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# Comprehensive efficiency measurement of port logistics: study based on DEA two-stage relative evaluation

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**Abstract:** Port is an important node in logistics system. Aiming at lack of calculating and analysis for comprehensive efficiency in Port Logistics research, we bring DEA two-stage relative evaluation into this paper, and get production efficiency value and X-efficiency value. Based on these values, a formula for comprehensive efficiency measurement is proposed. Finally, this paper uses this model in making the empirical analysis on 13 ports of China, and the result confirms the applicability of this model.

**Keywords:** Port Logistics, Production Efficiency, X-efficiency, Comprehensive Efficiency, DEA Two-Stage Relative Evaluation

## 1. Forward

As the acceleration of the globalization and the growth of the International trade amount, every country pays more attention to the port construction and running, make the port logistics efficiency as the main index of the port competitive strength, evaluate the resources configuration effect of the logistics system. After financial crisis happened, Comprehensive efficiency measurement of Port Logistics becomes the hotspot focused by academic world and business world. In the logistics develop plan of China issued recently, consider the configuration efficiency as well as running efficiency of Multimodal transport and logistics basic instruments as the important content. As the main node of the logistics system, port is the important support of the Multimodal transport. Therefore, research the running efficiency of the port logistics has the important theory value and practical significance.

Foreign scholars at first use single index to measure port efficiency, Kim and Sachish (1986) obtained port total factor productivity by single index; Chou and Lee (2004) use the unit profit of port throughput amount to measure the port effects.

Then Roll and Hayuth (1993) firstly use DEA method to evaluate port efficiency and solved the problem index is singular. But when use the multiple index to proceed evaluation, sometimes would exist part effect index improved but part of effect index deteriorate, then the changes in overall index is difficult to judge. So some scholars use comprehensive evaluation method for detail study from port technical efficiency and scale efficiency: Cullinane etc fixed the port input amount to measure the distance value of the actual and theoretical output, it represents some scholars who mainly focus on technical efficiency research; Zhong Ming and Lvyuan Yuan (2007) use of gray target model of the port economic efficiency to measure and solved the problem small sample and integrate index hard to evaluate; Pang Ruizhi (2006) use DEA and the Malmquist Productivity index to evaluate the dynamic efficiency of Chinese major ports along the coast and found there is a serious shortage which inputs crowded and outputs not enough. The above study only evaluate the port efficiency classification (technical efficiency, scale efficiency, pure technical efficiency), but not for the overall port efficiency and X-efficiency measurement.

Above research about the port efficiency measurement, establish the basis of measurement evaluation of port logistics efficiency and give better reference especially in the aspect of efficiency evaluation level, principle confirmation, evaluation methods, index system build, evaluation standards confirmation etc.

Current port logistics research mainly focus on its theoretical definition expound, few documents for the efficiency measurement: Khalid Bichou and Richard Gray (2003) proposed a framework for measuring the efficiency of port logistics; Wangling etc. (2005) divided port logistics into six sub-system and create the principles build the evaluation index system. But currently there are no scholars aim at port logistics integrate efficiency and X-efficiency proceed measurement, and there is no empirical data description, so the port cannot improve self logistics system objectively and profession, as a result, it couldn’t improve its position in the global logistics chain.

Based on the above analysis, this issue from perspective of port logistics, use DEA two-stage relative evaluation to measure the average production efficiency and X-efficiency of port logistics, finally compose the overall efficiency of port logistics, selected representative 13 ports to proceed empirical analysis, hope uncover the port logistics integrated efficiency's "veil" so that find limitation factor restrict the logistics efficiency, and let the port authorities make relative strategy corresponding to improve port production efficiency and X-efficiency.

## 2. Efficiency Measurement Method Choose——DEA Two-Stage Relative Evaluation Mould Applicability

Affect the port input and output efficiency are usually considered factors in addition to the allocation of resources, but also relates to the low efficiency of some unknown factor, mainly for the organization, motivation and other non-market factors, Leibenstein (1966) proposed X-basis efficiency theory, defined it as " Besides the scale and scope effect all the technical and allocate efficiency, is about the integration of technology, human resources and other assets to produce a given level of management determination."

