A comparative study on efficiency of two different circulation modes of agricultural products based on DEA model: wholesale market and logistics distribution centre

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Abstract

The purpose of this study is to find out the relatively efficient circulation mode of agricultural products through a comparative analysis on the operating efficiency of two different circulation modes of agricultural products: wholesale market and logistics distribution centre. Based on the input and output data collected from the survey of the main representatives of enterprises in the two modes in Zhangzhou, Fujian, including: fixed assets, number of employees, main business cost, main business net profit, gross margin, the paper uses Data Envelopment Analysis to conduct the analysis. The results show that the third party logistics mode based on logistics distribution centre is relatively more efficient, comparing with the traditional wholesale market mode. Therefore, in order to reduce circulation cost of agricultural products, and to promote the development of agricultural industry, it is necessary to make policies to encourage the development of the third party logistics mode based on logistics distribution centre.

Keywords: data envelopment analysis model, wholesale market mode, logistics distribution centre mode, operation efficiency

1 Introduction

Bain [1] analysed industry performance by using the S-C-P mode in the industrial organization, which is used to evaluate circulation efficiency by agricultural sector. Among them, S (structure) reflects the organizational characteristics of market; C (conduct) is the marketing strategies adopted by enterprises; P (performance) is the result of the overall operation of industry. Stern [7] pointed out that the circulation channel performance included effect, fairness and efficiency, in which the effect reflected accessibility and incentives, while efficiency reflected productivity and profitability. Chen [2] proposed the efficiency of food marketing system could be studied through the analysis of system and organization structure. Subsequently, Enke [3] proposed the spatial price equilibrium theory, based on which Samuelson [6], Takayama [8] put forward the commodity's price is decided by the transfer cost in a competitive market. Clark [4] considered that market efficiency could be studied from two aspects, namely the individual enterprises and the public. From the perspective of the enterprises, market efficiency were evaluated mainly through profit or cost; while from the perspective of the public, market efficiency were evaluated through circulation service level and circulation cost.

At present, both at home and abroad, many scholars have conducted fruitful researches on efficiency of circulation channels of agricultural products [2, 9-11]. Taking chickpea as an example, [8] used empirical analysis approach to analyse the circulation efficiency of different distribution channels, and the results of the study indicated that: farmers were facing a lot of problems in the circulation, and the circulation cost was the main part of the price of agricultural products. Based on the field survey of 112 retailers randomly selected from 6 farmers markets in 6 districts of Nanjing City, Zhou and Lu [11] chose some indicators such as the circulation level and cost, loss rate, producers share ratio and so on to analyse the circulation efficiency of fresh vegetables in different circulation channels in Nanjing City. Wang [9] combined with the results of the survey on large-scale circulation enterprises of fresh agricultural products in Wuxi and conducted the efficiency evaluation model of the supply chain management and the traditional circulation mode of fresh agricultural products, through the construction of input-output, efficiency evaluation system of circulation mode of fresh agricultural products and comprehensive preference cone model. Yang and Xiao [10] investigated and analysed the subject of circulation in each circulation link of the three kinds of circulation channels of grape circulation in Jinzhou city. Through the in-depth interview on the subject of circulation, she analysed the circulation cost and efficiency in different circulation channels. Chen, Cai and Dai [2] conducted a detailed analysis on the interior and exterior transaction cost of the three major circulation modes: farmer-spontaneous circulation mode, cooperatives-oriented circulation mode and contract-

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oriented vertical circulation mode, and then found out the factors influencing the transaction efficiency. Finally, it put forward some countermeasures to enhance the transaction efficiency of each circulation mode.

Owing to the difficulty to obtain the detail research data, the study on the comparative efficiency evaluation of wholesale market or the third party logistics of agricultural products mainly stays in the qualitative research, namely, the research on quantitative analysis is relatively less. Based on the previous studies, the paper uses Data Envelopment Analysis (DEA) approach to analyse the efficiency level of wholesale markets mode and the third party logistics mode of agricultural products, hoping the result can provide the reference basis for the management decision-making.

