Chapter 47
Ship Building Production in Jiangsu Province Based on DEA Efficiency Analysis

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Abstract The productivity of shipbuilding plays an important role in the transformation from a big shipbuilding province to a strong shipbuilding province of Jiangsu, which is now the largest shipbuilding province. DEA is applied when analyzing the Jiangsu province's productivity of shipbuilding both in the aspects of technology and scale in this paper, and we can get the conclusion that the excess capacity caused by over-input of personnel and material and poorly management led to the inadequate productivity about shipbuilding in Jiangsu, and the relevant countermeasures are proposed in this paper.

Keywords Jiangsu · Shipbuilding · DEA · Efficiency

47.1 Introduction

As the largest shipbuilding province in China, Jiangsu occupies absolute advantage on the number of shipbuilding, in 2009, 2010 and 2011, its shipbuilding completions accounted for the proportion of the national were 35.5, 34.5 and 36.4 %. In 2012, Jiangsu shipbuilding industry continued to maintain steady development trend, its shipbuilding completions amounted to 22.185 million dead weight tones, that is 15 % of the world's market share, and 36.8 % of the country's. Its strategic role in Jiangsu province's industrial development is becoming more and more obvious. Even though shipbuilding production capacity of Jiangsu has achieved stable development, it is insufficient in the production technology, management and utilization, and the problems of shipbuilding production's low efficiency and overcapacity are becoming increasingly prominent, due to blind expansion of investment. Lean man-

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ufacturing has become an important strategy of the development of the shipbuilding enterprises; therefore, the analysis of Jiangsu shipbuilding production's efficiency has both realistic and theoretical guiding significance.

Data envelopment analysis (DEA) is based on the concept of relative efficiency. The relative relation between the efficiency of decision making units, namely the relative effectiveness are permitted to use DEA method to estimate directly. DEA method of relative efficiency evaluation is now successfully applied in different fields of society and industry, such as city, bank,base maintenance, weapons and equipment efficiency analysis, military aircraft flight, etc., and significant results and good social reflect have been achieved. This method has also been used in the area of domestic shipbuilding efficiency research in recent years. Such papers are as Zhang [1] evaluated the technical efficiency of China's shipbuilding industry situation, Tao and Chen [2] analyzed the efficiency of shipbuilding industry in Yangtze River delta and Su [3] analysis of the working team activity responsibility cost for shipbuilding enterprise. This paper uses DEA method aiming to conduct a comprehensive evaluation of Jiangsu shipbuilding production efficiency by analyzing the production efficiency, technical efficiency and scale efficiency. And several countermeasures to improve the production efficiency are presented on the basis of analyzing the results.

47.2 The DEA Method

Wei [4] indicated that Data Envelopment Analysis, hereinafter referred to as DEA, is a nonparametric statistical method which evaluates the relative efficiency of Decision Making units (hereinafter referred to as the DMU) with the same type and multiple inputs and outputs. In order to solve the problem of finding the best production frontier, measuring DMU production point with the best front surface distance (curved section which takes on all the DMU) and obtaining the way to measure the efficiency of DMU. Charnes et al. [5] said that proposed DEA which was a new data statistic analysis method on the basis of the concept of "relative efficiency evaluation" in 1978. Zhang and Li [6] considered that his method can not only handle the problems of multiple inputs and outputs simultaneously without the restriction of index dimension, but also can be directly makes the comprehensive analysis of various qualitative indexes and quantitative indexes without data preprocessing. The CCR and BCC are two of the most representative research and application of DEA model in the theoretical system of the DEA method. Based on the analysis of Jiangsu shipbuilding production efficiency, the DEA models that this paper choose are also the CCR and BCC models. Here are the two kinds of data models:

1. The CCR Model. CCR model is on the premise of assuming the returns to the scale is a constant, that is, to increase the certain proportion of cast, the output should also be increased in the same proportion. It is used to calculate the comprehensive relative efficiency value of each decision making unit (comprehensive efficiency value including pure technical efficiency and scale efficiency). The CCR model can be expressed in Eq. (47.1).