The main method to measure X-efficiency is frontier analysis, the frontier analysis method mainly have two major types. The first non-linear programming method, proposed by A. Charnes (1978) in 1978, the data envelopment analysis (DEA, data envelopment analysis) as representative: Leibenstein (1966) discusses put the DEA method as the main method to measure and separation X-efficiency; Xie Zhaohua, Duan Jun Shan (2005) also used the DEA to analyze the X-efficiency of Commercial Bank of China. The second is the parameter measurement method, stochastic frontier analysis (Stochastic Frontier Analysis, SFA) as representative, Kuanghai Bo and Li and Zhong (2009) adopt the stochastic frontier production function measure the X-efficiency of the port and filled the port X-efficiency research gaps in China.

But both methods are a separate analysis on the production frontier, with a single cost-orientation of the state. Feng Ying Jun, Li Cheng Hong (1995) propose the two-stage relative evaluation mould based on fayrer measurement method and DEA method, it's closer to the thesis of Leibenstein (1966) X-efficiency depends on the organization and motivation. two-stage relative evaluation methods, evaluate unit according to self reference index to search the frontier value, excluding the impact of the basic merits conditions and replace the production frontier analysis with index condition frontier analysis, the reference index and the current index represents the evaluation unit status at different time points and making the evaluation get dynamic meaning, also exclude the influence of scale and scope, reflecting the management level measurement and fits for X-efficiency measure.

This article attempts to apply two-stage relative evaluation mould to the integrate efficiency evaluation of our port logistics, based on the average production efficiency and dynamic X-efficiency measurement to compose the port logistics integrate efficiency. However, the key point of DEA two-stage relative evaluation mould is in what method is adopted to confirm "Index Condition", in the past literatures mostly calculate the index of the condition by AHP method and it is too subjective. This article will adopt the C2R mould to confirm index condition to achieve an objective index condition frontier, so as to get a fair port logistics X-efficiency measurement.

# 3. Port Logistics Integrate Efficiency Measurement System Construction

Figure 1 shows the constructed measure of integrate efficiency of port logistics system, the basic idea is: first step: to determine the efficiency of port logistics evaluation index system; Step two: Confirm the "Index Status Set", that is, adopt the C2R of DEA model to confirm the "reference index set "and the" current index set ", separately indicate the base period and the current input-output efficiency of port logistics; the third step: Based on the" Index Status Set ", separately from the perspective of static and dynamic evaluation of relative efficiency proceed two-stage relative evaluation, that Synthesis from a static perspective and current base period input-output efficiency of port logistics and make production efficiency measure, from the dynamic angle, consider the "reference index set" and the "current index set" as the input and output sets, separately make the DEA model estimates of BC2 X-efficiency of port logistics; Finally, quote the parallel resistance formula compose the efficiency and X-efficiency of port logistics to achieve the port logistics efficiency integrate measurement.

## 3.1. Evaluation Index System Establishment

This section discusses the index for measuring the efficiency of port logistics system, origin from the literature of reference results, the specific index system divided into two layer: the first layer is the criterion level, are composed of the port logistics infrastructure, logistics support - hinterland economy, collection and distribution capacity, port logistics scale, port logistics development potential five criteria; second index layer, are composed of 12 index.

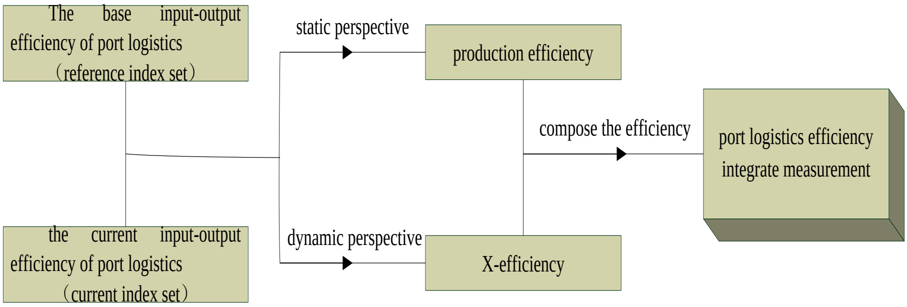


Figure 1: the constructed measures of port logistics system integrate efficiency.