2 The basic situation and sample selection

Zhangzhou City, located in the south-east of Fujian Province, is the largest plain in Fujian - a total area of 12,600 square kilometres with nearly 4,810,000 residents. As the "Flower and Fruit City", Zhangzhou City has a superior geographical position. It is the largest agricultural export base in Fujian Province and the key national export-oriented agriculture demonstration area. Its total agricultural output value in 2012 reached 55,885,000,000 Yuan. Its per capita of agricultural products such as fruit, aquatic products, vegetables, edible mushroom (fresh) and the flower ranks the forefront of districts, especially the fruit production in 2011 reached 2,726,600 tons. Its output and export volume exceeded more than half of the similar products of the province, while the banana is the greatest in production in Zhangzhou. The fruit of Zhangzhou export a lot every year. Therefore, the scale of the wholesale, transportation, warehousing, distribution of agricultural products promote the rapid development of agricultural products logistics in Zhangzhou City. The "Twelfth Five Year Plan" modern agricultural development planning of Zhangzhou City shows that there are 25 wholesale markets of all types of agricultural products in Zhangzhou City, covering the main agricultural products of the region. However, there exist some problems in the traditional wholesale mode in the actual operation, such as: the irrational allocation of resources, not timely and comprehensive information feedback, and the difficulty in meeting the needs of the development of modern logistics of agricultural products. Meanwhile, the third party logistics transformed from large wholesalers are developing rapidly. The logistics distribution centre of agricultural products sets acquisition, storage, distribution processing and distribution as one, and has gradually become an important bridge for agricultural super docking of supermarket. Many scholars believed that the development of the logistics distribution centre mode in China could adapt to the agricultural super docking, could improve circulation efficiency and reduce the circulation cost. However, many of these studies were qualitative descriptions, lack of empirical analysis.

Therefore, this paper chooses 10 representatives: 6 wholesale markets and 4 third party logistics companies of agricultural products in Zhangzhou City, using Data Envelopment Analysis to evaluate the operating efficiency of the traditional wholesale market mode and the third party logistics. The 10 economies are: ZQN wholesale market, ZPB wholesale market, MLN wholesale market, ZLS wholesale market, ZSS wholesale market, ZCT wholesale market, ZYS company, ZTL company, ZJX company and ZWG company.

3 Main circuit structure

3.1 RESEARCH APPROACH

Data Envelopment Analysis can be used for relative efficiency evaluation of complex system with multiple input and output. There are two basic models: CCR and BCC. In the paper, the CCR model is used, a multi-input and multi-output efficiency evaluation model under the assumption of a certain scale of reward. The basic ideas of the model are as follows: the model assumes there are n objects to be evaluated, called the decision making units (DMU), and there are m input and s output in each decision making unit. X_{ij} indicates the i input of the j decision-making unit, and Y_{rj} indicates the r output of the j decision-making unit, so the input and output vector of DMUj respectively can be expressed as:

$$X_j = (x_{1j}, x_{2j}, ..., x_{im})^T, j = 1,2,...,n, \quad (1)$$

$$Y_j = (y_{1j}, y_{2j}, ..., y_{im})^T, j = 1,2,...,n, \quad (2)$$

where v_i stands for input weight in i, and u_r stands for output weight in r. Therefore, the weight vector of input and output can be expressed as the following:

$$v = (v_1, v_2, ..., v_i)^T, \quad (3)$$

$$u = (u_1, u_2, ..., u_i)^T. \quad (4)$$

So the efficiency evaluation index for DMUi is:

$$h_j = \frac{u^T y_i}{v^T x_j}, j = 1,2,...,n. \quad (5)$$

Among them, h_j is variable. Adding u and v, it makes $hj \leq 1$. The larger h_{j0} is, the higher the efficiency it shows. In other words, less input can get more output. Therefore, the relative efficiency of DMU_{j0} can be made out through changes in u and v, until the maximum value of h_{j0} can be got. CCR model can be used to evaluate efficiency of each DMU. Weight coefficient is variable; the efficiency index of DMU_{j0} is the target; and all efficiency index of DMU h_j

$\leq 1, j = 1, 2,\ldots, n$ are the constraints; therefore, CCR model can be constructed as the following:

$$C^2R = \begin{cases} \max \dfrac{u^T y_i}{v^T x_j} = V^1_{C^2R} \\ s.t. \dfrac{u^T y_i}{v^T x_j} \leq 1,\ j = 1,\ldots,n \\ u \geq 0, v \geq 0 \end{cases} . \quad (6)$$

