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Study on the efficiency of China's main river ports based on DEA model

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Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no materials are included for which a degree has previously been conferred on me.

The content and research of this paper were completed by myself without any help from others.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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Supervised by

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Abstracts

Title of Research paper: **Study on the efficiency of China's main river ports based on DEA model**

Degree: **M.Sc.**

This paper uses the three-stage DEA method to conduct an empirical study on the efficiency of 15 inland river ports in China's four main water lines of the Yangtze river, Songhua river, Grand canal and pearl river in 2016. The empirical results show that, first of all, the efficiency of China's major inland river ports is generally low, among which, scale inefficiency is the main reason for the overall operating inefficiency. Second, there are large differences in the efficiency of inland river ports with different water systems. The Grand Canal canal is relatively high, followed by the Yangtze river and Songhua river water systems, while the pearl river system is relatively low. Third, China's major inland river ports have serious congestion in terms of input and output, which is more than 50%, indicating that the port resource waste is very serious. Fourth, environmental effect and random error do have different effects on the production efficiency of inland river ports. Fifth, there are differences in efficiency between upstream and downstream ports of the same water system.

Finally, this paper puts forward countermeasures and suggestions to improve the efficiency of China's inland river ports.

【**Key Words**】three-stage DEA; inland river ports; the efficiency

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1. The introduction

Economic development led to the further development of the logistics transportation, logistics and transportation industry development relies on the construction of roads, railways and shipping, especially in the current, the role of ports to promote regional economic development is more and more obvious, logistics service functions are powerful. China has entered into a new stage of development, the country attaches great importance to the inland waterway transport, many local governments invest more money and energy on the construction of inland port, hope to improve the city's economic and social development level that through the development of port logistics. Inland port logistics plays an important role in the modern integrated transportation network, and China will continue to deepen the construction of inland river port, because the construction and management of inland river port has the great significance.

At present, our country inland waterway and port infrastructure construction has achieved remarkable results, formed in the Yangtze river, pearl river, the grand canal, the Huaihe river, Heilongjiang and Songliao water system as the main body of the inland river navigation system, inland port hinterland in promoting economic development, promoting regional economic integration has played a more and more important role. However, the development of ports in China is very uneven, since a long time, the development of inland port behind the coastal ports, and inland port efficiency is very low with serious waste of resources, inland port did not play a role in comprehensive transportation system in our country.

The advantages of inland waterway transport are: low cost, less land, low energy consumption, low pollution, large capacity and speeding up the development of inland waterway transport, which can effectively alleviate the tension of land resources of river basin and commodities of road transport pressure, plays a positive role on saving energy and reducing emissions. The ministry of transport had promulgated the national plan for the distribution of inland waterways and ports. For the first time, it had made plans for the distribution of inland waterways and ports across the country. This paper used the three-stage DEA method to analyze the efficiency and problems of major inland river ports in China, and puts forward the direction of efficiency improvement and countermeasures and suggestions, which will help the healthy development of inland river ports and shipping in China.

With the deepening of international division of labor and the rapid development of economic globalization, port has become an important breakthrough for dynamic improvement of comparative advantage. In today's international division of labor based on the factors of production flow and restructuring, division of labor object into the internal process and link, and according to the element concentration in all stages of production factor allocation on a global scale. With the accelerating flow elements, products, logistics cost and transaction cost, dynamic enhance revenue generated by the comparative advantage may be offset, so the dynamic of comparative advantage does not automatically to achieve ascension. Especially significant for large developing countries with imperfect logistics networks and high transaction costs.In order to realize the enhancement of dynamic comparative advantage, China needs to improve the logistics efficiency of trade. However, port plays an important role in the global logistics network, and its efficiency improvement is undoubtedly of critical importance to the improvement of China's dynamic comparative advantage. With the evolution of port function under the current international division of labor, the port economic performance and its most important measurement index, port efficiency, have changed in connotation. In this paper, the connotation of port efficiency is divided into three levels according to the three main economic relations in the process of realizing port function. In the process of a port operations, at one port and other ports in economic ties, in the port and hinterland economic ties, various inputs relative to the port output capacity utilization, respectively reflect the port internal operational efficiency, and between the ports of the network efficiency, port radiation efficiency on the interior economy. Based on the existing gravity model, the port efficiency is introduced and the regression analysis is made. The results show that the improvement of port efficiency can have a significant positive effect on trade scale. This further demonstrates the importance of port efficiency to dynamic comparative advantage and trade scale. In view of this, this paper USES data envelopment analysis (DEA) method to measure and evaluate the efficiency of China's main inland river ports. In general, most of China's ports, port and hinterland regions of different degree of inefficiency, including in China trade occupy the important position of inland port, and the efficiency of the port system did not realize can improve step by step. For further analysis found that the evaluation result, or inadequate or excessive competition in the market competition, element configuration main body appear a certain degree of dislocation phenomenon, etc., was the main reason for the low efficiency of Chinese ports. Therefore, this paper puts forward some countermeasures that are more beneficial to the improvement of the efficiency of Chinese ports. The innovative exploration in this paper is embodied in: first, it breaks through the narrow limitation of the connotation of individual efficiency of port and constructs the connotation system of port efficiency. Second, reveal the mechanism of port efficiency to promote the deepening of international division of labor, as well as the functions of dynamic comparative advantage to enhance dynamic mechanism, and discusses the dynamic comparative advantage based on port efficiency enhancing mechanism. Thirdly, the relative efficiency of China's major inland river ports is measured and evaluated based on DEA method, and the causes of inefficiency and improvement direction are revealed by means of projection. Fourthly, from the aspects of effective competition in the market and allocation of factors, some countermeasures are put forward to improve the efficiency of Chinese ports. It is of great practical significance for China to improve the port efficiency and realize the improvement of dynamic comparative advantage through this breakthrough.

