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The study of evolutionary game model between the suppliers and manufacturers in green supply Chain

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ABSTRACT

Three evolutionary stable strategy are received in terms of evolutionary game model on the two groups' decision-making based on the function of manufacturers and suppliers to the green degree of supply chain. And then a series of proposal is given to promoting the green management degree of manufacturers and suppliers.

KEYWORDS

Green supply chain;
Manufacturers;
Suppliers;
Evolutionary game model.

INTRODUCTION

With the aggravation of ecological environment deterioration and resource depletion[1], each country has paid close attention to the environmental issue, and made the corresponding environmental regulation and the responsibility undertakes. At the same time,it caused a huge shock to the export of China. In order to overcome the green barriers and environmental regulation,which is drown up by other countries, domestic industries highly value the green supply chain management which focusing on solving environmental problems[2]. It is obvious that supplier and manufacturer make a great contribution to the Green degree of whole chain in the process of green supply chain management[3]. However, the reality is that supplier and a manufacturer always finally consider environmental issues based on their self-interest. In this paper, we can get a series of detailed understanding about suppliers and manufacturers which is obtained by using the evolutionary game model and external factors to introduced. Finally,getting the analysis of these information, it have the important theoretical and practical guidance for coordinate the green development of supply chain.

SETTING AND PRINCIPLE ASSUMED OF EVOLUTIONARY GAME MODEL

Under the two factors of asymmetric information and the thought maximizing their own interests, suppliers and manufacturers be in a game. Evidently, manufacturers play a more important role in the supply chain due to its great contributions to the green degree. In this case manufacturers' green idea is a challenge for supplier. Faced the green orders from manufacturers, suppliers supply raw materials based on analysing self-interest.,but suppliers used to ordinary materials instead of green products,the cheating often exist in reality. So it's absolutely essential to study how to reduce the suppliers' " breach " and improve the manufacturers' green idea through the analysis of the evolutionary game model[4].

In this model it assume supplier and a manufacturer as the two sides of game. The following is their strategy

decisions. The supplier usually takes two measures to getting the green orders from the manufacturer, one is providing green materials to manufacturers, second is using a common material instead of green materials supply. In this paper using "do" and "don't" to substitute two decisions. For manufacturers, two situations often exist in reality. One kind is that manufacturer's green consciousness is very strong, having strict requirements to suppliers to provide green material. And if the material is not getting their requirement,they will fine on suppliers or take other measures. The other kind is that low degree of attention for environment enterprise is not too concerned whether the material is the green and even does not pursue the supplier's fraud. In the following "firmly" and "inferior" are said two choices according to the level of awareness of manufacturer. Then we can get the strategy combination showed in Figure 1.

		manufacturer: firmly	manufacturer: infirmly
supplier	do	do firmly	do infirmly
	don't	don't firmly	don't infirmly

Figure 1 : Strategy combination

We will denote the variables involved with the letters in order to facilitate the analysis of the return of supplier and manufacturer under different conditions. They are all showed in TABLE 1.

Basic assumptions

- In order to facilitate the calculation, we assume the q as a unit of raw materials to produce one unit of the product.
- R_1 and R_2 are different function value from the same function. The external factors are more, such as government, the future potential income, third awards, corporate brand value,etc. We assume that R represents the external benefits. And the number of external benefits depends on the enterprises' environmental management attitude and behavior. We agree to that the resolute and action timely enterprise can gain more than the lack of resolve enterprise.

Now we can calculate the income of suppliers and manufacturers in different situations, and make the first quadrant supplier revenue calculation as an example:

Supplier revenue = production benefit - cost + penalty + reward

Then we can get that $R = q(1+\alpha)p_s - C_1 + A$

By the same token, we can get the following payoff matrix:

EQUILIBRIUM ANALYSIS OF THE EVOLUTIONARY GAME

In the initial stage of the game, we assume that the ratio of the supplier group selection " do" is x, " don't" is 1-x, and the ratio of manufacturer group selection "

TABLE 1 : Explanation of letters in the formula

letters	meaning	letters	meaning
q	Purchase quantity of manufacturer	A_0	" don't" supplier punishment " firmly" manufacturer
p_s	Common raw material price	R_1	The award of " firmly" and to provide green products manufacturer from outside
p_m	Ordinary commodity price	R_2	The punishment of " infirmly" and to provide green products manufacturer from outside
α	The ratio of green materials' price higher than ordinary materials'	C_0	General material cost
β	The ratio of Green products compared to the common products	C_1	Green material cost
A	"do" supplier award from " firmly" manufacturer		

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	manufacturer: firmly	manufacturer: infirmly
Supplier: do	$\left(q(1+\alpha)p_s - C_1 + A,\ q(1+\beta)p_m - q(1+\alpha)p_s - A + R_1\right)$	$\left(q(1+\alpha)p_s - C_1,\ q(1+\beta)p_m - q(1+\alpha)p_s + R_2\right)$
Supplier: don't	$\left(p_s q - C_0 - A_0,\ qp_m - qp_s + A_0\right)$	$\left(p_s q - C_0,\ qp_m - qp_s\right)$