This is a fractional programming model. By using Charnes-Cooper transformation, it will be transformed into a linear programming model:
if

$$t = \frac{1}{v^T x_0}, \omega = tv, \mu = tu ,$$

then

$$P_{CCR} = \begin{cases} \max \mu^T y_0 = V^1_{C^2R} \\ s.t. \omega^T x_j - \mu^T y_j \geq 0,\ j = 1,\ldots,n \\ \omega^T x_0 = 1 \end{cases} . \quad (7)$$

According to the dual nature, the dual model of the programming model is obtained. Because it is difficult to directly judge DEA efficiency, the concept of non-Archimedean infinitesimal is usually introduced, which makes up the CCR duality programming model with non-Archimedean infinitesimal:

$$D_{CCR} = \begin{cases} \min\left[\theta - \varepsilon\left(e^{T-} S^- + e^{T+} S^+\right)\right] \\ s.t. \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_0 \\ \sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0,\ j = 1,2,\ldots,n \\ S^+ \geq 0, S^- \geq 0 \end{cases} . \quad (8)$$

Among them, ε is the amount of non-Archimedean infinitesimal, while $e^{T-} = (1,1,..,1)$, $e^{T+}=(1,1,..,1)$, S^- and S^+ are the slack variables.

In the case of the CCR, DEA's economic meaning is: it is the technology efficiency, but also the scale efficiency. The former indicates that the output has reached the maximum, comparing with the input; and the latter means that the input is in the state of constant returns to scale. Θ $(0 \leq \theta \leq 1)$ the relative efficiency of DMU_j, is the reflection of the state of resource allocation efficiency in j decision-making unit. The bigger θ is, the higher relative resource allocation efficiency is, which means that the allocation of resources is more reasonable, and vice versa. Specifically, supposing λ^*, S^{+*}, S^{-*}, θ^* as the optimum solution of the model, there are:
1. when $\theta^*=1$, $S^{+*}=0$, $S^{-*}=0$, the decision-making unit is DEA efficient, which shows that the output has reached the optimal state under the present input level.
2. when $\theta^*=1$, $S^{+*}\neq 0$, $S^{-*}\neq 0$, the decision-making unit is weak DEA efficient, which shows that it is necessary to adjust the input or output.
3. when $\theta^*<1$, the decision-making unit is non DEA efficient, which shows that there must be a redundant input or output deficiency [5].

3.2 SETTING OF EVALUATION INDEX AND DATA SOURCES

Based on qualitative and quantitative principles, and systematic and comprehensive principle, this paper selects the total value of fixed assets, number of employees and the main business cost as the input index, main business net profit and gross margin of the main business as the output index. The specific meanings of each index are as follows:
1. The total value of fixed assets: it reflects the amount of capital investment. For the circulation subject of agricultural products, it includes transportation, warehouse, related equipment etc.
2. The number of employees: it reflects the labour input. The agricultural products circulation process requires a lot of manpower, therefore the number of employees in the enterprise is considered as an important input variable.
3. The main business cost: it reflects the direct input, the cost of resource value to get the business income.
4. The main business net profit: it reflects the output efficiency under a fixed input. The higher the main business profit is, the more efficient business shows.
5. The gross margin of the main business: this paper selects the economy's gross margin of the main business to reflect the proportion of the management expenses. Combined with the research results of these 10 economies, the data are sorted out as shown in Table 1.

Note: the data are from the corporate annual reports and the research results of project group of the 10 economies in 2009.

TABLE 1 Input and Output Indicators of 10 Economies in Zhangzhou

Decision making unit	Fixed assets (millions of Yuan)	Number of employees	Main business cost (millions of Yuan)	Main business net profit (millions of Yuan)	Gross margin of the main business (%)
1	2200	265	1200	600	15.65
2	2400	184	1380	600	19.01
3	2450	140	735	560	20.55
4	5850	280	1100	1300	25.29
5	960	162	600	600	27
6	3200	120	520	600	30.26
7	800	80	520	689	31.31
8	668	80	420	534	32
9	1890	157	881	675	21.03
10	596	114	340	350	24.52

The numbers represent respectively the related decision-making units:
1. ZPB wholesale market;
2. MLN wholesale markets;
3. ZLS wholesale markets;
4. ZJX Company;
5. ZCT wholesale market;
6. ZQN wholesale market;
7. ZWG Company;
8. ZYS Company;
9. ZSS wholesale market;
10. ZTL Company.