Assume that there are n DMU, each of which DMU ($k = 1, 2, \cdots, n$) uses m kind of inputs x_{ij}, and outputs s kind of outputs y_{ir} ($x_{ij} \geq 0$, $y_{ir} \geq 0$), v_i and u_r are respectively the weights of the i_{th} input index and the r_{th} output, Hence the relative efficiency of DUM o $h_{o(u,v)}$ can be written as the following form:

$$\begin{cases} \min h_{O(u,v)} = \dfrac{\sum\limits_{r=1}^{s} u_r y_{ro}}{\sum\limits_{i=1}^{m} v_i x_{io}} \\ \text{s.t.} \begin{cases} \dfrac{\sum\limits_{r=1}^{s} u_r y_{rj}}{\sum\limits_{i=1}^{m} v_i x_{ij}} \leq 1 \\ ur, vj \geq 0, r = 1, 2, \cdots, s \\ i = 1, 2, \cdots, m, \; j = 1, 2, \cdots, n. \end{cases} \end{cases} \tag{47.1}$$

According to the input and output vectors of DMU, we can conclude the comprehensive efficiency of each DMU by type (1). In order to calculate conveniently, make (u, v) satisfies the $\sum_{r=1}^{s} u_r y_{ro}$, the fractional programming problem is converted into easy to deal with linear programming problem through dual operation, to discuss and make it easy for computing applications, further introduction of slack variable s^+ and the rest of the variables s^-, the above inequality constraints into equality constraints, And then be able to get the Eq. (47.2):

$$\begin{cases} \min z_o = \theta - \varepsilon \left[\sum\limits_{i=1}^{m} s_i^- + \sum\limits_{r=1}^{s} s_r^+ \right] \\ \text{s.t.} \begin{cases} \theta x_{io} - \sum\limits_{j=1}^{n} x_{ij} \lambda_j - s_r^+ = y_{ro} \\ \sum\limits_{j=1}^{n} y_{rj} \lambda_j - s_r^+ = y_{ro} \\ y_j, s_i^-, s_i^+ \geq 0. \end{cases} \end{cases} \tag{47.2}$$

Set the optimal solution of (2) are θ^*, s_r^{*+},s_r^{*-},$\lambda*$. There are:
(1) If $\theta^* < 1$, DMU_O is not DEA efficient;
(2) If $\theta^* = 1$, then DMU_O is weak DEA efficient;
(3) If $\theta^* = 1$, and $s_r^{*+} = s_r^{*-} = 0$, then DMU_0 is DEA efficient.
2. The BCC Model. Determination of technical efficiency is the CCR model under the assumption of constant scale reward of relative efficiency, but not every DMU under the fixed scale production, The size of the DMU remuneration is not static, Different periods may be in a state of increasing or decreasing, there are two reasons for the inefficiency of DMU: (1) Their configuration of input and output is not reasonable. (2) Its size is not appropriate. Thus, Banker, Charnes, Cooper adds a convexity assumption conditions $\sum_{i=1}^{n} \lambda_i = 1$ on the CCR model, to show the change scale reward, that is the BCC model.

Steps of using DEA are: Wade and Joe [7] indicated that (1) define and select the evaluation object; (2) look for relevance and Suitable input-output project, to make it easy to evaluate the relative efficiency of object; (3) apply DEA model to analysis. In this paper, the above steps are regarded as the basis of DEA analysis.

47.3 Empirical Research and Analysis

47.3.1 The Selection of Decision Making Units

DEA method can evaluates the relative effectiveness among the comparative objects. Zhao et al. [8] point out that we must choose decision making unit (DMU) correctly so as to apply the DEA method correctly and obtain scientific evaluation conclusions and useful decision information. From the experience and technology, the DEA has the following requirements of decision making units: (1) all of DMU should have the characteristics of the same category; (2) It is better that the number of DMU is greater than the total number of the input and output indicators, because it can technically rules out the internal linear correlation of input or output set.

For any decision making units, Its achievement of 100 % efficiency refers to: (1) Under the condition of existing inputs, each kind of output elements won't be able to increase unless reducing other types of output elements at the same time. (2) To achieve the output elements of the existing unless it increases other types of investment at the same time, or any kind of input elements cannot be reduced. If efficiency of a decision making unit is 100 %, it shows that the decision-making unit is relatively effective, which is referred to as the effective decision making units.

All decision making units in this text are China's major shipbuilding provinces, which are in the same type.

