Research of Closed Supply Chain's Performance Evaluation —— Based on Two Frontiers' EDA Methods

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Abstract. With more and more people take attention to the quality of product, many scholars launched research on closed supply chain. However, few scholars research the performance evaluation of closed supply chain. The aim of this paper is discussing the method of performance evaluation on closed supply chain. This paper adopts the research methods of two envelopes' DEA model. There are two results. One is the index system of closed the supply chain performance evaluation. This system contains economic efficiency, stable cooperation between enterprises, government supervision level and customer satisfaction, witch contains 14 items specific evaluation index. Another is the evaluation using DEA model witch contains optimum frontier and most bad frontier, and calculating weight using information entropy method. Through these, can get the score of closed the supply chain performance evaluation.

Keywords: closed supply chain, Performance evaluation, DEA, Information entropy.

1. Introduction

With the increasing global competition,the competition between individual enterprise has been instead of enterprise groups. As supply chain management theory unceasingly rich, scholars have proposed agile supply chain, lean supply chain, virtual supply chain and green supply chain, etc. Scholars research them from below perspectives. There have production operation management, supply chain' coordination and integration, asymmetric information and motivation, bilevel programming and master-slave countermeasures, performance evaluation, etc.

At present, with the development of economy, more and more people attention the problem of product safety. Closed supply chain be taken much attached by enterprise and government because of that product 'information can be traceable. Scholars research of it mainly from closed supply chain logistics mode [8], dynamic cost [9], model optimization [10], operation mode [9], and so on. However, there has few scholar researching closed supply chain 'performance evaluation, and this is an important aspect in supply chain theory. Through establishment a scientific performance evaluation index system and using certain metering method, can help us understand the deficiency of each enterprises in the supply chain, and helpful for government to formulate corresponding policy. This paper constructed the index system of closed supply chain performance evaluation on the basis of related studies, and evaluated by using two aspects DEA model.

2. Connotation of Closed Supply Chain

The concept of closed supply chain was proposed by modern logistics research center in Nankai university in 2006. They think that the purpose of closed supply chain is to ensure the product safety and

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quality control, which through a series of management system standard and management mode innovation. The whole process can make production in strict quality supervision system, and achieve quality stable and cost control. From this definition we can see that closed supply chain mainly emphasis the controllable in the product circulation, guarantee product safety. By this definition can see, closed the whole supply chain main emphasis on circulation in operation management, guarantee product control the quality standard of the product and circulation of safety. Zhou rongzheng think that closed supply chain can be understood as a strategic cooperative partnership between supply chain subjects. For suppliers it has the characteristics of channel exclusiveness, and has the characteristics of goods source exclusiveness for distributors. Compared with open supply chain, closed supply chain has more strong controllability and coordination, more efficient in channel, more strong ability to resist risk. [5]Zhang zhong think that closed supply chain is a model which based on quality control in the whole system, and the purpose is to achieve the quality management of products. Jiao zhilun constructed urban food closed supply chain. These supply chain contains three angles, government access, enterprise multilevel inspection (main responsibility enterprise) and consumers tracing information.

Comprehensive above analysis, this paper argues that closed supply chain should contain following several content in addition to its general supply chain meaning. The first, supply chain node enterprises should be stable cooperation strategic relations. The second, the information of raw materials and semi-finished products should be traced back in circulation process. Third, government should formulate certain standards for each node enterprises. The fourth, consumers should have the power to trace the information of products.

3. Review of Supply Chain Performance Evaluation

The supply chain performance refers to the value which members created through Logistics management, product operation, marketing, customer service, information development, etc.

Meanwhile, supply chain performance must take infrastructure, human resources and technology development resources as the foundation.

At present, the research on supply chain performance evaluation is very limited. Stefan points out that the key of supply chain performance evaluation system is difficult to combine supply chain strategies with performance measure. Managers of supply chain often thought that supply chain performance equates to financial performance. Some index, has the characteristics of numerous, incompatible, and even physically dispersed, making comprehensive evaluation difficulties. Understanding of the supply chain performance remains in the performance system members. [1]Gunasekaran designed a series of supply chain performance evaluation index from the relationship between supply chain partners, production level, customer satisfaction, finance, etc. Gunasekaran also divided these indicators into strategy, tactics and operating levels. [2]

Beamon think that supply chain performance evaluation needs both quantitative indexes and qualitative indexes.

