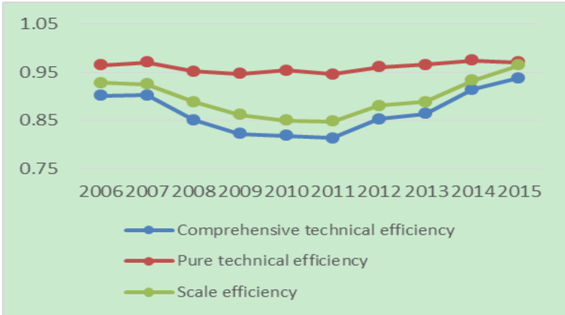

Fig. 1. Decomposition of urban infrastructure investment in Shandong Province.

From 2006 to 2015 as in "Fig. 1", the integrated technical efficiency curve and the pure technical efficiency curve and the scale efficiency curve are basically in the same direction. This shows that the efficiency of pure technology and scale efficiency of urban infrastructure investment efficiency has a certain effect on the comprehensive technical efficiency in each year. In particular, the integrated technical efficiency curve and the scale efficiency curve have larger vibration amplitude, and the fit is higher, and the pure technical efficiency curve has a very small vibration amplitude, this indicates that the efficiency of the scale efficiency of urban infrastructure investment in Shandong Province is stronger than pure technical efficiency, and the change of comprehensive technical efficiency is mainly due to the change of scale efficiency. This is mainly because the change in the size of the investment funds embodied in the scale efficiency will appear in the current period, for example, the increase of the number of buses and the increase of urban green space per capita; the change of management efficiency represented by pure technical efficiency is less obvious and the change is more stable. At the same time, it can be seen that the three trends can be divided into two stages in 2006-2015.

- Stage 1: 2006-2011. At this stage, comprehensive technical efficiency, pure technical efficiency and scale efficiency all present the trend of decline. Among them, comprehensive technical efficiency drops from 0.902 in 2006 to 0.813 in 2011, with a decline of 9.87%; the change in scale efficiency is similar to that of comprehensive technical efficiency, from 0.928 in 2006 to 0.848 in 2011, with a decrease of 8.62%; and the change of pure technical efficiency is relatively small, which shows the trend of the downward oscillation, from 0.965 in 2006 to 0.946 in 2011, with a decrease of 1.97%. It can be seen that the three efficiencies have declined in this stage.

- Stage 2: 2011-2015. At this stage, comprehensive technical efficiency, pure technical efficiency and scale efficiency all present rising trend. Among them, the overall technical efficiency increases significantly, from 0.813 in 2011 to 0.938 in 2015, up by 15.4%; the increase of scale efficiency is also relatively large, and its change is similar to that of comprehensive technical efficiency, from 0.848 in 2011 to 0.965 in 2015, up by 13.8%; the increase in pure technical efficiency is relatively small, from 0.946 in 2011 to 0.971 in 2015, with a rise of 2.64%. Thus, three efficiencies have risen in this stage.

2) Analysis on the difference of investment efficiency of urban infrastructure in 17 cities in Shandong Province: In this paper, a DEA model is established based on data from 17 cities in Shandong Province in 2015 to calculate the differences in the efficiency of urban infrastructure investment. The results are shown in "Table III".

TABLE III. DECOMPOSITION OF URBAN INFRASTRUCTURE INVESTMENT EFFICIENCY IN 2015

City	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Return to scale
Jinan	1.000	1.000	1.000	-
Qingdao	1.000	1.000	1.000	-
Zibo	1.000	1.000	1.000	-
Zaozhuang	1.000	1.000	1.000	-
Dongying	1.000	1.000	1.000	-
Yantai	0.860	0.980	0.878	drs
Weifang	0.968	1.000	0.968	drs
Jining	0.799	0.910	0.878	drs
Taian	1.000	1.000	1.000	-
Weihai	0.981	1.000	0.981	drs
Rizhao	1.000	1.000	1.000	-
Laiwu	1.000	1.000	1.000	-
Linyi	0.972	1.000	0.972	drs
Dezhou	0.905	1.000	0.905	irs
Liaocheng	0.754	0.794	0.951	irs
Binzhou	0.713	0.823	0.866	drs
Heze	1.000	1.000	1.000	-
Mean	0.938	0.971	0.965	

a. Note: the comprehensive technical efficiency is 1, indicating that the investment efficiency of infrastructure is optimal; the total technical efficiency is less than 1, indicating inefficiency; drs represents a diminishing return on scale, and irs represents an increase in the size of the payment, which represents the same amount of compensation.

