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Decision model for the subsides to low-carbon production by the government under the emission trading scheme

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Abstract: In the view of supply chain aspect, reducing carbon footprint becomes to the recent business trends. We build a model which includes a re-manufactory which can reduce the carbon emissions by using the recycled products participating in the production process. To support the environmental mode of production, national governments offer subsidies for the re-manufactory to support its production, but not to reduce the total profit of the whole supply chain. We build a bi-objective optimization model to analyze the optimal strategy to reduce the emissions without serious pernicious influence to the industry profit. The outcome proposes significant instructions for the decision making of government and manufactory, when they are under supply chain management.

Keywords: Low Carbon Production, Government Subsidies, Carbon Trading, Multi-Objective Optimization

1. Introduction

By the reason of huge consumption of fossil energy and accumulative emissions of greenhouse gases, global warming becomes worse. Thus, a series of policies have been introduced by governments in worldwide to encourage the public to use the low-carbon productions and support enterprises to reduce the emission in producing, marketing, and recycling process(de Brito et al.,2008; Sarkis,2006;Zhu & Dou,2007). Therefore many scholars focus on design green supply chain which can effectively reduce carbon emissions(Hall,2000; Koplin et al,2007; Vachon & Klassen,2008) and they seek to achieve the optimal state of the environmental and economic indicators(Ellerman & Buchner,2007). In this paper, we assume a kind of environmental manufacturer participating in production progress, we call it remanufacturer which produces by using the recycled materials like Nagurney et al. (2006). And it has a monopolistic competition relationship with the original manufacturer which produces in a normal way in the market. As we said below, the remanufacturer increases the cost recycling, classifying and sorting raw materials. Besides, remanufacturer produces less profit than the manufacturer due to the materials recycled and the lower perceived value of customers. To encourage these enterprises and avoid heavy polluted commercial activity, several policies of emission reduction are enacted and have effective results, such as emission tax, emission trade and government subsidies.

However, there are many restrictions in the policies and methods(Liu & Wang,2009;Shrum,2007). For instance, emission trade is available to the resource-intensive enterprises and government subsidies are suitable for the renewable resources enterprises. Based on actual situation of enterprises (Liu,2009), we design a combination measures that can offer appropriate emission reduction policy for various enterprises and the enterprises could accept and implement it better. That means that under a fixed transaction price of emission trading, the government should decide how much subsidies to the remanufacturer to reduce the total emission without affect the total profits of the whole industry. We build an optimal model including maximizing the interests and minimizing environmental impact as the targets. Finally the outcome of this paper offer useful suggestions about the strategy of government subsidies.

2. Research Methodology

2.1. Model Description

A remanufacturer which produces by recycling waste and sold products can greatly reduce the emissions in the process of production. But in competitive market, the remanufacturer's production cost is higher than the general production activities in both technically and economically. Besides, for the traditional consumers, the perceived value of remanufactured goods may become lowers. Generally, the government usually makes use of the subsidy policy to foster the remanufacturing enterprises in order to achieve reduction. Our research assumes that government affects the market share by subsidies. Obviously, if the manufacturer's markets share increase, the environmental indicators improve, while the economic benefits of the industry as a whole will be seriously affected. We focus on reducing the emission without affecting the economic benefit seriously. At the same time, based on the emission trading, it can transfer the emission target into profit function(Chaabane et al.,2012;

Farahani & Elahipanah,2008). In the model, it offers the suitable subsidy to get the largest profit.