4 Empirical results

Take the decision-making unit 1 for example, then the following equation can be obtained:

$$D_{CCR}=\begin{cases}\min\left[\theta-10^{-10}\left(S_1^{-}+S_2^{-}+S_3^{-}+S_1^{+}+S_2^{+}\right)\right]\\ 2200\lambda_1+2400\lambda_2+2450\lambda_3+5850\lambda_4+960\lambda_5+3200\lambda_6+800\lambda_7+668\lambda_8+1890\lambda_9+596\lambda_{10}+S_1^{-}-2200\theta=0\\ 265\lambda_1+184\lambda_2+140\lambda_3+280\lambda_4+162\lambda_5+120\lambda_6+80\lambda_7+80\lambda_8+157\lambda_9+114\lambda_{10}+S_2^{-}-265\theta=0\\ 1200\lambda_1+1380\lambda_2+735\lambda_3+1100\lambda_4+600\lambda_5+520\lambda_6+520\lambda_7+420\lambda_8+881\lambda_9+340\lambda_{10}+S_3^{-}-1200\theta=0\\ 600\lambda_1+600\lambda_2+560\lambda_3+1300\lambda_4+600\lambda_5+600\lambda_6+689\lambda_7+534\lambda_8+675\lambda_9+350\lambda_{10}-S_1^{+}=600\\ 15.65\lambda_1+19.01\lambda_2+20.55\lambda_3+25.29\lambda_4+27.00\lambda_5+30.26\lambda_6+31.31\lambda_7+32.00\lambda_8+21.03\lambda_9+24.52\lambda_{10}-S_2^{+}=15.65\\ \lambda_j\geq 0,\ j=1,2,\ldots,10\\ S_1^{+},S_2^{+},S_1^{-},S_2^{-},S_3^{-}\geq 0\end{cases}. \quad (9)$$

The results of other decision making units can be obtained in the same way. By using Matlab software, the calculated results are shown in Table 2. From the results, it is found that θ of ZTL Company, ZJX Company, ZWG Company and ZYS Company equal to 1, and S^{+}=0, S^{-}=0, which constitute the DEA efficient frontier of the whole evaluation model. That is to say, from the point of view of the above three inputs and two outputs, the operation conditions of the 4 economies are DEA efficient; the resources are fully utilized, and the output is high; therefore, this is a kind of ideal condition. Similarly, according to Table 2, the evaluation results of the 6 DEA economies can be obtained: θ of ZQN wholesale market, ZPB wholesale market, MLN wholesale market, ZLS wholesale market, ZSS wholesale market, ZCT wholesale market are respectively: 0.853, 0.804, 0.763, 0.816, 0.732, 0.928, compared with the other 4 economies, the operation conditions of the 6 economies are relatively inefficient.

In addition, according to the slack variables in Table 2, it comes out that it is necessary for the economies to continue to improve in each input and output indicators. Specifically, there exist problems in ZLS wholesale market such as employee redundancy and too high main business cost, but low main business net profit; there exist problems in MLN wholesale market and ZQN wholesale market such as employee redundancy, low main business net profit and low gross margin of the main business. While the input and output of the other 4 economies are more proportionate.

5 Analysis and Discussion

From the above evaluation results, it is not difficult to find out that, among the 10 economies, only the operation

efficiency of ZJX Company, ZWG Company, ZYS Company and ZTL Company is efficient, while the operation efficiency of the other 6 economies is relatively low. However, how much is the distance away from DEA efficiency? How to improve it? Therefore, the paper conducts the projection analysis. Taking the project analysis of the input cost as an example, the specific approach is: taking 4 efficient decision making units as a reference, the DEA evaluation values of the other 6 decision making units are set to be 1, and suppose that the value of the fixed assets, number of employees, the main business net profit and the gross margin of the main business of the 6 units were unchanged.