In fact, inland river port logistics is very promising. At present, inland river ports are relatively mature along the Yangtze river system in the Yangtze river delta region and ports in the pearl river delta region. Through corresponding opening of inland water transportation route and the local government, ports, customs, inspection, the combined efforts of the shipping company especially in nearly five years of development, the above areas of inland port has become the support of the main ports, for service in Shanghai, Guangzhou, Shenzhen port, as inland hinterland along the import and export enterprises, the main logistics channel and the north coastal city of goods. The biggest issue inland port, the first is the blind construction, each port cargo do not have enough to eat, resulting in poor part of port infrastructure, extensive management, form a complete set of logistics system (especially the local short delivery capacity) is imperfect, the second is inland port into the shipments do not match, causing some empty container transportation back and forth, increase the cost, the third is the Yangtze river have water season, during shipping limited ability. DEA method is used to evaluate the efficiency of inland river transportation supply system, which is easy to deal with the evaluation problems of multiple inputs and multiple outputs. The efficiency value will not be affected by different units of measurement. The result of DEA evaluation efficiency is a comprehensive index, which can describe the total factor productivity of inland river transportation. The determination of weight is not influenced by human subjective factors, which can satisfy the principle of foothold equity.

2. Literature review

Early studies on port performance usually rely on single or multiple indicators. Since it is difficult to describe the characteristics of port efficiency in a comprehensive way, we turn to comprehensive evaluation. In recent years, there are many literatures about port efficiency by DEA method in foreign countries. Tongzon combined dea-ccr and dea-additive models to analyze the efficiency status of four ports in Australia and 12 other container ports in the world in 1996.Itoh used DEA method to study the efficiency changes of 8 international container ports in Japan from 1990 to 1999. When Cullinane studied the efficiency of 57 major container terminals in the world with DEA, they found that small differences in the definition of input-output variables would lead to significant differences in the results. Diaz-Hernandez used DEA and Malmquist indices. Chudasama berth quantity, yard area, ship number, number of cranes and other loading and unloading equipment, and cargo throughput, measure the operation efficiency of India's 12 major coastal ports, and compare with the efficiency of the dynamic change from 2002 to 2006. However, the effect of objective environment and random factors was not taken into account, so the data conclusions were not objective enough.

There are relatively few literatures on quantitative research on port efficiency in China. Pang Ruizhi evaluated the operating efficiency of China's 50 major coastal ports from 1999 to 2002, and used Malmquist productivity index to analyze its dynamic efficiency, but only the one-stage DEA model was used. On the basis of DEA, Kuang Haibo conducts principal component analysis on the efficiency of China's eight major coastal ports, obtains the contribution rate of input index and gives corresponding policy Suggestions. Yu Yunze used stochastic frontier production function to calculate the efficiency of China's logistics industry, but did not conduct in-depth research on ports.

It can be seen from the above literature that studies on port efficiency at home and abroad mainly focus on coastal container ports, but lack of studies on operating efficiency of major inland river ports in China. This paper attempts to use the three-stage DEA model proposed by Fried and other inland river ports to analyze the operation efficiency of inland river ports more accurately.

3. Research methods and tools

Data envelopment analysis (DEA) was originally proposed by Charnes. DEA, Data Envelopment Analysis, the principle of this method is mainly by keeping decision making unit (DMU) input or output unchanged, with the aid of mathematical programming and statistical Data to determine the relative effective production frontier, each decision making unit projection to DEA on the production frontier, and by comparing the decision unit deviation degree of DEA front surface to evaluate their relative effectiveness.

DEA method has several features:

(1) It is applicable to the comprehensive evaluation of the effectiveness of multi-output and multi-input, and has an absolute advantage in dealing with the effectiveness evaluation of multi-output and multi-input.

(2) Without any weight assumption, the optimal weight is obtained by using the actual data input and output from the decision unit, which excludes many subjective factors and is highly objective.

(3) The DEA method is not directly the data is integrated, so the optimal efficiency of decision making units index has nothing to do with the input index and output index

of dimension selection, using DEA method to establish model need not dimensionless processing of data.

However, this model cannot measure the influence of environmental variables on the efficiency of decision units.Timmer proposed stochastic frontier analysis (SFA). Although environmental variables were taken into account, random errors were ignored.In order to overcome the technical defects of the model, Fried proposed the three-stage DEA model, which solved the influence of environmental variables and errors.