Figure 2 : Payoff matrix

firmly " is y, " infirmly " is 1-y. At the same time we assume that the suppliers' expected profit of " do" expressed as ES_1, of " don't" as ES_2 and the average payoff of the group as ES. Then we get the following results:

$$ES_1 = y[q(1+\alpha)p_s - C_1 + A] + (1-y)[q(1+\alpha)p_s - C_1]$$

$$ES_2 = y(p_s q - C_0 - A_0) + (1-y)(p_s q - C_0)$$

$$ES = xES_1 + (1-x)ES_2$$

We assume $B_0 = q(1+\alpha)p_s$, then:

$$ES_1 = y(B_0 - C_1 + A) + (1-y)(B_0 - c_1)$$

$$ES_2 = y\left(\frac{B_0}{1+\alpha} - C_0 - A_0\right) + (1-y)\left(\frac{B_0}{1+\alpha} - C_0\right)$$

$$ES = xyA + x(B_0 - C_1) - y(1-x)A_0 + (1-x)\left(\frac{B_0}{1+\alpha} - C_0\right)$$

By the same token, we assume that the manufacturers' expected profit of " firmly" expressed as EM_1, *of* "infirmly*" as* EM_2 and the average payoff of the group as EM.

We assume $D_0 = q(1+\beta)p_m$, then:

$$EM_1 = x(D_0 - B_0 - A + R_1) + (1-x)\left(\frac{D_0}{1+\beta} - \frac{B_0}{1+\alpha} + A_0\right)$$

$$EM_2 = x(D_0 - B_0 + R_2) + (1-x)\left(\frac{D_0}{1+\beta} - \frac{B_0}{1+\alpha}\right)$$

$$EM = xy(R_1 - A) + y(1-x)A_0 + x(D_0 - B_0 + R_2) - xyR_2 + (1-x)\left(\frac{D_0}{1+\beta} - \frac{B_0}{1+\alpha}\right)$$

The replicator dynamics equation of supplier group " do " ratio is as follows (Taylor P D, Jonker L B, 1978):

$$F(x) = \frac{dx}{dt} = x(ES_1 - ES) = x(1-x)\left[y(A+A_0) + B_0 - \frac{B_0}{1+\alpha} + C_0 - C_1\right]$$

If $y = \dfrac{\dfrac{\alpha}{1+\alpha}B_0 + C_0 - C_1}{A + A_0}$ ÿthen $F(x) \equiv 0$. This shows that all levels are in steady state.

If $y \neq \dfrac{\dfrac{\alpha}{1+\alpha}B_0 + C_0 - C_1}{A + A_0}$, then $x = 0, x = 1$ can make $F(x) = 0$, So these two points are all stable point. And then the derivative of $F(x)$is as follows:

$$\frac{dF(x)}{dx} = (1-2x)\left[y(A+A_0) + B_0 - \frac{B_0}{1+\alpha} + C_0 - C_1\right]$$

It is required in evolutionary stable strategy that $\dfrac{dF(x)}{dx} < 0$ (Jing S, Lei L H, 2006). Through the analysis of $B_0 - \dfrac{B_0}{1+\alpha} + C_0 - C$, we can obtain the below conclusions:

If $B_0 - \dfrac{B_0}{1+\alpha} + C_0 - C > 0$, then $y(A+A_0) + B_0 - \dfrac{B_0}{1+\alpha} + C_0 - C_1 > 0$, and $x = 1$ is an evolutionarily stable strategy.

If $\dfrac{B_0}{1+\alpha} - B_0 + C_0 - C_1 > A + A_0$, then $y < \dfrac{\dfrac{B_0}{1+\alpha} - B_0 + C_1 - C_0}{A_0 + A}$, and $x = 0$ is a stable point.

If $-(A_0 + A) < B_0 - \dfrac{B_0}{1+\alpha} + C_0 - C_1 < 0$, then:

If $y > \dfrac{\dfrac{B_0}{1+\alpha} - B_0 + C_1 - C_0}{A + A_0}$ and $\dfrac{dF(x)}{dx}\Big|_{x=0} > 0, \dfrac{dF(x)}{dx}\Big|_{x=1} < 0$ ÿthen $x = 1$ is a stable point.

If $y < \dfrac{\dfrac{B_0}{1+\alpha} - B_0 + C_1 - C_0}{A + A_0}$ and $\dfrac{dF(x)}{dx}\Big|_{x=0} < 0, \dfrac{dF(x)}{dx}\Big|_{x=1} > 0$, then $x = 0$ is a stable

point.