TABLE 2 The results of DEA Efficiency Evaluation of 10 Decision Making Units

Decision making unit	θ	Input slack variables			Output slack variables		Relative efficiency
		S1	*S2*	*S3*	*S*1*	*S*2*	
1	0.386	0.124	0.022	0.000	0.000	16.056	inefficient
2	0.435	0.287	0.000	0.113	38.213	12.526	inefficient
3	0.594	0.766	0.003	0.000	0.000	11.334	inefficient
4	1.000	0.000	0.000	0.000	0.000	0.000	efficient
5	0.771	0.016	0.045	0.000	0.000	4.706	inefficient
6	0.890	2.122	0.027	0.000	0.000	1.446	inefficient
7	1.000	0.000	0.000	0.000	0.000	0.000	efficient
8	1.000	0.000	0.000	0.000	0.000	0.000	efficient
9	0.580	0.308	0.011	0.000	0.000	10.342	inefficient
10	1.000	0.000	0.000	0.000	0.000	0.000	efficient

Project the input cost of the main business to the efficient frontier, and it is obvious to notice the gap between the actual input cost of the decision making units and DEA efficient frontier. The results of the projection analysis are shown in Table 3.

TABLE 3 Projection Analysis Results of the Main Business of 10 Decision Making Units

Decision making unit	Fixed assets (millions of Yuan)	Number of employees	Main business cost / (millions of Yuan)	Main business net profit / (millions of Yuan)	Gross margin of the main business (%)
1	2200	265	463.9	600	15.65
2	2400	184	600.2	600	19.01
3	2450	140	436.6	560	20.55
4	5850	280	1100	1300	25.29
5	960	162	462.6	600	27
6	3200	120	462.8	600	30.26
7	800	80	520	689	31.31
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9	1890	157	510.9	675	21.03
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Figure 1 is the comparison of ideal input cost and actual input cost of 10 decision making units. It is obviously that there exists a gap between the actual main business input cost and the ideal one of each decision making unit. Similarly, projection analysis can be done to other input or output indicators, in order to study the gap between the actual value of each index and the ideal one, which also can provide decision-making reference for business subject to improve the efficiency.

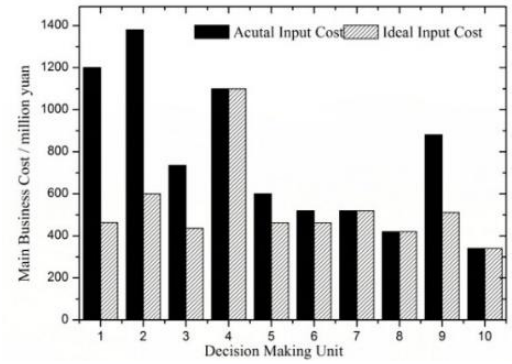

FIGURE 1 Comparison of Ideal Input Cost and Actual Input Cost of 10 Decision Making Units

The results of the efficiency evaluation of DEA show that the scale and technology of ZJX Company, ZWG Company, ZYS Company and ZTL Company are relatively efficient. In contrast, there exist some problems in the operation efficiency of the other 6 economies such as input redundancy or output shortage in different degree. These 6 economies are the traditional logistics economies of agricultural products -- wholesale markets. Through the projection analysis, it can be found that there are some problems in the 6 traditional economies such as employee redundancy, high operating cost, and low margin. Through comparative analysis, it can be found that the traditional mode of wholesale markets is of smaller scale and more dispersed, while the third party logistics is relatively efficient. Therefore, it is suggested that Zhangzhou City should devote much more effort to developing the third party logistics of agricultural products, so as to improve the overall operation efficiency of the logistics of agricultural products.

6 Conclusion

Based on DEA, the paper evaluated the circulation efficiency of the traditional wholesale market mode and the third party logistics. The circulation input and output data were collected from the 10 representative wholesale markets and the third party logistics companies of agricultural products in Zhangzhou City in 2009. The results showed that the third party logistics mode based on logistics distribution centre was more efficient comparing with the traditional wholesale market mode，while the problems that restricted the circulation efficiency of traditional wholesale market mode mainly existed in the employee redundancy, high operating cost and low gross margin.

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