3.1The first stage -- BCC model

The first stage is the traditional DEA model. Based on the principle of resource conservation, this paper adopts the input-oriented variable scale reward BCC model, which is a mature method. BCC model is a model to evaluate the technical efficiency. Relative efficiency means that the DEA efficiency in the DEA model is relatively effective, that is, compared with other similar DMU units, it is not really effective in technology and scale. The CCR model assumes that returns are constant on a scale, so this model can only measure whether the decision unit achieves both technical efficiency and scale efficiency. The CCR model is one of DEA model and data envelope model. In 1978, a.c. harnes and w.w. cooper and e.r. hodes, famous operational research scientists and professors from the university of Texas, published an important paper. The model that does not consider scale benefit is C2R model, and the model that considers scale benefit is BCC model. However, the assumption of constant scale reward is hard to establish in reality. Therefore, Banker et al. (1984) proposed the BCC model in consideration of variable scale remuneration. With n decision units, each decision unit has m inputs and S outputs, the input-oriented BCC model can be expressed as the following linear programming:

$$\min \theta$$

$$s.t \begin{cases} \sum_{k=1}^{n} x_k \lambda_k + s^- = \theta x_t \\ \sum_{k=1}^{n} y_k \lambda_k - s^+ = Y_t \\ \sum_{k=1}^{n} \lambda_k = 1, \lambda_k \geq 0 \\ k = 1, 2, ..., n; s^+ \geq 0, s \geq 0 \end{cases} \quad (1)$$

In Eq. (1), θ is the efficiency of decision making unit values, and the expression under the condition of invariable in output, will spend as much as possible by the same proportion reduced, if the input vectors are unable to make the same scaling, the linear programming to achieve the optimal value is equal to 1, the decision making units for DMU effective; If the input vector can be reduced by the same proportion, the linear programming optimal value less than 1, decision making units for non DEA effective, show that input variables can be a certain degree to reduce the output remains the same.

3.2The second stage -- SFA model

SFA refers to stochastic frontier analysis. In economics, technical efficiency refers to the ability to increase output with a given input or reduce input with a given output. The commonly used method to measure technical efficiency is the production frontier analysis method.

The so-called production frontier refers to the maximum output set corresponding to various proportional inputs at a certain technical level. The production frontier is usually represented by the production function.

Frontier analysis method according to whether the production function in the form of specific parameters of the known method and non-parametric method, the former is represented by stochastic frontier analysis (SFA), which is represented by data envelopment analysis (DEA).

SFA is a typical representative of parameter method in frontier analysis, that is, the specific form of production frontier needs to be determined. Compared with the non-parametric method, its greatest advantage is to consider the effect of random factors on output.

The problem the SFA has to solve is to measure the technical efficiency (TE) of n decision units in T period, each of which is m kinds of input and one kind of output.

In the second stage, SFA method was used to carry out regression analysis on environmental variables, and random error factors were added to overcome the shortcomings of the DEA model in the first stage.The first phase of the DEA analysis of input and output slack variable by environmental impact, management inefficiency and statistical noise of three factors, by building the SFA model can be observed the effect of the above three factors respectively. The specific idea is to set an input redundancy regression model for each input, so as to allow environmental variables to have different effects on different input redundancy.

First, the relaxation variable is established:

$$s_{nk} = x_{nk} - x_{nk} \times \lambda, n = 1, ..., N; k = 1, 2, ..., K$$

x_{nk} is the Nth input value of the KTH decision unit (DMU), $x_{nk} \times \lambda$ is the optimal mapping of the input value of the KTH DMU at the efficiency frontier, s_{nk} represents the corresponding input relaxation variable.

Then, the regression model of relaxation variables and environmental variables was established:

$$s_{nk} = f^n(z_k;\beta^n) + v_{nk} + u_{nk}, n = 1,...,N; k = 1,2,...,K$$

s_{nk} is a variable of investment redundancy, including capital investment redundancy, capital investment redundancy and labor investment redundancy. z_k is an exogenous environment variable, and it is the observation value of individual DMU management inefficient environment explanatory variables. β^n is the unknown parameter of the environment explanatory variable that needs to be estimated. v_{nk} is the random error of the production process of the Kth DMU at the Nth input; v_{nk} is not related to u_{nk}, and it is the mixed error term. And $n = 1,...,N; k = 1,2,...,K$.

Finally, input variables are adjusted in two steps:

The first step is to use the conditional estimate of management inefficiency to obtain the estimated statistical noise, so as to separate the statistical noise from the combination error. The formula is as follows:

$$\hat{E}(v_{nk} \mid v_{nk} + u_{nk}) = s_{nk} - z_k\beta^n - \hat{E}(u_{nk} / v_{nk}), n = 1,...,N; k = 1,2,...,K.$$

The second step is to adjust the DMU unit in a better environment and luck upward. The formula is as follows:

$$X_{nk} = x_{nk} + \left[\max_k(z_k \hat{\beta}^n) - z_k \hat{\beta}^n\right] + \left[\max_k(\hat{v}_{nk}) - \hat{v}_{nk}\right], n = 1,...,N; k = 1,2,...,K$$

3.3The third stage -- the regulated DEA model

The third stage build adjusted DEA model, namely the adjustment in the second stage of each input variable values to plug in the first stage of the BCC model, to calculate the DMU after the deduction of the environmental variables and random error term efficiency. The efficiency values obtained by this method exclude the influence of operating environment and statistical noise, and reflect the actual efficiency more objectively and truly.

The algorithm tool used in this paper is DEAP 2.1 and FRONTIER 4.0 software.

4. Selection of indicators and data sources

4.1Selection of input and output indicators

Currently, in the literature on port efficiency analysis by DEA method, the input index is mainly measured from capital, labor and land. The length of the dock, the number of loading and unloading equipment and the number of berths are the most important indicators of capital investment. In addition, warehouse and storage area and number of employees are also commonly used input indicators. For output indicators, almost all studies listed cargo throughput as an output indicator, and some also listed user satisfaction or port profit as an output indicator.