As can be seen, the investment efficiency of urban infrastructure in 17 cities in Shandong Province is ideal in 2015, the average technical efficiency is 0.938, the comprehensive technical efficiency of nine cities including Jinan and Qingdao is 1, which is effective. The comprehensive technical efficiency of the other eight cities is less than 1, and the efficiency of investment is ineffective. The comprehensive technical efficiency of Binzhou is only 0.713, which ranks the bottom of the list. From the perspective of the decomposition of pure technical efficiency and scale efficiency, the pure technical efficiency value of the four cities of Weifang, Weihai, Linyi and Dezhou is 1, the invalid comprehensive technical efficiency is caused by the low scale efficiency and pure technical efficiency; the low efficiency of comprehensive technical efficiency of Yantai, Jining, Liaocheng and Binzhou is the result of both the low efficiency of pure technology and the low efficiency of scale. In terms of scale revenue, nine integrated technologies, such as Jinan and Qingdao, have achieved the best performance of the city scale, the six cities of Yantai, Weifang, Jining, Weihai, Linyi and Binzhou are in the stage of diminishing returns, we should scale back investment and improve management level so as to improve the efficiency of urban infrastructure investment. Dezhou and Liaocheng are in a phase of increasing compensation; we should expand investment and improve management level so that the efficiency of urban infrastructure investment can be improved.

B. Analysis of Investment Efficiency of Urban Infrastructure in Shandong Province Based on Malmquist Index

1) Overall characteristics of Malmquist index of urban infrastructure investment in Shandong province: Importing the data into the DEAP2.1 software, the Malmquist index method is adopted to calculate a total of 170 decision-making units from 2006 to 2015 in 17 prefectural cities in Shandong Province, this paper gets comprehensive technical efficiency change(effch), technical progress change(techch), pure technical efficiency change(pech), scale efficiency change(sech) and total factor productivity change(tfpch). The specific results are shown in "Table IV".

a) Analysis of total factor productivity: In the decade between 2006 and 2015, the total factor productivity of urban infrastructure investment in Shandong Province increased by 4.9%, the comprehensive technical efficiency increased by 0.6%, and technological progress increased by 4.3%. Thus, the improvement of technological progress is the main factor in total factor productivity urban infrastructure investment in this decade, but the improvement of comprehensive technical efficiency is lower. Further analysis shows that the total factor productivity change in 2012 and 2015 is less than 1, which means the investment efficiency of urban infrastructure in Shandong Province has declined in this two years, and the remaining years have improved. At the same time, the decline of the two years is attributed to the decline in technological progress, which is 0.1% and 1.6% respectively. The three biggest increases in total factor productivity are in 2014, 2008 and 2011, increased by 10.3%, 8.7% and 8.5%, respectively. the impetus for growth in 2014 comes from the joint improvement of comprehensive technical efficiency and technological progress, and the contribution of comprehensive technical efficiency is greater. The growth in 2008 and 2001 comes from improvements in technology, but overall technical efficiency is falling. The above analysis shows that the investment efficiency of urban infrastructure investment in Shandong Province has been developing well in 2006-2015, and the overall level of investment in urban infrastructure has been rising. The driving force of growth is the technological progress, and the level of comprehensive technical efficiency needs to be improved.

b) Analysis of changes in technology progress: That the change of technological progress is greater than 1 indicates technological progress and less than 1 indicates technical regression. As can be seen from "Table IV", there are two years of decline in technological progress, which are 6.6% and 5% for 2012 and 2015 respectively, this corresponds to the year when total factor productivity declines, the rest of the year's

TABLE IV. MALMQUIST INDEX AND ITS DECOMPOSITION RESULTS OF THE URBAN INFRASTRUCTURE INVESTMENT EFFICIENCY IN SHANDONG PROVINCE

Year	Effch	Techch	Pech	Sech	Tfpch
2007	1.001	1.033	1.007	0.994	1.034
2008	0.940	1.157	0.980	0.959	1.087
2009	0.965	1.108	0.995	0.970	1.069
2010	0.989	1.052	1.006	0.983	1.040
2011	0.984	1.103	0.990	0.993	1.085
2012	1.070	0.934	1.020	1.049	0.999
2013	1.017	1.032	1.006	1.011	1.049
2014	1.061	1.039	1.010	1.050	1.103
2015	1.036	0.950	0.994	1.042	0.984
Mean	1.006	1.043	1.001	1.005	1.049

Technological progress is in a state of improvement. The three biggest increases in technological progress are in 2008, 2009 and 11, respectively, up 15.7%, 10.8% and 10.3%. This shows that the overall situation of technological progress in the past decade is good, but in recent years, especially since 2012, there has been a downward trend.