Table 1: Evaluate index for measuring the efficiency of port logistics system.

| Input | | Output | |
|---|---|---|---|
| criterion layer | index layer | criterion layer | index layer |
| port logistics infrastructure $X_1$ | production berths length（m）$X_{11}$ | Port Logistics Scale $Y_1$ | cargo throughput（100 million ton）$Y_{11}$ |
| | production berth quantities $X_{12}$ | | container throughput（ten thousand TEU）$Y_{12}$ |
| | production 10000-ton-capacity port berth quantity $X_{13}$ | | |
| logistics support-hinterland economy $X_2$ | GDP of direct hinterland of the port（100 million RMB）$X_{21}$ | Port logistics development potential $Y_2$ | port cargo increasing rate（%）$Y_{21}$ |
| | the proportion of tertiary industry in port city GDP（%）$X_{22}$ | | port container increasing rate（%）$Y_{22}$ |
| collection and distribution capacity $X_3$ | port hinterland's highway length（kilometer）$X_{31}$ | | direct hinterland GDP increasing rate（%）$Y_{23}$ |
| | port hinterland's railway length（kilometer）$X_{32}$ | | |

To some simple and normal index, this issue wouldn't make detail explanation, only a brief description of the meaning to part indexes.

Port logistics infrastructure: in the infrastructure investment, the berth length, cranes and berth quantity are always chosen by various literature, but when searching these data, could only get the berths length and quantity more integrate information, but to the crane quantity information, the writer could only try to get them from website of the ports, since many ports' website couldn't be log in or doesn't indicate which year date it is lead to they couldn't get more detail history data. Therefore, limited of data availability, this article selected production berths length, production berth quantities and production 10000-ton-capacity port berth quantity as the infrastructure index.

Logistics support-hinterland economy: in the existing literature, the economic hinterland has no objection to port logistics support, and the GDP of direct hinterland of the port and the proportion of tertiary industry in port city GDP has close relationship, so we adopt these two indexes as input standard.

Collection and distribution capacity: Previous efficiency research mainly focused on port operation ability itself but ignore the port cargo finally must by road or railway to achieve the goods door to door service. Only complete collection and distribution capacity logistics could keep the smooth operation of the port logistics. Therefore, put port hinterland's highway length and railway length into this article is necessary.

Port Logistics Scale: most studies emphasized consider the cargo throughput and container throughput as output index, the research continue using the two indexes to indicate the current status and scale of the port.

Port logistics development potential: port cargo and container increasing rate reflects the changing trend of the port, it is a reflection for port development in future; and direct hinterland GDP increasing rate supply the side development potential for protect port inputs and outputs amount.

## 3.2. "Reference Index Set" DP with the "Current Index Set" DC's Confirmation

Assuming evaluate n quantity ports logistics' input-output efficiency, so each port as a decision DMU unit. Each DMU has m types of input (that the cost of resources) and s types output (the volume of output results), $X_j = [x_{1j}, x_{2j}, \cdots, x_{mj}]^T (j = 1, 2, \cdots, n)$ is an m-dimensional of j decision unit, $Y_j = [y_{1j}, y_{2j}, \cdots, y_{mj}]^T (j = 1, 2, \cdots, n)$ is the s-dimensional output vector of j decision unit. According to Charness et al. (1978) proposed the traditional C2R model, lead into the introduction slack variable $S^-$ and $S^+$, measure the quantity $j$ ports' (decision DMU unit) input and output efficiency, a decision unit for the first $j_0$,decision DMU $j_0$' s DEA model linear indicate.

$$\min\{\theta\}$$
$$s.t. \quad \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_{j0},$$
$$\sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_{j0},$$
$$\lambda_j \geq 0, S^- \geq 0, S^+ \geq 0,\ j = 1, 2, \cdots n, \theta \text{free。} \tag{1}$$

$X_{j_0}$ represents input vector, $Y_{j_0}$ a DMU output vector $Y_{j_0}$ represents the No $j_0$. $\theta$ output vector, indicates efficiency of input and output values, $\lambda$ indicates that the coefficient of linear combination of decision making units. If $\theta^* = 1$ , $S^{-*} = S^{+*} = 1$ the $j_0$ unit as the DEA is effective; if, there is non-zero value, called $j_0$ is weak DEA efficient; if $\theta^* \prec 1$ called as the $j_0$ unit is DEA invalid.

Set $t = P$ , $C$ , respectively, the base period and current period, put the base period j, a DMU's input-output efficiency called quantity $j$ -ports of the "reference index" and indicated by DP, the efficiency of a DMU's input and output ports as the first $j$ "current index" to show, indicates by $\theta_j^C$ similarly to DC, as the "current index set"; (DP, DC) is the index of the state set.