In view of the availability of data, this paper selects two input indicators, namely, the length of wharf and the number of berths. For some ports, the investment is not only used for shipping, but also used for passenger transport, therefore, this article selects three output indicators, namely: cargo throughput and container throughput and passenger throughput.

4.2 Selection of environmental variables

Environmental variables refer to the factors that affect the efficiency of inland river ports but are not within the subjective control range of samples, including natural environment and socio-economic environment. Compared with coastal ports, inland river ports are restricted by more factors, such as hydrological and geographical conditions, which greatly restrict the development of inland river shipping and ports. From the perspective of economic environment, the level of economic development and the development of foreign trade will have a significant impact on port construction and operation efficiency. Therefore, this paper mainly considers the following four factors as environmental variables:

(1) Foreign trade (X1) : reflect the demand of port, the port cargo throughput, the throughput occupies a considerable proportion of foreign trade, under the same investment level, foreign trade will impact on output;

(2) Regional GDP (X2) : it reflects the level of regional economic development. It is not only a demand factor for the development of inland river shipping, but also an influence on supply from the aspects of port construction.

(3) Regional population (X3) : it reflects the demand level of residents. Under the same input level, it not only affects the cargo throughput, but also affects the passenger throughput.

(4) Whether it is plain landform (X4) : represents the natural limiting conditions of inland river navigation, which is described by 0-1 virtual variable. Generally speaking, the consolidation conditions of plain landform are better, and the output will be higher at the same level of input.

4.3 Samples and data sources

Given the availability and integrity of data, this article selects the Yangtze river, the Songhua river water system, water system of the Grand canal and the Pearl river water system, a total of four water system of main 15 major inland port as sample, a total of 75 input and output measurements. This article selects the data of 2016, they mainly comes from 《China statistical yearbook》,《China port statistics yearbook》, GuoYan net, Chinese port network, the official website of the ministry of communications and the statistical communique on the 2016 national economic and social development of corresponding cities.

5. Empirical analysis

How to analyze and evaluate the efficiency of resource allocation in inland river transportation is based on the theory of resource allocation efficiency of economic system. Theoretically transportation resources allocation's goal is to meet the requirements in the conditions, the pursuit and should be able to achieve input (cost) to minimize or output (profit) to maximize, the efficient allocation of production resources or ideal configuration. But in the actual production and operation activities, due to the low level of production technology or management technique, production scale, unreasonable factors of production resources limited or obtain condition can be obtained, and the production is less than or inadequate information all sorts of reasons, often difficult to achieve the efficient allocation of productive resources and maximum output, so that the transportation resources allocation inefficiency to some extent, has the universality. The research on the allocation efficiency of production resources has very important theoretical significance and practical value. Transportation allocation efficiency is the ratio between the actual allocation level of transportation resources and the ideal allocation level. If the actual transportation configuration status is defined as S and the ideal configuration status is defined as L, the transportation configuration efficiency E can be defined as follows:

E = SE * TE

The efficiency of transportation allocation reflects the effective utilization of transportation resources, which consists of scale efficiency (SE) and technical efficiency (TE) of transportation allocation. Consider combined together by ship, waterways, ports and other subsystems of inland water transport supply system, if the ship, port and waterway, regarded as the inputs of the system, the system of the frontier production function is shown as shipping, port and waterway, multiple input and output of the frontier production function, the configuration efficiency of efficiency of shipping, port and waterway, the combination of the subsystem, the system configuration of high efficiency must be ship, waterways, ports and other subsystems of combinatorial optimization, which is the structure of inland water transport supply system performance optimization.

The optimization of transportation structure is consistent with the high efficiency of transportation configuration. The high efficiency of different transportation production areas corresponds to the optimization of transportation structure in different areas. The high efficiency of inland river transportation is based on the high efficiency of simple transportation production and the high efficiency of transportation enterprise (combination) production. From the perspective of the supply and demand equilibrium theory，inland water transport enterprises production structure optimization and regional inland water transport supply system structure optimization, and inland water transport supply system of the subsystem structure optimization and the total system of inland water transport supply structure optimization, showing the local equilibrium and the relationship between the global equilibrium.

5.1Empirical results of the first phase DEA model

In the first stage, DEAP 2.1 was used to analyze the efficiency level and scale rewards of 15 major inland river ports in China, as shown in table 1.As you can see, without considering the environment variables and random factors, the main inland port comprehensive efficiency to an average of 0.608, the average pure technical efficiency is 0.895, the average scale efficiency is 0. 644, shows that the overall efficiency of inland port industry in our country is lower.