2.2. Variables Descriptions

P_m, C_m, L_m, E_m : per new unit product's selling price, cost, profit and carbon emission;

P_r, C_r, L_r, E_r : per remanufactured unit product's selling price, cost, profit and carbon emission;

γ : the market share of remanufacturer;

E_l : the emission limit for whole industry;

P_s , P_b : selling and buying price of per unit emission;

$\lambda \in [0, C_r - C_m]$: subsidies for per remanufactured product;

Λ : total profit of whole industry;

E : total emission of whole industry

2.3. Model Assumptions

Several complex conditions will be simplified without changing the nature of the problem. The simplifications of the model are as follows:

(1) We roughly assume that both the manufacturer's market share is inversely with their prices. And the market share of manufacturer is $\frac{P_r}{P_r + P_m}$, and the remanufacturer's is $\gamma = (1 - \frac{P_r}{P_r + P_m})$.

(2) We assume that the total market demand is 1, and the prices of both kinds of products are denoted on the interval $(0,1)$ (Mitra & Webster,2008). Based on assumption (1), γ represents the demand of the remanufactured products.

(3) We use the carbon emission factor of the electronic and communications industry, which is the amount of carbon dioxide emissions per unit of economic output as the carbon emissions(Jin et al.,2011). We assume that the emission limit is 10.

(4) The subsidy can compensate for high cost, and the cost becomes $C_r - \lambda$. We assume that government subsidies are just used to expand the market share of the remanufacturer. If so, the market share becomes $\gamma = \frac{P_m}{P_m + (P_r - \lambda)}$.

(5) We assume that the ability of selling and buying carbon emission is limitless. So the price of selling or buying is constant. And the resource for recycling is limitless, so the remanufacturer doesn't have to consider

the ability of product.

2.4. Model Building and Optimal Solutions

$$\max \Lambda = [(P_r - \lambda) - (C_r - \lambda)]\gamma + (P_m - C_m)(1-\gamma) \quad (1)$$

$$\min E = E_m(1-\gamma) + E_r \bullet \gamma \quad (2)$$

Subject to $0 \le \lambda \le C_r - C_m$

$E_m > E_l > E_r$

We can combine two objective functionsinto one profit function based on emission trading[12, 13].

$$F(\lambda) = \begin{cases} \Lambda + (E_l - E)P_s & (\lambda \ge P_r - \frac{E_l - E_r}{E_m - E_l}P_m) \\ \Lambda - (E - E_l)P_b & (\lambda \le P_r - \frac{E_l - E_r}{E_m - E_l}P_m) \end{cases} \quad (3)$$

In the following, we just consider the realistic situation: $\frac{P_r - C_r + C_m}{P_m} \le \frac{E_l - E_r}{E_m - E_l} \le \frac{P_r}{P_m}$

(1) If $E_m - E_r \ge \frac{L_m - L_r}{P_s}$, namely emission saved cost of producing one more unit of manufactured products more than the profit of producing one more unit of new products. When we let subsidies $\lambda = C_r - C_m$ we can get the optimal profit function as follow:

$$F_1 = L_m - (E_m - E_l)P_s + \frac{P_m[L_r - L_m + (E_m - E_r)P_s]}{P_m + P_r - (C_r - C_m)} \quad (4)$$

(2) If $E_m - E_r \le \frac{L_m - L_r}{P_s}$, when the subsidies denoted $\lambda = P_r - \frac{E_l - E_r}{E_m - E_l}P_m$ we can get the optimal profit function:

$$F_2 = L_m + \frac{(E_m - E_l)[L_r - L_m]}{E_m - E_r} \quad (5)$$

(3) If $E_m - E_r \ge \frac{L_m - L_r}{P_b}$, namely buying permits cost of producing one more unit of 'new' product is more than the profit of producing one more unit of new products. When we let subsidies $\lambda = P_r - \frac{E_l - E_r}{E_m - E_l}P_m$, we can get the optimal profit function as follow:

$$F_3 = L_m + \frac{(E_m - E_l)[L_r - L_m]}{E_m - E_r} \quad (6)$$

(4) If $E_m - E_r \le \frac{L_m - L_r}{P_b}$, when the subsidies denoted $\lambda = 0$, we can get the optimal profit function:

$$F_4 = L_m - (E_m - E_l)P_b + \frac{P_m[L_r - L_m + (E_m - E_r)P_b]}{P_m + P_r} \quad (7)$$

Now, we give an overall strategy about the government subsidies for the remanufacturing under the emission trading as follow:

$$F(\lambda) = \begin{cases} F_4 = F(0) \\ F_{2,3} = F(P_r - \frac{E_l - E_r}{E_m - E_l} P_m) \\ F_1 = F(C_r - C_m) \end{cases} \quad (8)$$

Then, our numerical experiments simulate the decision-making process and analyze the relationship between strategy and emissions.