## 3.3. Two-Stage Relative Evaluation Measurement

Based on the "Reference Index" $\theta_j^F$ and "Current Index" $\theta_j^C$ of No. j, separately from $X$ -static efficiency and dynamic efficiency to proceed with two -stage relative evaluation.

### 3.3.1 Static Produce Efficiency Measurement

Productivity is mainly from a static view to reflect the relationship between port input and output. Thus, static efficiency of No. j ports compose the average value "reference index" and "current index" to determine corresponding: $\alpha_j = (\theta_j^F + \theta_j^C)/2$.

### 3.3.2 Dynamic Model of Efficiency Measurement

$X$ -efficiency of port logistics is under the status of eliminating objective basis condition and dynamic response port logistics management level. The measure will be in front of the port logistics base period of performance index as a basic condition of the port logistics measurement, consider as an input; and current performance of the port logistics integrate index as an output, called array $(\theta_j^P, \theta_j^C)$ for the No. j port logistics efficiency index status, called the convex set.

$$T = \{(\theta_j^P, \theta_j^C) / \sum_{j=0}^{n} \lambda_j \theta_j^P \le \theta_j^P, \sum_{j=0}^{n} \lambda_j \theta_j^C \le \theta_j^C,$$
$$\sum_{j=0}^{n} \lambda_j = 1, \lambda_j \ge 0, j = 0,1,2,\cdots n\}$$

The index status possible set is composed of the index status, where $(\theta_0^P, \theta_0^C)$ =（0，0）T satisfy the "convexity axiom."The index status possible set may same with the Charnes (1978), Cooper etc proposed BC2 production possible set , so this time changed for the facing output of BC2 model measurement.

$$\begin{aligned} & \max \omega, \\ s.t. \quad & \sum_{j=0}^{n} \lambda_j \theta_j^P \le \theta_{j0}^P \\ & \sum_{j=0}^{n} \lambda_j \theta_j^C \ge \omega \theta_{j0}^C \\ & \sum_{j=0}^{n} \lambda_j = 1, \lambda_j \ge 0, j = 1,2,\cdots n \end{aligned} \tag{2}$$

$\theta_j^P$ and $\theta_j^C$ separately evaluated, respectively by No.j0 decision unit DMU's "reference index" and the "current index", λj indicate the decision to re-construct a valid decision unit DMU's combination ratio of No. $j$ . Set $\omega_j^*$ os the nest value of the No. j port get from the above formula, it means the $X$ -efficiency measurement value, and called $\beta_j = 1/\omega_j^*$ .as the two-stage relative evaluation of ports logistics, that is the port value of X-efficiency measurement. No. j port's efficiency can be seen as a reference in the same conditions $\theta_j^P$, could reach the largest percentage of the current index.

## 3.4. Integrate Efficiency Combination

Integrate efficiency of port logistics has very similar characteristics with the parallel circuit and the study calculated by resistance of parallel circuit, then we obtain the measurement formula of port logistics integrate measurement:

$$\delta = \frac{\alpha_j * \beta_j}{\alpha_j + \beta_j} \qquad (3)$$

Where, $\delta$ is the integrate efficiency of port logistics, $\alpha_j$ based on static port logistics production efficiency, and $\beta_j$ is the $X$ -efficiency of dynamic port logistics.

# 4. Chinese Port Logistics Integrate Efficiency Measurement Empirical Simulation

## 4.1. Sample Selection

To measure the integrate efficiency of port logistics in China, this study selected a sample of a typical domestic coastal ports. According to the 2008 Index of China's comprehensive competitiveness of the port list, this article selected the top 13 ports; there are Ningbo, Shanghai, Qingdao, Tianjin, Guangzhou, Shenzhen, Dalian, Lianyungang Port, Yingkou, Xiamen, Yantai, Rizhao and Suzhou the study sample port. These 13 ports are the most development district in China for port logistics: in 2009, the 13 ports in the national total port cargo throughput takes $^{2/3}$ or more, so basically the 13 ports can be broadly representative the port development in China situation.

Port investment recovery period is usually 5 years, 5 years after the investment to measure the full extent of efficiency gains, while Chinese port planning is ever y5 years. If measuring the increase degree of dynamic efficiency must adopt an interval of 5 years data. In this article adopts the end of 2004 and 2009's cross-sectional data. The main source of sample data for 2005, 2010 comes from "China Statistical Yearbook" and "China Ocean Yearbook", part of the data from the Statistical Bullet of port hinterland.