The replicator dynamics equation of manufacturer group " firmly" ratio is as follows:

$$F(y)=\frac{dy}{dt}=y(EM_1-EM)=y(1-y)[x(R_1-A-R_2-A_0)]$$

If $x=\frac{A_0}{A+A_0+R_2-R_1}$, then $F(y)\equiv 0$. This shows that all levels are in steady state.

If $x\neq\frac{A_0}{A+A_0+R_2-R_1}$ and $F(y)=0$, then $y=0, y=1$ are stable points.

If $A+A_0+R_2-R_1<0$, then $x>\frac{A_0}{A_0+A+R_2-R_1}$, and $y=1$ is a stable point.

If $0<\frac{A_0}{A_0+A+R_2-R_1}<1$, then:

If $x>\frac{A_0}{A_0+A+R_2-R_1}$ ÿ then $\frac{dF(y)}{dy}\Big|_{y=0}<0, \frac{dF(y)}{dy}\Big|_{y=1}>0$. And $y=0$ is a stable point.

If $x<\frac{A_0}{A_0+A+R_2-R_1}$, then $\frac{dF(y)}{dy}\Big|_{y=0}>0, \frac{dF(y)}{dy}\Big|_{y=1}<0$, and $y=1$ is a stable point.

A graph of the tow groups' dynamic replication trend on a coordinate plane is as follows :

The arrows in the diagram are explained in the following:

- Arrow 1 means that if $y>\frac{\frac{B_0}{1+\alpha}-B_0+C_1-C_0}{A+A_0}$, then x tends to 1. Similarly we can know the meaning of arrow 2.
- Arrow 1 means that if $x>\frac{A_0}{A_0+A+R_2-R_1}$, then y tends to 0. Similarly we can know the meaning of arrow 2.

From the Figure 3 we can know that $(x,y)=(1,0),(x,y)=(0,1),(x,y)=(1,1),(x,y)=(0,0)$ are all saddle point and not the evolutionarily stable strategies.

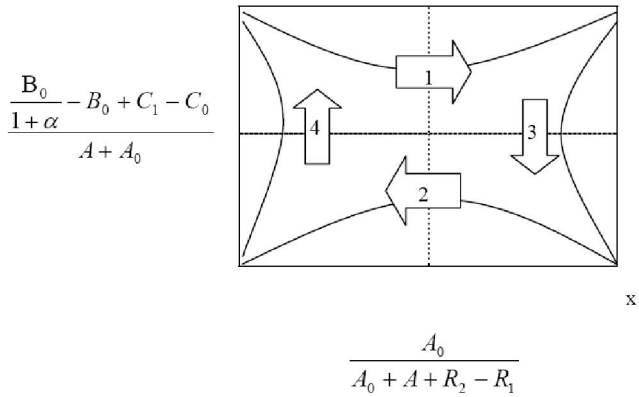

Figure 3 : Schematic diagram of two groups of evolutionary game

CONCLUSION

There are three evolutionary stable strategies in the process of the game:

- if $B_0-\frac{B_0}{1+\alpha}+C_0-C>0$, then $x=1$ is the evolutionary stable strategy. In this case the supplier groups are chosen "do" strategy. From the view of strategy equilibrium, in order to encourage suppliers to provide green raw materials, need manufacturer order green materials price is higher than the ordinary material prices, then we draw out daily often see problems: Manufacturers hope to get green materials, but they are not willing to pay a high price, and just impose the cost to the supplier. So, in order to get the better green effect, manufacturers should take the initiative to share green raw material cost with suppliers. In addition, manufacturers need achieve large centralized purchasing, this can also promote the supplier consciously provide green materials.
- if $A+A_0+R_2-R_1<0$, then $y=1$ is balanced strategy. In this case, all manufacturers have cho-

sen the "resolutely" strategy. From this equilibrium point of view, in order to improve the manufacturer's green consciousness, we can adopt the measures by the government and other external organizations to improve the award on the enterprise[7]. This award is not simply a direct reward, also includes the future potential benefits and the enhance of brand value by the implementation of green management. In addition, when external organizations take an incentive to enterprises, they should strictly distinguish the rank of enterprise based on the enterprise green awareness level. In order to have a good incentives to enterprise in system of prize external organizations must widen the difference. Meanwhile, A, A_0 should not too high, company need a proper distribution.

- if $\left(\frac{B_0}{1+\alpha} - B_0\right) - (C_0 - C_1) - A_0 > A$,then The supplier groups will choose "not" strategy, which should be appropriate to increase the amount of A,. However, this also leads to a conclusion that is contrary to the conclusion of the second. So we can consider the establishment of the third party to assume the reward and penalty function, manufacturers will be isolated. This can not only reduce the manufacturer's profit loss but also realize penalty amount of free transfer at the same time.

Based on the consideration of convenient calculate. The factor from the above will be selected simply. If we want to make the model have more practical significance, we need make a specific assumption on factors according to the characteristics of industry.

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