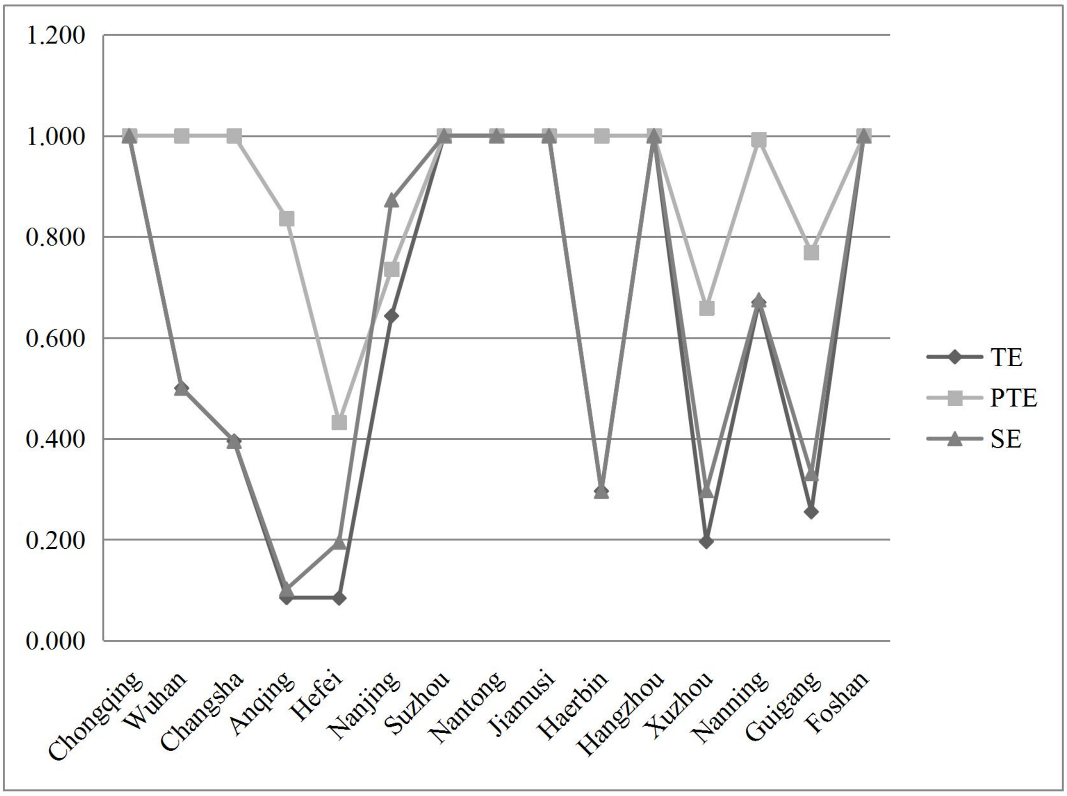
Table 1 .comparison of efficiency of major inland river ports in China in 2016

Port	Combined efficiency	Pure technical efficiency	Scale efficiency	Returns to scale
重庆 CHONG QING	1.000	1.000	1.000	-
武汉 WU HAN	0.500	1.000	0.500	irs
长沙 CHANG SHA	0.395	1.000	0.395	irs
安庆 AN QING	0.085	0.836	0.102	irs
合肥 HE FEI	0.084	0.432	0.195	irs
南京 NAN JING	0.643	0.736	0.873	irs
苏州 SU ZHOU	1.000	1.000	1.000	-
南通 NAN TONG	1.000	1.000	1.000	-
佳木斯 JIA MU SI	1.000	1.000	1.000	-
哈尔滨 HA ER BING	0.296	1.000	0.296	irs

杭州 HANG ZHOU	1.000	1.000	1.000	-
徐州 XU ZHOU	0.196	0.659	0.297	irs
南宁 NAN NING	0.670	0.993	0.675	irs
贵港 GUI GANG	0.255	0.769	0.331	irs
佛山 FO SHAN	1.000	1.000	1.000	-
Average value	0.608	0.895	0.644	

The results of table 1 reflect using line charts in figure 1, you can see, in addition to the port along the Yangtze river delta region, most comprehensive efficiency and scale efficiency of port line is consistent, and below the line of pure technical efficiency, thus can preliminary judgment, the inefficiency of China's inland port mainly comes from scale inefficiency, but also do not rule out the possibility of objective environment and random factors.

Figure 1 the efficiency line chart of China's major inland river ports in 2016



The investment target value is compared with the actual investment value, and the improvement direction of port efficiency is analyzed. The efficiency target value in table 2 is calculated by the BCC model according to the efficiency frontier set by the efficient port, and refers to the target value that the inefficient port should achieve if it wants to achieve the efficiency standard. It can be seen that the actual values are all higher than the target values, indicating that there is significant input congestion at the given output level, but the DEA results of the first stage cannot show the accurate source of such waste.

Table 2 comparison between the efficiency target value and the actual value of the input-oriented BCC model

	Efficiency target	Actual input value	The actual input value exceeds the target value	
			The absolute value	The percentage
Berth length	8437.40167	10392.93333	1955.531667	18.82%
The berth number	209.1902	232.4666667	23.27646667	10.01%

5.2 SFA regression analysis results of the second stage

The second stage SFA regression analysis result in the second stage of FRONTIER 4.1 amount of each input variable relaxation is the first stage is as explained variable, the foreign trade, GDP, regional population, whether for plain landscape as explained variable, build a sales force automation (SFA) regression model, the results as shown in table 3.The likelihood ratio test of unilateral error (representing management inefficiency) is not significant, and the original hypothesis (management inefficiency does not contribute to portfolio error) is accepted. γ said management technical inefficiency variance ratio of total variance, the berth quantity redundancy variable γ tends to zero, the difference show that the efficiency of management is not obvious, and the random factors has a great influence on the input of slacks. Therefore, it is of little significance to use SFA to analyze berth number variable equation.