## 4.2. Chinese 13 Major Ports Logistics "Index Status" Calculation and Analysis

"Index Status" refers to the "Reference Index", "Current index" and mainly reflects the efficiency of port input and output. Since DEA model requires very high quantity for the samples required, sample limited may cause DEA efficient DMU unit too much and cannot be effectively distinguish. In order to overcome this shortcoming, this article by setting a virtual best DMU, make the original DMU efficiency index relative to the same virtual DMU become non-effective to achieve the same DMU efficiency index compare the difference degree purposes. Set the data input and output indicators for the xi = min xij, yr = max yrj (i = 1,2 ... m; r = 1,2 ... s; 1 ≤ j ≤ n); xn +1 = (x1, x2, ... xm) T, yn +1 = (y1, y2, ..., ys) T, so the xn+1 and yn+1 is the input and output decision unit n +1 and the No. n decision unit's virtual DMU *, which is the best DMU, put DMU incorporated into the actual decision unit, can get the best DMU the DEA extended model.

In this article use the extended DEA model and DEAP software to calculate, by the end of 2004 and 2009's port logistics input and output level to measure, as shown in Table 2, the two CRSTE efficiency values were used as "Reference Index" and "Current Index" .

Table 2: Chinese 13 major ports efficiency of port input and output

| | 2004 base year efficiency | | | | 2009 Current efficiency | | | |
|---|---|---|---|---|---|---|---|---|
| DMU | CRSTE | VRSTE | scale | Returns to scale | CRSTE | VRSTE | scale | Returns to scale |
| Ningbo port | 0.781 | 0.858 | 0.911 | irs | 0.489 | 0.754 | 0.648 | irs |
| Shanghai port | 0.635 | 0.635 | 1.000 | - | 1.000 | 1.000 | 1.000 | - |
| Qingdao port | 0.812 | 0.833 | 0.975 | irs | 0.507 | 0.703 | 0.721 | irs |
| Tianjin port | 0.545 | 0.680 | 0.801 | irs | 0.684 | 0.864 | 0.792 | irs |
| Guangzhou port | 0.546 | 0.604 | 0.904 | irs | 0.469 | 0.740 | 0.634 | irs |
| Shenzhen port | 0.790 | 0.842 | 0.938 | irs | 0.438 | 0.600 | 0.730 | irs |
| Dalian port | 0.620 | 0.760 | 0.815 | irs | 0.625 | 0.788 | 0.794 | irs |
| Lianyungang | 0.938 | 0.938 | 1.000 | - | 0.752 | 1.000 | 0.752 | irs |
| Yingkou port | 0.801 | 1.000 | 0.801 | irs | 0.786 | 0.925 | 0.850 | irs |
| Xiamen port | 0.755 | 0.980 | 0.771 | irs | 0.570 | 0.740 | 0.770 | irs |
| Yantai port | 0.951 | 0.976 | 0.975 | irs | 0.721 | 1.000 | 0.721 | irs |
| Rizhao port | 0.975 | 1.000 | 0.975 | irs | 1.000 | 1.000 | 1.000 | - |
| Suzhou port | 0.980 | 1.000 | 0.980 | irs | 0.810 | 0.810 | 1.000 | - |
| $DMU^*$ | 1.000 | 1.000 | 1.000 | - | 1.000 | 1.000 | 1.000 | - |

- Note: CRSTE: technical efficiency from CRS DEA
- VRSTE: technical efficiency from VRS DEA
- Scale: scale efficiency= CRSTE / VRSTE
- Returns to scale: ”-, drs, irs” stand for constant returns to scale, decreasing returns to scale, increasing returns to scale

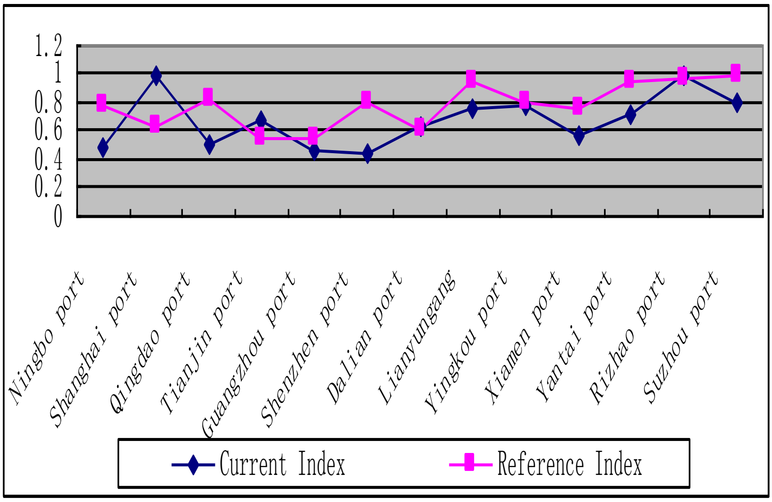


Figure 2: the "reference index" and the "current index" distribution of 13 ports in China.