3. Numerical Experiments

In this sector, we rely on a numerical analysis to compare the pros and cons of several emission reduction approach through the assignment of variables in the model. And then, we analyze the sensitivity of total profit to (E_r, λ).

3.1. Comparison of Emission Reduction Efficiency

It is seen from that (8) the best subsidies are influenced by the emission of remanufacturer. Based on our assumption below, we have the result of best subsidy policies and the best profit by the assignment of the variable in Tab.1.

Table1: Variable assignment

E_l	P_m	C_m	P_r	C_r	P_s	P_b
10	1	0.5	0.9	0.7	0.08	0.15

The current emission reduction will make the emission reduction efficiency (economic losses of reducing per unit emission) lower. When we just consider the government subsidy under the assignment and the assumption, our profit ranges from $F_{\max} = 0.342$ to $F_{\min} = 0.323$, and the emission range from $E_{\max} = 10.15$ to $E_{\min} = 9.94$,when the subsidies range from 0 to $C_r - C_m$. But when we consider the subsidy under the emission trading, the profit rang from $F_{\max} = 0.342$ to $F_{2,3} = 0.328$, and the emission range from $E_{\max} = 10.15$ to $E = 10$. It will easily discover that the new emission reduction way can decrease more emission with the same economics loss.

3.2. Sensitivity of Total Profit to (E_r, λ)

With the consideration that the emission from (re)manufacturer can also affect the most optimal subsidies in (8), we have conducted a set of four sensitivity analyses of the total profit with respect to (E_r, λ), where the remanufacturer's production emission E_r have to be subjected to $\frac{P_r - C_r + C_m}{P_m} \le \frac{E_l - E_r}{E_m - E_l} \le \frac{P_r}{P_m}$ and the manufacturer's emission $E_m = 11, 11.5, 12, 12.5$. The results are illustrated in Figs.1a-d.

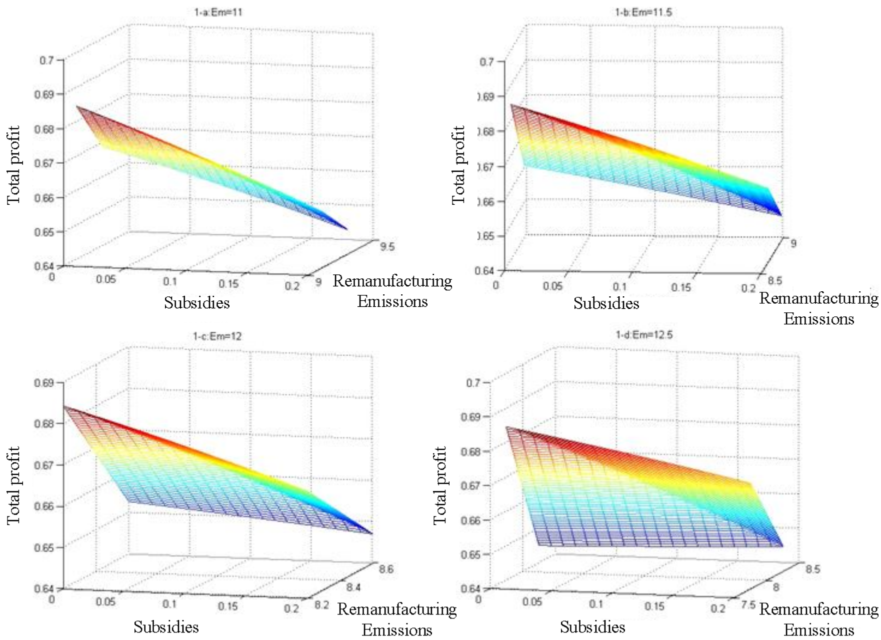

Fig.1: The images of profit function respect to (E_r, λ)