Table 3 regression analysis results of input relaxation variables

	Y1（Berth length redundant）	Y2（The berth number redundant）
Constant term	9583.531（626.72）***	583.648(154.38)***
Foreign trade	-32.642（-2.56）**	-0.3165（-0.16）
Regional GDP	8.428（1.45）*	0.158（1.57）
Regional population	-26.682（16.81）***	-0.482（-1.83）*
sigma-squared	16832.643(5239.26)***	19663（2749.18）***
gamma	0.068（0.53）	0.006（0.02）
Log Likelihoood Funciton	-83.648	-167.284
LR test of one-side error	0.000***	0.000***

Note: * indicates a significant level of at least 10%;The value T is in parentheses.

Due to environmental variables are for slack variable in the regression, so when the regression coefficient is negative, said slacks increase environment variable value is helpful to reduce investment, which is helpful to reduce the waste of each input variable.

(1) Foreign trade: the berth length and the number of berths slack variable are favorable factors, this may be due to the increase of foreign trade, lead to the increase of cargo throughput, so as to improve the utilization rate of the port is put into.

(2) Region gross domestic product (GDP) : the berth length and the number of berths slack variable are unfavorable factors, this may be because as the growth of the GDP, the investment of inland port is increased, but did not bring port throughput in proportion to growth, resulting in the port the waste of resources.

(3) Regional population: the berth length and the number of berths slack variable are favorable factors, this may be due to increased with the increase of population, the passenger demand increases correspondingly, thus increase the demand for passenger

terminal, improve unit input output capacity.

(4) Whether plain landscape: the berth length and the number of berths slack variable are favorable factors, this may be due to the plain of the landscape waterway is generally high grade, transportation conditions are relatively good, to improve port resource utilization.

5.3Empirical results after the third stage investment adjustment

According to the second phase SFA analysis results, the adjusted input value and the output value generation DEA again - BCC model, can obtain the third phase of each decision making unit state of efficiency value and scale reward, the results are shown in table 4.

Table 4 Comparison of efficiency under homogeneous environment of major inland river ports in China in 2016

Port	Combined efficiency	Pure technical efficiency	Scale efficiency	Returns to scale
重庆 CHONG QING	1.000	1.000	1.000	-
武汉 WU HAN	0.508	1.000	0.508	irs
长沙 CHANG SHA	0.431	0.997	0.432	irs
安庆 AN QING	0.092	0.881	0.105	irs
合肥 HE FEI	0.086	0.733	0.118	irs
南京 NAN JING	0.644	1.000	0.644	irs
苏州	1.000	1.000	1.000	-

SU ZHOU				
南通 NAN TONG	0.995	1.000	0.995	irs
佳木斯 JIA MU SI	0.998	0.998	1.000	-
哈尔滨 HA ER BING	0.304	1.000	0.304	irs
杭州 HANG ZHOU	1.000	1.000	1.000	-
徐州 XU ZHOU	0.213	0.942	0.226	irs
南宁 NAN NING	0.689	0.996	0.691	irs
贵港 GUI GANG	0.265	0.893	0.297	irs
佛山 FO SHAN	1.000	1.000	1.000	-
Average value	0.615	0.962	0.639	

Contrast table 1 and table 4, the first and third stage efficiency value exists obvious difference, from 0.608 goes to 0.615, from 0.644 goes down to 0.639. But the average pure technical efficiency varies greatly, from 0.895 goes up to 0.962, suggesting that this article selected environment variables and the corresponding random factors do affect efficiency value, so it is necessary to adjust the input variables. Since the results of the third stage can more truly reflect the efficiency of various inland river ports than those of the first stage, the efficiency analysis and improvement should be based on this.

(1) Efficiency comparison before and after adjustment

The average comprehensive efficiency and scale efficiency of inland river ports have little change. In addition to Wuhan, Changsha, Hangzhou, Nanjing, Nantong, Xuzhou and Foshan, most of the port comprehensive efficiency of a sharp decline, the reason for this is that scale efficiency has fallen dramatically, that scale economy is our country most of the inland river port of the main causes of low efficiency. Another significant change is that the scale remuneration of all ports increases after adjustment, which further indicates that the scale efficiency of inland river ports in China needs to be improved urgently. Before and after the adjustment the biggest change is the pure technical efficiency, pure technical efficiency value of some ports such as Wuxi modestly decline, before the relative efficiency of closely related with its favorable environment and good luck. The rest of the vast majority of ports, especially in the Yangtze river shelter-forest and ports in the pearl river water system, the pure technical efficiency values have risen sharply, shows that the comprehensive efficiency of low before is indeed a poor environment or bad luck.

(2) The adjusted comprehensive efficiency, pure technical efficiency and scale efficiency

The average comprehensive efficiency of inland river ports is low, and the comprehensive efficiency of each port is very different. Setting 0.6 as the critical point, the comprehensive efficiency in the forefront of Nantong, Suzhou, Hangzhou and Foshan, the rest will present different degree of comprehensive inefficiency, especially the comprehensive efficiency of Anhui province ports is very low. Analysis efficiency frontier port of input and output data can be found that high efficiency is the result of large passenger throughput in Hangzhou, and Suzhou and Foshan is the result of container transportation and coastal ports and cohesion. In addition, the pure technical efficiency is at a high level after adjustment, and there is no significant difference, indicating that the technical management level of inland river ports in China is relatively high. After the adjustment, all ports show increasing returns on scale, which indicates that the overall scale is relatively small, which is a common problem faced by most inland river ports in China.

