

A Game Model Between Governments and Enterprises in the Green Supply Chain of the Home Appliance Industry

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Abstract: Green supply chain management is a kind of effective management approach for home appliance industry to pursue the strategy of sustainable development and improve the product international competitiveness. In this paper, a game model is proposed to study the relationship and game status between governments and enterprises in the green supply chain of the home appliance industry. Through the equilibrium analysis of the game model, some countermeasures are put forward, which can be helpful to improve the construction of the green supply chain in the home appliance industry.

Key Words: Green supply chain; Home appliance industry; Governements; Enterprises; Static games of complete information; Nash equilibrium.

1 Introduction

Since the beginning of the 21st century, to protect the ecological environment and realize sustainable development has become a topic of common concern around the world. In recent years, many countries in the world formulate more strict environmental protection laws and regulations to strengthen the environmental protection and management.

WEEE directive 2002/96/EC (Waste Electrical and Electronic Equipment, as amended by 2003/108/EC) and RoHS directive 2002/95/EC (Restriction of Hazardous Substances) are two important regulations relating to household electrical and electronic equipment used by consumers. The objective of the WEEE directive is to improve the level of environmental protection within the European Union through the reduction of waste from household electrical and electronic equipments. Equipment producers are responsible for the management of takeback and disposal of waste starting from 13 August 2005. The RoHS directive aims at harmonization

of the legislation in the EU Member States on the restriction of the use of hazardous substances in household electrical and electronic equipment. The general rule is that equipment containing a certain level of lead, mercury, cadmium, hexavalent chromium, PBB's and PBDE's may not be placed onto the market after 1 July 2006. As the main country of manufacturing and exporting home appliances, China will be seriously affected by these regulations. Therefore, there is no time to delay for Chinese home appliance industry to establish green supply chain, which could be with great significance to improve our product competitiveness in the international market, protect the environment and implement the strategy of sustainable development.

Green supply chain, like traditional supply chain, is a cooperative system typically needs coordination and management and may be more complex due to its diversifying components and operational objectives. Hence the mutual relationship between the main stakeholders, especially the relationship between governments and enterprises, will influence the effective implementation of green supply chain (Xu et al, 2012)^[1].

2 Research Status on Game Analysis of Green Supply Chain

In 1996, the National Scientific Funds (NSF) in USA provided \$400,000 financial aid to the Manufacture Research Consortium (MRC) in Michigan State University to conduct a research project named "Environmental Responsible Manufacture" and then the definition of Green Supply Chain was proposed firstly (Handfield, 1996)^[2]. From then on, more and more scholars began to research the green supply chain from different perspectives. The so-called green supply chain is a kind of modern management mode which takes the environmental impact and resource efficiency into a comprehensive consideration within the entire supply chain. Taking green manufacturing theory and supply chain management technology as the foundation, it involves suppliers, manufacturers, distributors and users, with the purpose to make the environmental impact (negative effect) minimum and resource efficiency maximum during the whole process from material acquisition, processing, packaging, storage, transportation, usage to scrapping (Dan Bin and Liu Fei, 2000)^[3]. The basic objective of green supply chain management is to protect environment and make use of resources effectively.

As for game theory, in mathematics, it models strategic situations, or games, in which an individual's success in making choices depends on the choices of others (Myerson, 1991)^[4]. Game theory has been widely used in many subject areas, including the field of supply chain management. Many researchers have studied supply chain coordination with contracts and proposed many game models.

However, game analysis between the participating subjects in the green supply chain is still very limit. Only a few researchers have conducted some study on the relationships by using game theory. Pantumsinchai (1992)^[5] pointed out that government's support increased enterprise's economic and environmental performance, and then the enterprise further integrated and make the whole supply chain 'green'. In order to investigate the game between governments and core-enterprises in green supply chains, Zhu and Dou (2007)^[6] analyzed their respective costs and benefits, and studied the game status by evolutionary game theory. Li and Liu et al (2007)^[7]. from the government supervision's angle, built up dynamic game models of reverse logistics by using the game theory. Xu and Zheng (2008)^[8] studied the relationship between governments and corporations in green supply chain under the condition of impeaching. Cao and

Wen (2011)^[9] also set up a game model between governments and enterprises in green supply chain and analyzed their behavior and equilibrium strategies. There are also a few scholars having tried to conduct preliminary analysis of the multilateral game relationship between governments, enterprises and consumers in the green supply chain, e.g., Wang (2004)^[10]. Yu and Liu (2011)^[11]. Xu et al (2011)^[12].