47.3.2 The Choice of Input and Output Index

When it comes to selecting input and output indicators, Chen and Liu [9] indicated that we should consider the following aspects: First of all, the choice of indicators can meet the requirements of evaluation, reflect the competitiveness of the evaluation objects objectively; Secondly input (output) sets with strong linear relationship between the internal index should be avoided technically; Finally the importance and availability of indicators should be considered.

The production characteristics of shipbuilding enterprises and enterprise goal are the main consideration in this text when we choose input and output project of the shipbuilding enterprises. According to the principles of unity, comparability of the data size, at the same time avoiding higher rate and correlation index, combining with the actual fact of shipbuilding industry, we can select industry staff number, major equipment (the total number of berth and dock) as inputs factors, total outputs as output factors.

Table 47.1 Relevant data list of shipbuilding industry in Jiangsu province in 2007–2011

Year	The average number of practitioners	Output
2007	43,049	4,518,829
2008	70,593	8,976,506
2009	113,862	14,090,157
2010	198,397	17,577,618
2011	228,489	20,985,626

Table 47.2 Relevant data list of major shipbuilding in 2011

Province	Annual average workers	The number of dock and berth	Annual output
Liaoning	478,662	13	5,803,402
Shanghai	28,993	33	5,788,723
Jiangsu	228,489	94	20,985,626
Zhejiang	54,311	429	7,838,776
Anhui	13,950	14	1,635,372
Fujian	14,874	3	1,274,456
Shandong	36,764	29	4,605,131
Hubei	26,135	34	2,417,143
Guangdong	42,835	25	4,142,949
Chongqing	13,477	48	1,737,970

47.3.3 The Original Data and the Corresponding Processing

We made an Analysis of the production efficiency about the main producing area of shipbuilding and Jiangsu province in China in this text. The data derive from the yearbook of China shipping industry statistics in 2007–2011 and related collected materials (Tables 47.1, 47.2).

1. Calculation process

Choosing DEAP2.1 as DEA operation platform, DEAP2.1 is free calculation software provided by Professor Celli, who is from the New England University in Australia. Using of DEAP2.1 software, we can gradually apply the CCR and BCC models in data envelopment to operate, after dealing with the data, the production efficiency, pure technical efficiency and scale efficiency can be calculated, the result of data is shown in the Tables 47.3 and 47.4.

2. Analyzing the calculation result

(1) Comparative analysis of Jiangsu province in recent five years. From Table 47.3, we can get the change of production efficiency, technical efficiency and scale efficiency of shipbuilding in Jiangsu province in 2007–2012 (as shown in Fig. 47.1). Changes can be seen from the diagram, production efficiency of the shipbuilding is mainly affected by the change of the scale efficiency, scale efficiency first increased and

Table 47.3 The DEA model calculation results of shipbuilding industry in Jiangsu province in 2002–2011

Years	Production efficiency	Technical efficiency	Scale efficiency	Scale reward
2007	0.826	1.000	0.826	↑
2008	1.000	1.000	1.000	-
2009	0.973	1.000	0.973	↓
2010	0.697	0.866	0.804	↓
2011	0.722	1.000	0.722	↓

Note "↑" means increase, "-" means keeping the same, "↓" indicates decreasing in table

Table 47.4 The DEA model calculation results of the main shipbuilding in our country in 2011

Province	Production efficiency	Technical efficiency	Scale efficiency	Scale reward
Liaoning	1.000	1.000	1.000	-
Shanghai	1.000	1.000	1.000	-
Jiangsu	0.686	1.000	0.686	↓
Zhejiang	0.723	1.000	0.723	↓
An hui	0.625	1.000	0.925	↑
Fujian	0.925	1.000	0.925	↑
Shandong	0.745	0.764	0.976	↑
Hubei	0.463	0.672	0.963	↑
Guangdong	0.647	0.672	0.963	↑
Chongqing	0.646	1.000	0.646	↑

Note "↑" means increase, "-" means keeping the same, "↓" indicates decreasing in table