(3) Port efficiency difference between different water systems

As shown in table 5, the comprehensive efficiency of Grand canal water system is much higher than that of other water systems, which is due to the high efficiency of pure technology and scale. However, the pearl river system is lower than other water systems in terms of comprehensive efficiency, scale efficiency and pure technical efficiency, indicating that the scale inefficiency of pearl river system port is more serious in homogeneous environment. Comparing the mean efficiency of all water systems before and after the adjustment, it is found that the comprehensive efficiency of the Songhua river and pearl river systems decreased significantly after the adjustment, while that of the Yangtze river and Grand canal was opposite. The improvement of the pure technical efficiency of the four major water systems means that they have faced bad luck or environment before. The decline in the scale efficiency of the Yangtze, Songhua and pearl river systems also suggests that previous efficiency have been overestimated.

Table 5 Comparison of efficiency of inland river ports of different water systems in China

	Thefirst stage（A）	The first stage（B）	The first stage（C）	The third stage（A）	The third stage（B）	The third stage（C）
The Yangtze river	0.588	0.876	0.633	0.595	0.951	0.601
The Songhua river	0.648	1.000	0.648	0.651	0.999	0.652
The Grand canal	0.598	0.830	0.649	0.607	0.971	0.613
The Pearl River	0.621	0.888	0.658	0.651	0.963	0.663

A represents the comprehensive efficiency.

B represents the pure technical efficiency.

C represents the scale efficiency.

(4) The efficiency difference between the upper and lower ports of the same water

system

In the first phase of DEA results, the average comprehensive efficiency and scale efficiency of the middle and lower reaches of ports are higher than that of the upstream ports, while the pure technical efficiency is lower than that of the upstream ports. Without consideration of environmental factors and random errors, it shows that the comprehensive inefficiency of upstream and downstream ports is mainly caused by the inefficiency of technical management level. When environmental factors and random errors were removed, the results of the third stage changed significantly. First of all, the upstream port comprehensive efficiency and scale efficiency values were higher than in the middle and lower reaches of the port, to some extent, explain the upstream port does face an adverse environment and bad luck, cause its the efficiency value in the first stage was significantly undervalued; Second, the upstream and middle and lower reaches of the pure technical efficiency there is biggish difference in front of the adjustment, but adjusted the difference does not exist, and close to the most efficient value of 1, all show that management technology is not the main factors of comprehensive inefficiency, diseconomies of scale is the root cause.

6. Conclusions and suggestions

6.1Obstacles to improving the efficiency of China's inland river ports

To a certain extent, the reform of China's port management system has improved the problem that the port investment and operation subjects are single, and indeed has played a role in stimulating local vitality and promoting the great development of port construction. However, in the process of system transformation, the path dependence of institutional change and curing interest relations, on the one hand, not solve the absence of "at the end of the client" and "insider control", property right structure, on the other hand, tend to lead to market distortions and unfair competition, forming invisible barriers to entry, and thereby impede Chinese ports in realizing the function of its various kinds of economic ties to enhance the efficiency of the whole. Specific performance in the following aspects:

(1) the vast majority of port enterprises at present in China are state-owned controlling shareholders "a dominant", even if is already listed share-holding system reform of port enterprises, the actual also mostly state-owned legal person or state holding. Such equity structure can play a positive role in capital accumulation and factor mobilization, but it is difficult to mobilize the enthusiasm of employees due to lack of internal incentive, thus causing the principal-agent problem. However, the lag of the system reform makes the internal organization of enterprises bloated and the information is seriously asymmetric, which leads to the systematic inefficiency of the port related operation activities.

(2) the interests of the relationship between local government and state-owned enterprises in the port while it is possible to make state-owned port companies against external competitors, but also limits the state-owned port enterprise developed market and freedom of investment and financing. In order to support the development of local economy, local governments are scrambling to invest, duplicate construction and even vicious competition, resulting in waste of resources. Administrative areas is more serious is that, in order to artificially dissever the connection between the port and port of state-owned enterprises is affected by the local government investment and financing behavior target, to a group of ports

through the establishment of more efficient form of equity and port network system, and thereby impede to promote the efficiency of the port.

(3) the lack of effective market competition mechanism, port of state-owned enterprises as the main element configuration, increase input in the process of port resource allocation is not concerned about whether it will bring the increase of output, resource waste and low efficiency. On the other hand, the combination of intangible barriers caused by the solidification of interests and the characteristics of natural monopoly of ports forms a "double monopoly", which hinders the entry of private enterprises. But barriers to entry make it hard to do so. The lack of sufficient intensity of competition within the port, between the ports and among the port groups results in the loss of efficiency.

As mentioned above, in the process of the transformation of China's port system, a relatively single property right structure has been formed, with the government and state-owned enterprises as the main allocation subjects. The special relationship between state-owned port enterprises and local governments forms an invisible barrier. In addition, the natural monopoly characteristic of port industry itself hinders the entry of private enterprises, and the market lacks effective competition. Obviously, further deepening the reform of port management system, realize the diversification of element configuration, eliminating barriers to entry and maintain market contestability, even in the port market structure under the condition of natural monopoly characteristics, is still possible to achieve efficiency.