We can see from Figure 2, at 13 ports in China the distribution trend of "reference index" and the "current index" is closer to each other, but the individual development of port speed has slightly larger difference between the two indexes.

Shanghai grows fastest in these 13 ports, the index value jumped from 0.635 directly to 1. Reference index in the infrastructure index (input redundancy) is large, but there are also non-zero growth rate (less output), indicating the facility in 04 is higher than the flow of goods at the time, and caused inefficient. But with the rapid economic development, the accuracy of forward-looking strategy has been verified in 2009 when it reached the output efficiency 1. Yun Jun and Zhang Fanze based on the data before 2005 get and these several years is the period of rapid development of Shanghai Port. Western countries vigorously promote economic development by China and Shanghai also accelerated the Yangtze linear network layout, formed from the lower reaches of Yangtze River to the container loading and unloading, transportation, regional train service agency network and feeding ports, make its cargo as well as growth rate improved significantly; besides, Shanghai port benefited from the construction of Yangshan Deepwater Port. High standards of port construction, not only to make up for lack of channel depth of the Yangtze River estuary and reduce the limitation of the large container ships entering the Port of Shanghai Yangtze Estuary restrictions. As a result, the "water of transit" greatly enhance the proportion of more effectively improve the port container integrated operation efficiency and make the throughput technical content and core competencies of

Shanghai Port achieve the level of world-class port. It's also the same opinion which the Shanghai port logistics is inefficient mainly caused by lack of water depth.

## 4.3. The Average Production Efficiency of China's 13 Major Ports and the X-Efficiency Measurement

The average production efficiency, based on the "Reference Index" and the "current index", calculates the input-output efficiency of port logistics from a static point; X-efficiency dynamically reflects the port logistics management under the facts of eliminating the objective basic condition. DEA described in this paper is the second relative evaluation method, which calculates the average production efficiency y (PE) and X-efficiency y (XE) of port logistics port 13, the results shown in Table 3.

Due to different inspection emphases, X-efficiency of port logistics and average productivity are slightly different in values. Different from the static production efficiency measure, the X-efficiency measure of port logistics focused on the enhancement of input and output level. The port's management can be reflected objectively through deducting the differences in natural basic condition from the perspective of dynamic, other than the low efficiency because of the differences in the hinterland and configurations. That is the reason why some experts use X-efficiency showing the level of management.

Table 3: the production efficiency and X-efficiency of port logistics port 13.

| | Ningbo | Shanghai | Qingdao | Tianjin | Guangzhou | Shenzhen | Dalian | LianYungang | Yingkou | Xiamen | Yantai | Rizhao | Suzhou |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PE | 0.635 | 0.8175 | 0.6595 | 0.6145 | 0.5075 | 0.614 | 0.6225 | 0.845 | 0.7935 | 0.6625 | 0.836 | 0.9875 | 0.895 |
| XE | 0.341 | 0.858 | 0.34 | 0.684 | 0.468 | 0.302 | 0.549 | 0.437 | 0.535 | 0.411 | 0.413 | 0.559 | 0.45 |

