A Study on Environment-Friendly Steel Enterprise Supply Chain Cooperation in View of Game Analysis

Xueling Nie [a], Xiaolin Zhu and Baozhi Zhang

School of Business Administration, University of Science and Technology Liaoning, Anshan 114000, China

[a]nxlok@163.com

Abstract. In order to improve the environment-friendly steel enterprise (EFSE) dynamic competitive ability and sustainable development ability, the measures to improve collaborative operation of EFSE supply chain was put forward. The model based on game theory was built to analyze the collaborative operation process of the EFSE supply chain and the factors affecting it. Results show that keeping long-term cooperation with supply chain members, improving cooperation environment gradually, and establishing a fair and honesty assurance system are necessary to implement EFSE supply chain collaborative operation.

Keywords: Environment-friendly steel enterprise, supply chain, collaborative operation, game analysis

1. Introduction

The EFSE refers to the steel enterprise who will make its production operation based on rational demand of consumers, realize harmonious management between human and environment under the network economy, attach great importance to mass customization of customer service and "green" production management based on environmental protection. Since the steel enterprises in china adopt extensive production model for a long time, although the total outputs are great, the energy consumption for unit GDP production and the environmental pollution index are still higher. Now, the steel enterprises must adopt environment-friendly model of production and operation under serious environment pollution and lack of resources, pay more attention to increase unit production while reduce energy consumption and environment pollution, realize the transformation of steel production country into steel power country. It's a serious problem confronting us that the steel enterprises in china want win victory in the keen international market competition, they should not only produce environment-friendly product, break through green trade barrier in developed country, satisfy international environmental protection needs, but also enhance the supply chain members' collaborative operation level, to acquire fleeting market opportunity rapidly and satisfy the environmental protection and individual needs of customer.

It is an important way to improve our steel enterprise's competitive ability in new economy condition that to enhance .EFSE collaborative operation level overall.

2. The Analysis of EFSE's Collaborative Operation Based on Coordination Game

To facilitate the research, this paper reduces the “n” enterprises in EFSE collaborative operation system into enterprise A and B, so the participants in game analysis are enterprise A and B. It forms hypothesis as below to construct the cooperative game model of EFSE collaborative operation system.

2.1 Hypothesis

Since the collaborative operation system is composed of enterprise A and B, it assumes C as the total value of investments of A and B, namely the total cost of cooperation. The proportion of cost of A in total cost is a, and the proportion of cost of B in total cost is b, then $a+b=1$.

To facilitate the research, it reduces the cooperation strategy of enterprise A and B into cooperation or noncooperation. It makes R_{ik} resent the revenue of the i th collaborative operation for enterprise k ($k = A, B$). It assumes the probability of A adopting cooperation is P, and then the probability of A adopting noncooperation is $1-p$. The probability of B adopting cooperation is q, then the probability of B adopting noncooperation is $1-q$, and $p \in [0,1]$, $q \in [0,1]$. The game of A and B is dynamic, the equilibrium diversity in game means that behavior actor's judgment of other participants' action is uncertain, so there are time series in the game, T represents the total times of game, δ ($\delta > 0$) represents the motivation factor of feed and feedback. With time series T developing, δ is cumulative. The more δ is the better cooperative innovation effect and the more revenue A and B will be got.

In cooperation competition, if one of A and B adopts cooperation, the other adopts noncooperation, then the cooperator's revenue will be negative, the loss will be the cost that ha has invested, noncooperation's revenue will be zero. In collaborative operation system dynamic game, the times of enterprises participate in repetitive game are i, $i = 1,2 \cdots\cdots n$. The total allocated revenue of all node enterprises participated in collaborative operation system equals the system's total revenue, and the allocated revenue of each node enterprise is not less than the revenue of they operated independently, as formula (1) and (2) shown. R represents the total revenue of the system, and R_{ik} is the revenue of the node enterprise operated independently.

$$R = \sum R_{ik}(1+\delta)^{r-1} \tag{1}$$

$$R_{ik}(1+\delta)^{r-1} \geq R_{ik} \tag{2}$$

2.2 Situation Analysis

According to the hypothesis as before, the matrix of the T th cooperative competition for A and B can be described as below.