He pointed out that the quantitative indexes including financial (cost minimization, sales maximization and profit maximization, etc), the customer's response ability (fill rate maximization, product delays minimization, customer response time shortest, etc.). Qualitative indexes including customer satisfaction, flexible, information and material flow integration, effectiveness of risk management and supplier's performance, etc. [3] Kaplan and Norton proposes to using the balanced score card (BSC) evaluating organizational performance. BSC measures organizational performance from financial, customers, business processes, innovation and future growth. [4]

Liu yuanhong think that supply chain performance evaluation index including total operating income index, total operating costs index, total operating expenses index, the gross profit index and social contribution index, etc. [6]

Zhang pei evaluated green supply chain performance. From the perspective of the whole supply chain, through constructed index system, he evaluated the objectively situation of green supply chain using the quantity statistics and operational research methods. The evaluation results can be used to improve green supply chain. [7] Zhao tao and Li xiaopeng evaluated green supply chain management using the grey correlation analysis. [12] Zhang tianping and Jiang jinghai constructed index system of supply chain

performance evaluation from strategic layer, tactical layer and operating layer. [13]Xu jihui and his colleagues do deeply study on aviation materials supply chain performance. They first established aviation materials supply chain performance evaluation system. Then establish the Fuzzy comprehensive evaluation model using AHP and Fuzzy method. Finally, the model was applied through an example. [14]

To sum up, according to research goal, scholars build supply chain performance evaluation index system from different point of view, and used some methods such as BSC, AHP, DEA and gray theory. We draw two consensuses. First, setting evaluation index system should scientific. Second, selected method should be reasonable. In the studies of supply chain performance evaluation, no scholar have made the performance evaluation to closed supply chain, and no scholar evaluated closed supply chain using two envelope surface' DEA model. Therefore, this paper will build the index system of closed supply chain performance evaluation, in addition evaluate it using two envelope surface' DEA model.

4. Construct Index System of Closed Supply Chain Performance Evaluation

We should comply with the following principles to constructing index system of closed supply chain performance evaluation. Firstly, it should be systematic. Closed supply chain is composed by many nodes. So the selected indicators not only represent the interests of internal system, buy also reflect integral at the same time. Secondly, it should be scientific. The index should seize the essence of evaluation object. So the concept of index should rigorous and reasonable. Meanwhile, in order to reflect the supply chain performance level, index 's derived and data calculation all should have scientific basis. Thirdly, it should be simplicity. Closed supply chain is a complex system, we should choose important and representative index, and eliminate unimportance indexes. Fourth, it should be easy operating. Indexes should have stronger feasibility, and have stable data sources. If encounter some indexes which collected difficult, we should use a few simple indexes instead of them. Meanwhile, each indexes should have strong independence.

According to above principle, we divided the index system of closed supply chain performance evaluation into three layers, target layer, criterion layer and index layer. Criterion layer contains economic benefit, cooperation level, supervision level, customer satisfaction, and criterion layer further subdivide into 14 indicators. As shown in table 1.

Tab. 1: The index system of closed supply chain management performance evaluation

target layer	criterion layer	index layer
closed supply chain management performance	economic benefit	unit cost of supply chain operation
		Products sales ratios
		Net assets yield
	cooperation level	Just in time delivery
		Product quality qualified
		The completion of orders total cycle
		Matching degree of cash flow products circulate
		Cooperation age
	government relevant departments supervision level	Complete degree of relevant supervisory system
		Executive degree of supervision
		Degree of products reach the standard
	customer satisfaction	Consumer satisfaction to product prices
		Consumer satisfaction to product quality
		Degree of product information traceability

Closed the supply chain performance evaluation mainly considered the economic benefit, each enterprise's stable cooperation degree, government departments supervision level and customer satisfaction. Among them, economic benefit layer evaluate closed supply chain from the point of view of economic. The first two indexes mainly reflect the assets turnover and operating ability. The third reflect the return on investment and profit-seeking ability. Stability cooperation relationship between node enterprises mainly measure closing degree. Stable cooperation relationship is helpful for reducing supply chain cost, improve product quality, and strengthen supply chain flexibility. Government relevant departments' supervision level main purpose is to strengthen the forcing restriction, and ensure products' quality. Customer's satisfaction is the final inspection

stage for closed supply chain. For consumers, the quality of the products, price and information traceability are all very important indexes.