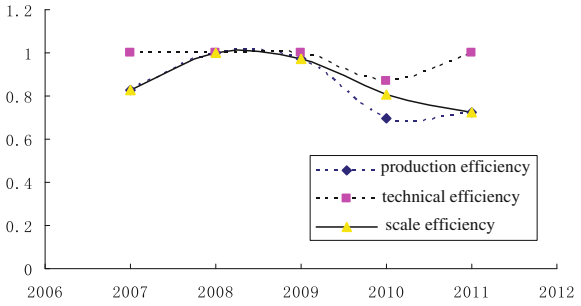

Fig. 47.1 The change of production efficiency, technical efficiency and scale efficiency of shipbuilding in Jiangsu province in 2007–2012

then decreased. And see from Table 47.3, Scale reward also fell in reducing years, this shows the capacity of shipbuilding production in Jiangsu is become excess since 2009. Demand of the ship industry was increasing in 2007, so was scale reward, enlarging the production scale will improve the production efficiency, it leads to expansion of the Shipbuilding capacity of the Jiangsu province; the reasons why the shipbuilding production efficiency to achieve effective and scale reward keeps a constant in 2008 are: In 2008, the outbreak of the financial crisis had the negative

effect on the shipping industry and leaded to the reduction of the blind production of shipbuilding industry. But due to the poor demand of market, since 2009, the new orders appear, hand-held orders have a downward trend. From Table 47.3, technical efficiency value is higher than the scale efficiency value of Jiangsu shipbuilding industry, and both of them are less than 1. On the one hand: technical inefficiency and scale inefficiency are the source of the inefficiency of the Jiangsu shipbuilding, on the other hand, the major source of production inefficiency is scale inefficient, and it can be obtained from diminishing size: Jiangsu shipbuilding industry is in a state of excess production capacity in 2010. At the same time, the enterprise management level is poorer, which is also one of the reasons for the inefficiency of Jiangsu shipbuilding industry.

(2) Comparative analysis between Jiangsu and other shipbuilding areas. The Table 47.4 shows the lateral comparison of Jiangsu shipbuilding productivity and we can see that the productivity in Jiangsu shipbuilding industry was very low relative to other shipbuilding areas in China in 2011. It only ranked sixth. From BCC model, we know that productivity equals technical efficiency plus scale efficiency, but the technical efficiency in Jiangsu was 1.000 so that we can get the information that the low productivity attributed to the low scale efficiency. In addition, the scale reward was also decreasing, so it indicates that the production capability was excess in 2011.

47.4 Conclusion, Countermeasure and Suggestion

47.4.1 Conclusion

It can be concluded from the analysis that the main reason of the shipbuilding inefficiency in Jiangsu province is scale efficiency, whose decreasing is resulted from the surplus productivity in Jiangsu shipbuilding industry. Besides, the fluctuation of technical efficiency also reveals the fact that the instability of shipbuilding management needs continuous improvement. Therefore, to enhance the competitiveness of shipbuilding industry in Jiangsu province, it not only should change the extensive expansion mode and readjust the scale of shipbuilding industry to a reasonable level, but also needs to improve the management.

47.4.2 Countermeasure and Suggestion

1. Optimizing productivity

The main reason of the shipbuilding inefficiency in Jiangsu province is enlarging the production scale blindly when this industry was thriving, which leads to the excessive capability now. Jiangsu is one of the largest provinces which build ships in China.

To becoming a competitive province, it is essential to increase productivity. That's why we must solve the problems of capacity surplus.

In first place, to solve the above problems, the government is supposed to Strengthen macro-economic control and cannot enlarge the production scale merely by expand the scale of production to increase productivity, the government should prevent the blind expansion of production scale. Besides, carrying on some special project to rectify the situation where there exist low-quality ships, cleaning up and recognizing the projects under or awaiting construction, prohibiting the illegal shipbuilding as well as repetitive construction at low level. Changing the develop pattern to make shipbuilding industry go on a sustainable development road.

What's more, it is necessary for shipbuilding to optimize the product structure. When we vigorously develop the large and ultra-large ships, it's also important to enhance the level of shipbuilding and build ships with high technology and high added value. Therefore, We should make great effort on the building of ships such as LNG, LPG, ocean engineering ships and others with high technology and added value. It is the best choice that launching the diversified operating and optimizing business structure when facing the inadequate market demand.

2. Improving the management level

The research made by the relevant department of shipbuilding industry shows that management optimization will account for 31 % of the whole increase in productivity considering the impact on the proportion of production efficiency from each factor. Obviously, there is huge profit potential underlying the enterprise internal management. To improve the management, except for coordinating the relationships among the design, process, technology, management mechanism, institution structure and production layout, it also needs to take all aspects into consideration to make them cooperate and complete each other. Only by these ways can we reach the target of improving the internal management and reducing the production cost.

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