		A	
		p	1-p
B	q	R1A.R1B	R2A.R2B
	1-q	R3A.R3B	R4A.R4B

Fig. 1 The matrix of the T th cooperative competition for A and B

Situation1: when A and B both adopt cooperation, the total revenue of A subtracts total cost leaves payoff matrix as formula (3) shown. In the same way, the payoff matrix of B can be described as formula (4).

$$R_{1A} = pqa(1+\delta)^{r-1}C - pqaC \tag{3}$$

$$R_{1B} = pqb(1+\delta)^{r-1}C - pqbC \tag{4}$$

Situation2: when A adopts cooperation and B adopts noncooperation, the payoff matrix of A and B can be described respectively as formula (5) and (6)

$$R_{2A} = -p(1-q)aC \tag{5}$$

$$R_{2B} = 0 \tag{6}$$

Situation3: when A adopts noncooperation and B adopts cooperation, the payoff matrix of A and B can be described respectively as formula (7) and (8)

$$R_{3A} = 0 \tag{7}$$

$$R_{3B} = -(1-p)qbC \tag{8}$$

Situation 4: when A and B both adopt noncooperation, the payoff matrix of A and B are both zero, as formula (9) shown.

$$R_{4A} = R_{4B} = 0 \tag{9}$$

2.3 Game Analysis

From formulas above, it can be concluded that if A and B both adopt cooperation, then the revenue of theirs will not less than zero. If they both adopt noncooperation, then the revenue of theirs will be zero. If one of them adopts cooperation, and the other adopts noncooperation, then the noncooperation's revenue will be zero, and cooperator's revenue will be less than zero, his investments will be all lost, as formula (10) and (11) shown.

$$R_{1A} \geq R_{3A} = 0 = R_{4A} \geq R_{2A} \tag{10}$$

$$R_{1B} \geq R_{2B} = 0 = R_{4B} \geq R_{3B} \tag{11}$$

To discuss payoff function from A, it has complete information of his own action and incomplete information of B. A adopts cooperation or not will be decided on the difference between expectation return of adopting cooperation ($p = 1$) and adopting noncooperation ($p = 0$), it can be represented by "ΔR_A", as formula (12) shown.

$$\Delta R_A = \sum_{i=1}^{4} R_{iA}(p=1) - \sum_{i=1}^{4} R_{iA}(p=0) \tag{12}$$

From formula (3) to formula (9), we can conclude formula (13) and (14).

$$\sum_{i=1}^{4} R_{iA}(p=1) = qa(1+\delta)^{r-1}C - aC \tag{13}$$

$$\sum_{i=1}^{4} R_{iA}(p=0) = 0 \tag{14}$$

Taking formula (13) and (14) into (12), formula (15) can be concluded.

$$\Delta R_A = qa(1+\delta)^{r-1}C - aC \tag{15}$$

When A adopt cooperation, his expectation revenue should not less than zero, as formula (16) shown.

$$\Delta R_A \geq 0 \tag{16}$$

Taking formula (15) into (16), formula (17) can be concluded.

$$q \geq \frac{1}{(1+\delta)^{r-1}} \tag{17}$$

Since $q \in [0,1]$, the formula (18) can be concluded from (17).

$$1 \geq q \geq \frac{1}{(1+\delta)^{r-1}} \tag{18}$$

In the same way, to discuss payoff function from B, B has complete information of his own action and incomplete information of A. When the expectation return of adopting cooperation is not less than adopting noncooperation, B will adopts cooperation.

3. Conclusion

From analysis above, it can be concluded that EFSE collaborative operation is a process of dynamic game. Measures as below should be taken to realize effective collaborative operation for steel enterprise.

3.1 Establish Long-term Cooperation with Other Member Enterprises in Supply Chain.

Formula (18) and (19) are two basic condition for implementing EFSE collaborative operation It can be concluded from formula (18) and (19) that when δ is a constant, with cooperation times T increasing the cooperation will with each other will become more stronger, it is helpful to establish long-term cooperation with other member enterprise in supply chain.

3.2 Improve cooperation Environment

It can also be concluded from formula (18) and (19), when T is a constant, with motivation factor δ increasing, the cooperation with each other also can become stronger. So EFSE should strengthen the information communication with cooperative enterprises, cultivate a good cooperation institutional, law environment, cultural environment and achievements fair distribution system to increase motivation factor δ .

3.3 Establish a Fair and Honesty assurance system.

In formula (15), computing partial derivative of q , the formula (20) can be concluded.

$$a(1+\delta)^{r-1}C > 0 \tag{20}$$

Formula (20) is the 3rd basic condition for implementing EFSE collaborative operation. With the cooperation probability q of enterprise B increased, the cooperation will of A will be strengthened. In the same way, with the cooperation probability P of enterprise A increased, the cooperation will of B will be strengthened. So, it can promote implementing EFSE collaborative operation that to establish a fair and honesty assurance system.

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