Some researchers analyzed the relationship between the enterprises within green supply chain, e.g., Wang and Yan (2009)^[13] analyzed the respective costs and benefits of suppliers and core-enterprise in green supply chain, and established an evolutionary game model between governments and enterprises based on evolutionary game theory. Hou and Wang (2010)^[14] studied the relationship between enterprises of green supply chain and those of traditional one.

Some scholars conducted some analysis of the game relationship in the green supply chain connected with specific industries, e.g., Zhou and Zhang (2007)^[15] analyzed the relationship between government, coal and electricity, Feng and Wang (2010)^[16] analyzed the different intention and game action between client and general contactor in the progress of constructing green supply chain in construction industry. The authors of this paper have ever analyzed the relationship between enterprises and consumers in green supply chain of home appliance industry (Xu et al, 2011)^[17].

It can be found that the research results about the game analysis between the main stakeholders is so limit and there is no research result found about the game relationship analysis connected with the background of home appliance industry except the authors' previous study. Concerning of the pressure from the more strict environmental rules such as WEEE and RoHS, it will be essential to study the game relationship between the main stakeholders in the green supply chain of home appliance industry, which will be helpful to promote the construction and development of the green supply chain.

3 A Game Model between Governments and Home Appliance Enterprises

3.1 Basic assumptions and definitions

The construction of the green supply chain of home appliance industry requires involvement of governments, enterprises, consumers and other relevant society members. In order to facilitate the analysis, here we assume that there are only two stakeholders, i.e. governments and home appliance enterprises (simply as "enterprises"). Governments refer to local governments and also include some relevant organizations or committees who focus on the environment protection and are entitled to issue some environmental regulations or rules. Enterprises refer to those who are engaged in home appliances manufacturing or sales. Meanwhile, we assume that governments and enterprises are all rational economic men, who take the benefit maximization as their goal. The players of the game know the strategies and payoffs of others. In short-term equilibrium, the game problem can be regarded as a kind of static games of complete information and to seek Nash equilibrium.

In the current market conditions with green home appliances and traditional home appliances coexist, the enterprises have two strategies: one is to offer green home appliances, e.g., home appliance manufacturers actively develop ecological design and introduce some available technologies to manufacture green home appliances, or retailers actively promote and sell the green home appliances; the other one is to offer traditional home appliances by using traditional

methods to design, manufacture and sell home appliances, and in this circumstance enterprises will be punished by governments and pay for penalty due to not meeting the requirements of environmental protection. As for governments, they can adopt the strategy of supervision, which means they will supervise whether the enterprises has deployed green supply chain management. If they find the enterprises are offering green home appliances, they give them a sum of money as subsidy. Conversely they will punish the enterprises. Governments can choose the strategy of unsupervision too, which means they will do nothing-no subsidy and no penalty.

According to existing literatures, we make some assumptions and definitions about the benefits and costs for governments and enterprises in order to determine the payoff for each player with every possible combination of actions. When enterprises choose to offer traditional home appliances, R_B and C_B respectively represent the total revenues and the total costs, and F_B represents the payable penalty to governments due to not meeting the requirement of implementing green supply chain. When enterprises choose to offer green appliances, R_B' and C_B' respectively represent the total revenues and the total costs in this case, and S_B represents the subsidy that they can obtain from governments. As for governments, except the subsidy S_B , C_E represents the costs of supervision and L_E shows the loss of the social welfare due to the environmental disruption from the traditional home appliances.

3.2 Payoff matrix of governments and enterprises

Based on the above assumptions and definitions, we can construct a game model between governments and enterprises, which is represented by a payoff matrix shown in Table 1. Each player has two strategies, which are specified following the name of players. The payoffs are provided in the interior. The first number is the payoff received by governments; the second is the payoff for the enterprises.

Table 1 - Payoff Matrix of Governments and Enterprises

		Enterprises	
		Offer Green Home Appliances (B_1)	Offer Traditional Home Appliances (B_2)
Governments	Supervision (E_1)	$-C_E - S_B, R_B' - C_B' + S_B$	$-C_E - L_E + F_B, R_B - C_B - F_B$
	Unsupervision (E_2)	$0, R_B' - C_B'$	$-L_E, R_B - C_B$

4 Equilibrium Analysis of the Game Model between Government and Enterprises

Now we conduct detailed equilibrium analysis of the game model proposed above.