As we seen from the Fig.1, the optimal policy of the government subsidies is influenced by the two types of manufacturer's emissions. First, when the optimal total profit comes to the flex point, the government need supply the more subsidies, with the E_r increasing. Secondly, if E_m is in higher position, emission reduction efficiency of government subsidies increases.

We can find that the (re)manufacturer emission can determine the optimal strategy of government subsidies. When the two kind of manufacturers' emission decrease, the subsidies can have more choices to balance the emission reduction and the total profit. On the contrary, one unit emission reduction can affect the economic benefits.

4. Discussions and Conclusions

In this paper, we established a multi-objective optimization model to discuss the relationship between the economic benefit and the emission reduction. And we analyzed the optimal government subsidies in different situation that different emission of two kinds of manufacturers. And we gave the optimal strategy of subsidies for the government. And we can summarize several suggestions. Firstly, the combination of a variety of emission reduction policies can bring higher emission reduction efficiency and less economic loss than single original policy. Secondly, if the remanufacturer's emission is low, the government is able to balance the economic and environmental benefit by adjusting the subsidies. Thirdly, if manufacturer's emission is high, the efficiency of subsidy will decrease. These recommendations can guide the government to make the optimal subsidy policy.

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References

Chaabane, A., Ramudhin, A. & Paquet, M.(2012).Design of sustainable supply chains under the emission trading scheme. *International Journal of Production Economics*,135(1):37-49.

de Brito, M. P., Carbone, V. & Blanquart, C. M.(2008).Towards a sustainable fashion retail supply chain in Europe: Organization and performance. *International Journal of Production Economics*,114(2),534-553.

Ellerman, A. D. & Buchner, B. K.(2007).The European Union Emissions Trading Scheme: origins, allocation, and early results. *Review Environmental Economics and Policy*,1(1),66-87.

Farahani, R. Z. & Elahipanah, M.(2008).A genetic algorithm to optimize the total cost and service level for just-in-time distribution in a supply chain. *Int. J. Production Economics*, 111(2),229-243.

Hall, J.(2000).Environmental supply chain dynamics.*Journal of Cleaner Production*,8(6),455-471.

JIN, K. D., CHU. C. L. & WANG, Y. S.(2011).Chinese high-tech industrial carbon emission trends and influencing factors analysis.*JIANGHUAI TRIBUNE*,3,16-20.

Koplin, J., Seuring, S. & Mesterharm, M.(2007).Incorporating sustainability into supply management in the automotive industry：The case of the Volkswagen AG.*Journal of Cleaner Production*,15(11-12),1053-1062.

Liu, X. C. & Wang, Z. T.(2009).Carbon dioxide emissions policy and our optimization options. *Journal of Shanghai University of Finance and Economics*,11(4):73-80.

Mitra, S. & Webster, S.(2008).Competition in remanufacturing and the effects of government subsidies.*Int. J. Production Economics*,111(2):287-298.

Sarkis, J.(2006).*Greening the Supply Chain*. Springer-Verlag London Limited ,London.

Shrum, T. (2007).*Greenhouse gas emissions: policy and Economics*.

Vachon, S & Klassen, R. D.(2008).Environmental management and manufacturing performance: The role of collaboration in the supply chain.*International Journal of Production Economics*,111(2),299-315.

Zhu, Q. H. & Dou, Y. J.(2007).An evolutionary model between governments and core—enterprises in green supply chain.*Systems Engineering:Theory & Practice*,12(12),85-89.