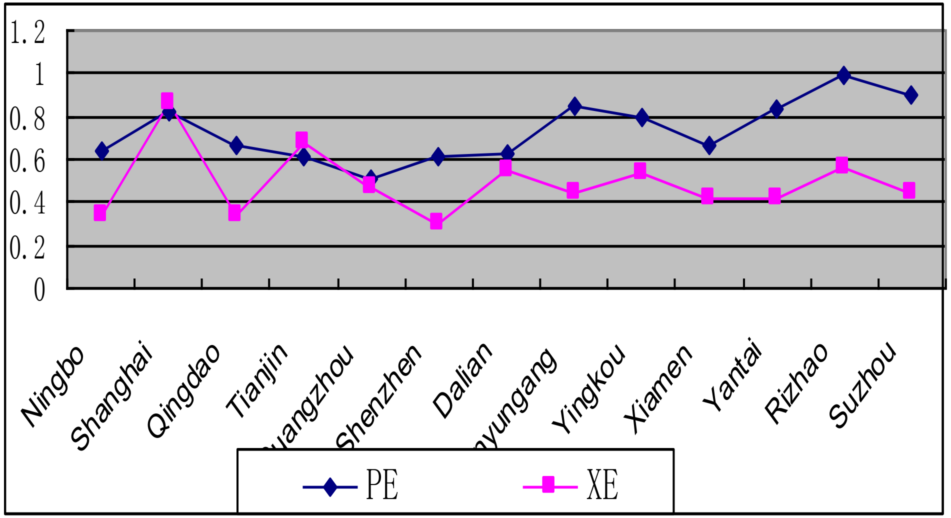


Figure 3: the production efficiency and X-efficiency of port logistics port 13.

From the chart we can see that the production efficiency distribution is roughly same as the index state trend in Figure 2. Guangzhou Port Logistics productivity is lower than the other 12 ports, which is in contradiction with the research result of comprehensive competitiveness index conducting by the Dalian Maritime University, the main reasons are: competitiveness index focus on the comparison in absolute magnitude, such as scale and throughput, while this paper, from an efficiency point of view, requiring getting the maximum output under minimum investment, put more importance in the relative amount.

The port city GDP index of Guangzhou port has significant input redundancy value, while the output value of insufficient of throughput can reach more than 70% of original value, so that makes the efficiency value of Guangzhou Port is very low. This is also consistent with the actual situation: located in the heart of the Pearl River Delta, Guangzhou port is outstanding in collecting and distributing conditions. However, Shenzhen port has most coincidence with Guangzhou port. Shenzhen port has the unique advantage, production efficiency is much higher than that of Guangzhou, which makes the heart of Guangzhou has an excellent collection and distribution conditions, but not the size and growth rate of equilibrium with them, resulting in redundant inputs, outputs inadequate. Under the condition of occupying large input while the output is limited, it is understandable that Guangzhou port’s production efficiency is low. Note that, Guangzhou port’s logistics X-efficiency is relatively high; indicating the level of management and effort of Guangzhou is relatively high. If provided appropriate conditions, there will be a larger space for development.

This paper has many similarities on the analysis of X-Efficiency with the conclusions of scholars Kuang Haibo. He believes that the economic hinterland of the port plays an active role in X-efficiency, while plays a negative role in port scale, the paper's results also verify this view.

The X-efficiency of China's major port logistics is between the 0.4-0.8, however, the X-efficiency of Shenzhen port for, with relatively high productivity, is only 0.468, and is contradiction with the fact that it ranks 6th in the comprehensive competitiveness of the ports. The main reason is the financial crisis. Before the financial crisis, high-yield caused high base in Shenzhen, so when the crisis broke out, Shenzhen port experienced the worst fall. From 2004 to 2009, infrastructure collection and distribution conditions of Shenzhen Port rose a lot, but the high input is out of date, not been given a high output. The negative growth was more than 10%, high rates of growth have not got a corresponding input output growth. As can be seen from Figure 3, the "current index" of Shenzhen port is relatively high, but because of the base period "reference index" is too high, result to the X-efficiency value is very low.

### 4.4. Comprehensive Logistics Efficiency Measurement Result Analysis of China's 13 Major Ports

Port logistics comprehensive efficiency measurement model designing according to the paper, based on production efficiency and the X-efficiency measure value, referring to parallel resistance formula calculations, China's 13 major port logistics comprehensive efficiency measurement results are shown in Figure 4.

Table 4: Logistics comprehensive efficiency of Chinese 13 major ports (CE).

| Ningbo | Shanghai | Qingdao | Tianjin | Guangzhou | Shenzhen | Dalian | LianYungang | Yingkou | Xiamen | Yantai | Rizhao | Suzhou |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.222 | 0.419 | 0.224 | 0.324 | 0.243 | 0.202 | 0.292 | 0.288 | 0.320 | 0.254 | 0.276 | 0.357 | 0.299 |