4.1 Pure strategy nash equilibrium

4.1.1 If $R_B' - C_B' + S_B < R_B - C_B - F_B$

then as for enterprises, this means that the payoff of offering green appliances is less than the amount of offering traditional appliances. This condition can also be expressed in another way, i.e., $(C_B' - C_B) - (R_B' - R_B) - S_B > F_B$, which means that the increased cost of offering green appliances will be greater than the penalty F_B even if have being compensated by the increased revenue and governments subsidies. Next we consider two circumstances:

(1) if $-C_E - L_E + F_B > -L_E$, i.e. $-C_E + F_B > 0$, which means the penalty governments gained from the enterprises is greater than the supervisory cost when the governments adopt the strategy of supervision, then there will be a unique pure-strategy Nash equilibrium and the stable strategies combination will be (Supervision, Offer Traditional Home Appliances). In this case, the increased cost for green home appliances is maybe too high and the penalty from the government is lesser, therefore, driven by interests, enterprises may prefer to offer traditional appliances.

(2) if $-C_E - L_E + F_B < -L_E$, i.e., $-C_E + F_B < 0$, which means the penalty governments gained from the enterprises can not compensate the cost for supervision, hence the governments would prefer to adopt the strategy of unsupervision. Then it will be discussed further as following two circumstances.

If $R_B - C_B > R_B' - C_B'$, which indicates that the payoff of offering green appliances is less than the amount of offering traditional appliances and the enterprises do not need to pay for the penalty because the governments do not supervise. Then there will be unique pure-strategy Nash equilibrium and the stable strategies combination will be (Unsupervision, Offer Traditional Home Appliances).

If $R_B - C_B < R_B' - C_B'$, which means the payoff of offering green appliances surpasses the amount of offering traditional appliances, then the enterprises would be willing to offer green home appliances and the governments would adopt the strategy of unsupervision, thus the game has a unique pure-strategy Nash equilibrium. The stable strategies combination is (Unsupervision, Offer Green Home Appliances).

This is the ideal case, under which the enterprises are actively adopt the strategy of "Offering Green Home Appliances" and the governments do not need to supervise.

4.1.2 If $R_B' - C_B' + S_B > R_B - C_B - F_B'$

then as for enterprises, this means the payoff of offering green appliances surpasses the amount of offering traditional appliances. This condition can be expressed in another way, i.e., $(C_B' - C_B) - (R_B' - R_B) - S_B < F_B'$, which indicates that the increased cost of offering green appliances are compensated by the increased revenue and governments subsidies and the surplus is less than the penalty F_B . In this circumstance, the enterprises would rather offer green home appliances. While the governments would adopt the strategy of Unsupervision as a rational economic men. It is obviously that the strategies combination (Supervision, Offer Green Home Appliances) will not become the pure Nash equilibrium. It should be discussed further in two cases.

If $R_B' - C_B' > R_B - C_B$, then there will be a unique pure-strategy Nash equilibrium and the stable strategies combination will be (Unsupervision, Offer Green Home Appliances).

If $R_B' - C_B' < R_B - C_B$ and $-C_E - L_E + F_B < -L_E$, then there will be a unique pure-strategy Nash equilibrium and the stable strategies combination will be (Unsupervision, Offer Traditional Home Appliances).

If $R_B' - C_B' < R_B - C_B$ and $-C_E - L_E + F_B > -L_E$, then there will be no pure-strategy Nash equilibrium and the players will choose mixed strategies.

4.2 Mixed strategy equilibrium

If no pure-strategy Nash equilibrium exists, the players will choose mixed strategies, where a pure strategy is chosen at random, subject to some fixed probability. Here we assign governments the probability p_1 of playing E_1 (Supervision) and $(1-p_1)$ of playing E_2 (Unsupervision), assign enterprises the probability p_2 of playing B_1 (Offer Green Home Appliances) and $(1-p_2)$ of playing B_2 (Offer Traditional Home Appliances), where $0 \leq p_1 \leq 1$, $0 \leq p_2 \leq 1$, then the expected revenue for governments and enterprises can be determined by the following equations.

$$E_E(p_1, p_2) = p_1[p_2(-C_E - S_B) + (1-p_2)(-C_E - L_E + F_B)] + (1-p_1)[0p_2 + (1-p_2)(-L_E)] \quad (1)$$

$$E_B(p_1, p_2) = p_2[p_1(R_B - C_B + S_B) + (1-p_1)(R_B - C_B)] + (1-p_2)[p_1(R_B - C_B - F_B) + (1-p_1)(R_B - C_B)] \quad (2)$$

$$\text{Make } \frac{\partial E_E}{\partial p_1} = 0, \text{ then } p_2 = \frac{-C_E + F_B}{S_B + F_B} \quad (3)$$

$$\text{Make } \frac{\partial E_B}{\partial p_2} = 0, \text{ then } p_1 = \frac{(R_B - R_B') - (C_B - C_B')}{S_B + F_B} \quad (4)$$