c) Analysis of comprehensive technical efficiency changes: From the perspective of the comprehensive technical efficiency change, comprehensive technical efficiency of urban infrastructure investment in Shandong Province in ten years shows a tendency of decreasing firstly and then increasing, this change is made of pure technical efficiency and common scale efficiency. In the phased stage, the comprehensive technical efficiency of 2008-2011 is reduced, which is mainly influenced by the decrease of pure technical efficiency and scale efficiency, while the influence of scale efficiency is greater. The comprehensive technical efficiency of 2012-2015 keeps increasing, which is mainly influenced by the improvement of pure technology efficiency and scale efficiency, and the impact of scale efficiency is greater. This indicates that the comprehensive technical efficiency level of the ten years has maintained an upward trend overall, but the average growth rate of 0.6% means that the increase of the comprehensive technical efficiency level is smaller. The average growth rate of 0.1% of pure technical efficiency and the average growth rate of 0.5% of scale efficiency illustrate the urban infrastructure management methods and management efficiency remain to be improved, and it is necessary to optimize the configuration structure of the inputs, realize optimum scale of urban infrastructure configuration, and improve the efficiency of scale.

2) Study on the differences of Malquist index between the 17 cities in Shandong Province: The Malmquist index of urban infrastructure investment based on the output of different urban models is calculated as shown in table V, which analyzes the change of total factor productivity in various cities between 2006 and 2015. "Table V" includes comprehensive technical efficiency change, technical progress, pure technical efficiency change, scale efficiency and total factor productivity change according to the Malmquist index decomposition of 17 decision-making unit.

TABLE V. AVERAGE VALUE OF INVESTMENT EFFICIENCY OF URBAN INFRASTRUCTURE INVESTMENT IN VARIOUS CITIES IN SHANDONG PROVINCE FROM 2006 TO 2015

City	Effch	Techch	Pech	Sech	Tfpch
Jinan	1.013	1.039	1.000	1.013	1.053
Qingdao	1.056	1.130	1.004	1.052	1.193
Zibo	1.000	1.048	1.000	1.000	1.048
Zaozhuang	1.000	1.019	1.000	1.000	1.019
Dongying	1.000	1.069	1.000	1.000	1.069
Yantai	0.983	1.055	0.998	0.986	1.038
Weifang	1.023	1.091	1.010	1.012	1.116
Jining	1.002	1.019	0.995	1.006	1.021
Taian	1.000	1.052	1.000	1.000	1.052
Weihai	0.998	1.073	1.000	0.998	1.071
Rizhao	1.000	1.020	1.000	1.000	1.020
Laiwu	1.006	1.066	1.002	1.004	1.073
Linyi	0.997	0.992	1.000	0.997	0.989
Dezhou	1.085	1.018	1.046	1.037	1.104
Liaocheng	0.984	1.052	0.982	1.002	1.035
Binzhou	0.963	1.049	0.979	0.984	1.010
Heze	1.000	0.950	1.000	1.000	0.950
Mean	1.006	1.043	1.001	1.005	1.049

From the perspective of the change of total factor productivity, only the value of Linyi and Heze is less than 1, the value of other 15 cities is greater than 1, which indicates that the investment efficiency of Linyi and Heze is in decline in the past 10 years, and the average decline is 1.1% and 5%, respectively. The decrease of total factor productivity of Linyi is derived from the decline of comprehensive technical efficiency and technical retrogression, Heze mainly comes from technology regression. In addition, the growth rate of urban infrastructure investment is the largest in Qingdao, Weifang and Dezhou, the growth rate is 19.3%, 11.6% and 10.4%, respectively. The three cities keep higher total factor productivity growth, both from the high degree of growth of comprehensive technical efficiency, also from technological progress, the contribution of technological progress is greater than the contribution of the comprehensive technical efficiency growth in Qingdao and Weifang, and the contribution of comprehensive technical efficiency growth is greater than the contribution of technological progress in Dezhou.

From the change of comprehensive technical efficiency, the value of Jinan, Qingdao, Weifang, Jining, Laiwu is greater than 1, which shows that the comprehensive technical efficiency keeps a rising trend; value of Zibo, Zaozhuang, Dongying, Taian, Rizhao and Heze is equal to 1, which shows that the comprehensive technical efficiency remains the same; and the value of Yantai, Weihai, Linyi, Liaocheng and Binzhou is less than 1, which shows that the comprehensive technical efficiency keeps downward trend. The biggest increase is in the city of Dezhou, with a growth rate of 8.5%, the increase is mainly due to the growth of scale efficiency. The steepest decline is in Binzhou, with a decline of 3.7%, its decline comes from the decline of pure technical efficiency, and also from the decline of scale efficiency.

From the perspective of technological progress, only Linyi and Heze present the trend of technology retrogression, and other cities as a whole has a certain degree of technology progress, the technological progress of Qingdao is sharpest, achieving 13%. The growth of Weifang, Weihai and Dongying is larger, at 9.1%, 7.3% and 6.9% respectively; the technical progress of Zaozhuang, Jining and Dezhou is relatively low, at 1.9%, 1.9% and 1.8% respectively.