6.2Countermeasures to improve the efficiency of China's inland river ports

The empirical results show that, first of all, the efficiency of China's major inland river ports is generally low, among which, scale inefficiency is the main reason for the overall operating inefficiency. Second, there are large differences in the efficiency of inland river ports of different water systems. The Grand canal' efficiency rate is relatively high, followed by the Yangtze river and Songhua river system, while which of the pearl river system is relatively low. Third, China's major inland river ports have serious congestion in terms of input and output, which is more than 50%, indicating that the port resource waste is very serious. Fourth, environmental effect and random error do have different effects on the production efficiency of inland river ports. Fifth, there are differences in efficiency between upstream and downstream ports of the same water system.

Major inland port management technology in China is relatively high, the random factors such as natural geographical environment and belongs to the uncontrolled factors, environmental factors and port scale becomes the key to improve the efficiency of inland port. In view of this, the following Suggestions are proposed:

(1)To strengthen infrastructure for inland waterways and improve port capacity. A safe and unobstructed waterway is an important basis for the development of shipping. Inland waterway in China's overall level is low grade, part of the waterway, disrepair of water conservancy facilities, human factors damage is serious, seriously affected the ship navigation ability, but also lead to poor cohesion and prudent high-grade waterway. Increasing the investment in waterway construction and raising the standard of waterway classification is the key to the development of inland waterway shipping.

Inland port and harbor has a larger difference, in both the size and characteristics, there are significant gap between the two, so in the process of the construction of the inland river port, we must pay attention to the construction layout is reasonable, can not blindly pursue the construction scale, in the process of construction, must be based on the actual characteristics of the local for the determination of building layout and scale, thus effectively saving land resources, and coastal resources. If in the process of construction, inland port land area is relatively small, then can be reference to similar harbour construction pattern, focus your yard in the rear of the relatively flat terrain and the land price is low, and then through the logistics channel and terminal berth is linked together, so as to make the terminal cost can reduce to the maximum, to better attract business investment. In the process of construction planning for port, inland port should be planning for comprehensive transport hub, the railway, highway and waterway transport a variety of ways to effectively fuses in together, so as to make the inland port in the position in comprehensive transportation system is able to effectively improve, so as to effectively improve the comprehensive utilization of resources.

(2)Integrate resources to build large-scale ports with accessible river and sea. Although there are a large number of inland river ports in China, they are relatively backward in terms of scale, service capacity, mechanical equipment level and wharf level. At this stage should strengthen the inland port planning, economical utilization coastline, control the number of inland port, focus on the limited funds, in the construction of ports the main node of regional logistics network, perfect supporting facilities and equipment, energy saving and emission reduction to accelerate the process of mechanization, scale and specialization of inland port.

We need to optimize the development environment and eliminate non-compliant wharves. First, clean up the environment, then let the inland river port in a healthy environment to achieve large-scale development. But it is important to note that can not blindly to the expansion of inland port, need to be closely connected with practice, according to the actual economic condition of port hinterland and development plan for balance, so as to realize scale benefit maximization.

(3)Try to develop inland shipping in containers and solve structural problems. To improve the level of transport rationalization and standardization, improve the efficiency of the comprehensive transportation, inland port should be focusing on the container transport development, accelerate the construction of container multimodal transport hub, promote smooth cohesion and coordinated development of river and sea port.

(4)The development model is green. In the process of construction of inland river ports, attention must also be paid to sustainable development, so as to realize the protection of the environment and the conservation of resources. So in the process of plan for inland river port of, be sure to make the development of port organically combined with the development of the natural environment, if encounter some rare species or is non-renewable resources, must take effective measures to protect them. And in the process of the construction of the inland river port, tend to produce large amounts of waste, so in the process of construction, also must be effective treatment for the waste, through to the application of some advanced technology to effectively avoid the waste to the environment pollution caused by, so as to better protect the ecological environment. In addition, you also need to increase for the propaganda of environmental protection, in the process of the construction of the inland river port, the application and cleaning equipment and raw materials as much as possible, so as to control the construction process of the production of waste, reduce the pollution to the environment.

(5)In order to concentrate on the construction of green port inland, in addition to the corresponding technical measures, the government should give full play to its function, and give corresponding economic support from policy, to ensure that the construction of inland port can be more environmentally friendly. When building new inland river ports, it must protect the environment from construction planning. For example, in terms of port facilities and equipment, it must meet the requirements of energy conservation and emission reduction. In the process of constructing inland river ports, new energy-saving and emission-reduction technologies must be developed to ensure the construction of green inland river ports. And must ensure that port enterprises fully realize the importance of building a green inland port, in the process of construction should be energy-saving emission reduction as a strategic move to increase the competitiveness of enterprise core, further strengthen the employee's environmental protection consciousness, and establish a special examination system and the system. Our government should also actively formulate corresponding policies, conduct green assessment of port enterprises, and further promote port enterprises to build energy-saving, emission-reduction and environment-friendly ports.

(6)Try to build a harbor industrial area and expand the demand for inland river ports. Port is highly dependent on manufacturing, commerce and related industry development demand, make full use of the location advantage of port, the development of harbor industrial area, construction of export processing zones and commodity products, agricultural products, characteristic base and form a complete set of logistics park, which can effectively improve the efficiency of the port.

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