In order to facilitate the analysis, another presentation of p_2 is proposed as equation (5).

$$p_2 = \frac{-C_E + F_B}{S_B + F_B} = 1 - \frac{C_E + S_B}{S_B + F_B} \quad (5)$$

4.2.1 Influencing factors of p_2

From the equation (3) and (5), it can be found that:

1) P_2 is an increasing function of F_B . When F_B increases, the governments would be more willing to supervise driven by economic benefits. Meanwhile, the enterprises would be willing to offer green home appliances in order to avoid to be punished.

2) P_2 is a decreasing function of S_B and C_E . The more the number of C_E , the more the unwillingness of the enterprises to offer green home appliances will be. Similarly, when S_B increases, the governments would provide more subsidy to enterprise, which will affect the governments' enthusiasm to supervise. In this circumstance, the possibility of enterprises to offer green home appliances will decrease, because they would lack of initiative due to the high expenditure for green products, and under the condition of without the governments' supervision as well.

4.2.2 Influencing factors of p_1

From the equation (4), it can be found that:

1) P_1 is an increasing function of $R_B - R_B'$. $R_B - R_B'$ means the difference between the revenue of offering green home appliances and offering traditional ones. When $R_B - R_B'$ increases, which means the revenue for green products will decrease more ($R_B' < R_B$) or increase less ($R_B' > R_B$), thus the enterprises will lack of initiative to offer green home appliances. The supervision of the governments would be necessary, then p_1 will increase.

2) P_1 is a decreasing function of $C_B - C_B'$, S_B and F_B . Normally, the non-equality $C_B' > C_B$ exists, i.e., $C_B - C_B' < 0$. Therefore when $C_B - C_B'$ increases, the cost difference between offering green appliances and traditional ones decreases, which means there will be not too much cost increase for offering green appliances. Taking further considering of the governments penalty, enterprises would have more motive power to offer green home appliances. Similarly, when S_B and F_B increases, the enterprises would rather offer green home appliances driven by the subsidy from the governments and restricted by the penalty as well. As for governments, the possibility of supervision would decrease due to the increasing initiative of enterprises to offer green home appliances.

5 Conclusions

In general, in the static game of complete information between governments and enterprises in the green supply chain of home appliance industry, there are three pure-strategy Nash equilibriums, i.e., (Unsupervision, Offer Green Home Appliances), (Unsupervision, Offer Traditional Home Appliance) and (Supervision, Offer Traditional Home Appliance). It is obvious that the solution of (Unsupervision, Offer Green Home Appliances) is what we desire. The condition is $R_b' - C_b' > R_b - C_b$. However, offering green home appliances requires higher level of technology and operation management. Hence the cost would be greater than offering traditional ones. At the same time, enterprises have to quote a favorable price in order to attract more consumers to accept green home appliances. Therefore, the condition is hard to accomplish in the current reality.

In the mixed strategy, through the analysis on the influencing factors of p_1 and p_2 by combining the governments and enterprises, it can be found that: (1) when the governments have more initiatives to supervise, the enterprise would be under the pressure and choose to offer green home appliances; (2) when the enterprises could actively adopt the strategy of green supply chain, the governments would not need to supervise. Since there are not conditions for enterprises to actively adopt the strategy of green supply chain, so it is necessary to promote the enterprises to implement green supply chain through governments' necessary supervision. In other words, the governments should play a leading role in the green supply chain management of the home appliance industry. The governments can improve the enthusiasm and possibility of enterprises to participate in green supply chain by setting appropriate subsidy S_b and penalty F_b for the case not deploying the strategy of green supply chain management.

In the long run, governments will play a very important role in the construction of green supply chain of home appliance industry. The governments should begin with improving laws and regulations about environmental protection, cultivating green price system and green market in order to create favorable external conditions to improve the construction of the green supply chain of home appliance industry. Meanwhile the role of market in the aspect of resource allocation should effectively come into play and lead the enterprises in consciously pursuing scientific management approaches and techniques of green supply chain. Only by doing so, the home appliance industry can realize sustainable development.

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