From the changes of pure technical efficiency and scale efficiency, the overall change of the 17 cities in Shandong Province is not large, and it remains relatively stable. The average growth rate of pure technical efficiency in Dezhou is relatively large, with the increase of 4.6%. The scale efficiency of Qingdao and Dezhou is relatively significant, with the growth rate of 5.2% and 3.7% respectively.

IV. Conclusion

A. Research Conclusions

Based on the DEA-Malmquist index method, this paper analyzes and studies the investment efficiency of urban infrastructure in 17 cities in Shandong Province from the perspective of multi-input and multi-output, and draws the following conclusions: between 2006 and 2015, the investment efficiency of urban infrastructure in 17 cities in Shandong Province is in good condition and keeps the upward trend. The main effect on it is technological progress, and the role of management level and investment scale is not obvious. Specific to the situation of the cities, most cities maintain the growth of investment efficiency of urban infrastructure, but the difference in the increase is large, and some cities have the problem of technology regression, insufficient management level and uneconomical scale. Therefore, to continue to improve the efficiency of urban infrastructure investment in Shandong Province, we need to comprehensively consider the factors such as technological progress, management innovation and optimizing the investment scale.

B. Countermeasures and Suggestions

Continue to improve the technological innovation capacity of urban infrastructure. Improving the ability of technological innovation and accelerating technological progress is the fundamental way to improve the efficiency of urban infrastructure investment. Through the calculation of Malmquist index in 17 cities in Shandong Province, it can be seen that the improvement of investment efficiency is mainly due to the improvement of technology. Through technological innovation, it can effectively reduce the cost of investment, improve the construction level and service capacity of urban infrastructure, and thus improve the efficiency of investment. In the development of urban infrastructure construction of Shandong Province, therefore, we should give full play to the role of technological progress, both to improve the scientific and technological innovation capability of urban infrastructure construction, and to improve the level of technology in the urban infrastructure maintenance.

Improve the level of urban infrastructure management. The empirical analysis shows that the pure technical efficiency growth which responds management level is very small, which indicates that the government has some deficiencies in urban infrastructure management, and there is a waste of resources, nevertheless this kind of situation has not been given enough attention and reasonable solution. Therefore, in the city infrastructure construction of Shandong Province, we should raise the management awareness of the management department, increase the management of the infrastructure, avoid the phenomenon of repeated construction, and gradually solve the problem of waste of resources.

Allocate resources reasonably and realize the scale effect of urban infrastructure construction. In recent years, the scale efficiency of urban infrastructure construction in Shandong Province has been increasing gradually, but the overall growth level is not high. In this regard, we should optimize the investment structure and maintain a moderate scale of investment growth, optimize the allocation of resources among cities, and optimize the allocation of resources among urban infrastructure categories. By realizing the scale effect of urban infrastructure construction, we can improve investment efficiency and give full play to the role of urban infrastructure development in promoting economic and social development.

References

[1] Lin Senmu, "Urban infrastructure management," Beijing capital press, pp. 13-14, 1998.

[2] Wu Wenzhong, Investment efficiency of infrastructure and economic effect analysis - based on DEA analysis. Economic problems, 2011, pp.41-45.

[3] Hu Zongyi, Lu Yaochun, Liu Chunxia, Evaluation of investment and financing performance of urban infrastructure construction in China -- empirical analysis based on the three-stage DEA model. East China economic management, 2014, pp. 85-91.

[4] Li Xiaoyuan, Analysis and policy recommendations on urban infrastructure investment efficiency in the new urbanization process. Macroeconomic research, 2015, pp. 35-43.

[5] Wei Wei, Kuang Xiong, Analysis of investment efficiency and influencing factors of urban infrastructure construction in China, based on the DEA - TOBIT model . Modern business, 2016 , pp. 178-179.

[6] Charnes A, Cooper W W, Rhodes E, Measuring the efficiency of decision making units. European Journal of Operational Research, 1978, pp. 429-444.

[7] Li Qi, Sun Yu, Cui Yin, Evaluation of infrastructure investment efficiency based on DEA method. Resources and environment in dry areas, 2016, pp. 26-30.

[8] Zhang Qi, Tong Jixin, "One Belt And One Road" urban infrastructure utilization efficiency analysis -- based on DEA and Malmquist index model. Soft science, 2016, pp. 115-116.

[9] Cheng Min, Pei Xinjie, Time and space differences in the input efficiency of urban infrastructure in China and above - based on DEA and Malmquist index model. Management review, 2017, pp. 79-80.