5. Evaluation Model Based on Optimum Frontier and the Most Bad Frontier

The index system of closed supply chain performance evaluation belongs to typically many inputs and outputs indexes, so this paper adopts the DEA method. Inputs indexes are those the less, and outputs indexes are those the more the better.

Many scholars have applied the DEA method. But most of the DEA method just used the optimal frontier. In recent years, a few studies began to focus on the most bad frontier. However, considering optimal frontier and the most bad frontier together, was blank in this years. [15]

5.1. DEA model based on optimal frontier

Suppose there have n decision units. Each unit needs m inputs, and product s outputs. For the j decision unit is concerned, the i input is x_{ij} ($i = 1, 2, \cdots, m$), and the r output is y_{rj} ($j = 1, 2, \cdots, s$).For the d decision unit, based on optimal frontier, we can calculate CCR efficiency. Process as follows.

$$\theta_d^E = \max \frac{\sum_{r=1}^{s} u_{dr} y_{rd}}{\sum_{i=1}^{m} v_{di} x_{id}} \tag{1}$$

$$s.t. \quad \frac{\sum_{r=1}^{s} u_{dr} y_{rj}}{\sum_{i=1}^{m} v_{di} x_{ij}} \leq 1, \quad j = 1, 2, \cdots, \ n$$

$$u_{dr} \geq 0, v_{di} \geq 0, \forall r, i$$

Sign model (1)'s optimal solution as $(\theta_d^{E*}, u_{dr}{}^*, v_{di}{}^*)$

Obviously, for other decision unit j, also can obtain optimal solutions $(\theta_j^{E*}, u_{dr}{}^*, v_{di}{}^*)$ ($j = 1, 2, \cdots, n$).

5.2. DEA model based on the most bad frontier

For d decision unit, based on the most bad frontier, we can calculate CCR invalid efficiency. Process as follows.

$$\theta_d^{IE} = \min \frac{\sum_{r=1}^{s} \bar{u}_r y_{rd}}{\sum_{i=1}^{m} \bar{v}_i x_{id}} \tag{2}$$

$$s.t. \quad \frac{\sum_{r=1}^{s} \bar{u}_r y_{rj}}{\sum_{i=1}^{m} \bar{v}_i x_{ij}} \geq 1, \quad j = 1, 2, \cdots, n$$

$$\bar{u}_r \geq 0, \bar{v}_i \geq 0, \forall r, i$$

In conclusion, we can get closed supply chain's optimal frontier evaluation value and the most bad frontier evaluation value. In order to combine the two evaluation value together, this paper uses information entropy method. Through the information entropy method, we can get the two models' weight. Combined with decision unit efficiency value, we obtain each decision units' aggregation efficiency value. Therefore, we can get the order of the decision units. Procedure is as follows.

Step 1: sign efficiency value as E_{jk} in the j decision unit in the k model, and standard it through below type.

$$e_{jk} = \frac{E_{jk}}{\sum_{j=1}^{n} E_{jk}}, \quad j = 1, 2, , n; \ k = 1, 2 \tag{3}$$

Step 2: calculating every models' information entropy.

$$f_k = -\frac{1}{\ln n} \sum_{j=1}^{n} e_{jk} \ln(e_{jk})$$ (4)

Step 3: calculating each models' relative weight.

$$W_k = \frac{d_k}{\sum_{k=1}^{K} f_k}, d_k = 1 - f_k$$ (5)

Step 4: calculating every decision units' weighted efficiency score.

$$\theta_j = \sum_{k=1}^{K} W_k E_{jk}$$ (6)

Through above steps, we can get each decision units' totaled score, and the more totaled score, the higher closed supply chain performance.

6. Conclusion

This paper combining domestic and foreign research situation, construct index system of closed supply chain performance evaluation. According to the characteristics of index system, constructed DEA model. This DEA model contains two frontiers, optimal frontier and the most bad frontier. Using two frontiers model evaluating decision unit, can get two efficiency evaluation values. In order to put two evaluation values together scientifically, this paper introduces the information entropy methods. So, we can work out the overall efficiency value of the decision units. This paper provides a method of evaluated closed supply chain performance.

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