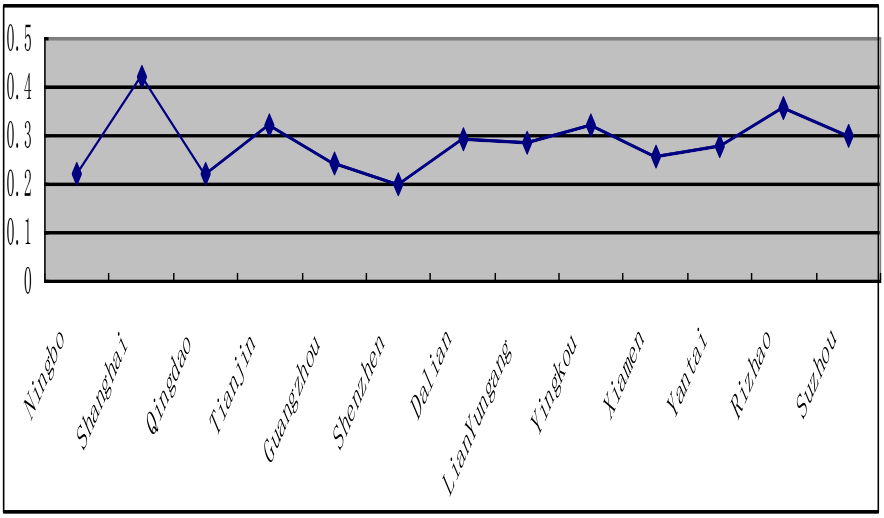


Figure 4: Chinese 13 major port logistics comprehensive efficiency.

Its X-efficiency is quite high, indicating the success of Shanghai port is not only due to its economic hinterland and excellent port conditions, but also because of Shanghai people's hard work and the higher management level, what's more, the overall efficiency is the highest.

As the 4th largest port in coastal port container throughput, Ningbo Port's overall efficiency is slightly lower. Ningbo Port officially merged with the "Zhoushan Port", established the "Ningbo Zhoushan Port" in 2006. Since that, the throughput has been greatly increased. However, the X-efficiency is the lowest among the 13 ports. There are many reasons. From the input and output indicators data and model results, the primary reason is it develops with rapid pace and brings a lot of hidden problems. To stimulate growth, Ningbo Port is on a large scale expansion, which makes its hardware and equipment get the highest level of our ports, such as large container yard, fully furnished, high-density liner routes. However, these are higher than the current freight volume requirements, result to the low productivity. Meanwhile, rapid economic growth enables the expansion, management effectiveness decreased, but also led to the low X-efficiency of the port. Although the overall efficiency of Ningbo Port is lower, the decision to increase infrastructure investment is a forward-looking strategic in the long run, which has been fully indicated by Shanghai's development process. With further economic development, the good equipments of Ningbo Port will play a greater role, and the efficiency will definitely be enhanced

From the calculation results, the port logistics production efficiency value in China, especially the 2009 input-output efficiency value is higher. This indicates five-year all the ports have got a high speed development during the 5 years; but the X-efficiency values are below 0.8, some individual port are even as low as 0.2, exposing that most attention are made to the development of hardware and infrastructure, management did not timely raised, personnel quality are not good enough, all of these results the low X-inefficiency, affecting the further development of port logistics. On the basis of the two Efficiency values, Chinese port logistics comprehensive efficiency is generally very low. Comparing with foreign ports, the port is still under the extensive development, focusing only on the infrastructure construction, neglecting improving the management, which led to the logistics on the low side. But need to be explained that the majority of port logistics in China are in the state increasing, indicating our ports are through a rapid growth and have a great room for development.

# 5. Conclusion

The research core of this issue divided into three parts: port logistics productivity efficiency measurement, X-efficiency measurement and integrate efficiency. First, on the basis of previous literature, we construct an efficiency measurement index system for port logistics inputs and outputs, and on this basis, use the C2R model in DEA measures the produce efficiency value of port logistics; Second, make the productivity efficiency value as the "reference index" and "current index" which separated in five years to use the BC2 model in DEA to measure the X-efficiency value in port logistics after confirm index condition; Third, base on the productivity efficiency and X-efficiency of the port, adopt parallel connection formula to calculate integrate efficiency of the port logistics; Finally, apply this model to proceed demonstration simulation for thirteen ports of our country.

Research the X-efficiency measurement of our country's port logistics recover the blank of this item research in domestic, this issue is to provide more a kind of idea, but since the factors impact the port logistics efficiency are very complex, limited by the space, we couldn't involve all the content and the model application is not very mature, this is where the limitations of this article. However, consider the similar questions from the DEA two-stage relative evaluation to measure the X-efficiency, is very helpful to the theory and practice of the efficiency measurement.

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