Advances in Economics, Business and Management Research, volume 159
Fifth International Conference on Economic and Business Management (FEBM 2020)

Green Supplier Selection With Government Subsidy

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ABSTRACT
The purpose of this paper is to investigate the impact of government subsidy on the retailer's supplier selection in a green supply chain. We develop a game model where the supply chain consists of a green manufacturer, a non-green manufacturer and a common retailer. The retailer should determine its sourcing strategy: only selling non-green products (N), only selling green products (G), or selling both products (D). Both the retailer and the green manufacturer consider environmental impact as well as profit maximization. We identify thresholds of social responsibility for the retailer to make sourcing strategy without government subsidy. The results show that the retailer would not select green supplier when it has a relatively low social responsibility. Further, we explore the effect of government support, namely sales subsidies, on the retailer's supplier selection. We show that government subsidies always stimulate the market demand for green products. When the retailer has low or moderate social responsibility, government subsidy could induce the retailer to shift its sourcing strategy from N to D, or from D to G. However, when the retailer' social responsibility is high enough, it would always choose to sell green products(G) even without government subsidy. Numerical examples are included to illustrate the major results.
Keywords: *Supply chain, supplier selection, government subsidies, game theory*

1. INTRODUCTION

In the circular economy, the public is paying more and more attention to the environment and consumers are increasing their awareness on sustainability. In response to the growing public interest in sustainable development, green products are increasingly popular for consumers and form internal competition with non-green products. Chen [1] studied the self-selection of green and non-green products by the masses and market segments. The result shows that green products development and stricter environmental standards might not necessarily benefit the environment. Shen et al. [2] studied the impact of inventory service level on the selling sequence of green and non-green products with environmental impact consideration. Corporate social responsibility issues have also become one of the hot topics in the area of operations and supply chain management. On the one hand, enterprises undertaking social responsibility can gain more market share and improve the competitiveness of supply chain. Tan [3] studied the consumer investment decision based on product safety responsibility of manufacturing and marketing supply chain alliance. On the other hand, there are still many disadvantages in producing or distributing green products. Green products incur higher production cost resulting in higher prices than non-green ones, besides they generally have lower qualities than non-green products [4, 5].

Governments have realized these issues and introduced policies to support enterprises to produce green products. They provide financial incentives, for firms or for consumers, to stimulate production and consumption of green products [6]. Cohen et al. [7] studied two common types of government support, namely R&D support and sales subsidies. Zhang et al. [8] investigated the interactions among customers' preferences, firms' product strategies, and government subsidy policies.

Our study differs from the aforementioned studies in two key aspects. First, not from the production end, but from the sales side, to consider promotion of green products. Second, this paper focuses on government subsidy which aims to stimulate the retailer to select green suppliers and sell green products. We seek to answer two research questions: (i) How does the retailer's social consciousness affect its supplier selection strategy without government subsidy? (ii) How does the government subsidy affect the retailer's sourcing strategy? We develop a game model where the supply chain consists of a green manufacturer, a non-green manufacturer and a common retailer. The retailer should determine its sourcing strategy.

This paper researches Green Supplier Selection and Government Subsidy Mechanism from the perspective of the retailer. Our major contributions in this paper are as follows. First, research results of this paper can provide important guidance for the retailer' channel decision-making based on consumer classification. Second, we offer new insights on how government subsidies influence the retailer decisions of supplier selection.

This paper is structured as follows. Section 2 proposes a benchmark model. Section 3 extends it to the model with government subsidy. Numerical examples and managerial implications are placed in Section 4. Section 5 concludes the paper.

2. THE BENCHMARK MODEL

In the benchmark model, there is a supply chain with two manufacturers (M1 and M2) and a common retailer (R). We consider M1 produces non-green products (Product 1) and M2 produces green products (Product 2). The retailer has three options when deciding its sourcing strategy: (1) only selling non-green products (Strategy N), (2) only selling green products (Strategy G), and (3) selling both non-green and green products (Strategy D). The market size is normalized to 1 and each consumer can purchase at most one unit of the good. Consumer's valuation for the product is equal to *v*, which is uniformly distributed from 0 to 1, with a density of 1. Let α ($\alpha \in [0,1]$) denotes the ratio of consumers who are socially conscious. When purchasing green products, they obtain an additional homogeneous valuation μg, where μ denotes consumers' social responsibility and *g* denotes the greenness of green products. The remaining $1-\alpha$ ratio of customers are assumed to be unconscious of social responsibility. Following Shen [2], the utility for non-socially conscious consumers is $u_i = q_i v - p_i$, and the utility for socially conscious consumers is $u_i = q_i - p_i + ug$, where q_i is product quality. The supply chain members consider environmental utility and economic profit simultaneously. Let r_m and r_n denote the social responsibility of the green manufacturer (M2) and the retailer, respectively. The unit production cost for Product *i* is c_i, where $c_2 > c_1$. The game sequence is as follows. First, the retailer determines supplier selection strategy. Second, the manufacturers determine the wholesale price (w_i) simultaneously. Third, the retailer determines the retail price (p_i). Finally, consumers decide whether or not to purchase the product and if there are two options, they also decide which type of product to purchase.

We now derive game equilibriums under each of the retailer's strategy. Under Strategy N, a consumer will purchase a non-green product if and only if $q_1 v - p_1 \geq 0$. Thus, the market demand of non-green products and the profit functions of the retailer and manufacturer are as follows:

$$d_1^N = (1-\alpha)(1-\frac{p_1}{q_1}) + \alpha(1-\frac{p_1}{q_1}) = 1-\frac{p_1}{q_1} \quad (1)$$

$$\pi_{M_1}^N = (w_1 - c_1)d_1 = (w_1 - c_1)(1-\frac{p_1}{q_1}) \quad (2)$$

$$\pi_R^N = (p_1 - w_1)d_1 = (p_1 - w_1)(1-\frac{p_1}{q_1}) \quad (3)$$

Under Strategy G, the proportion α of consumers will purchase green products if and only if $q_2 v - p_2 + \mu g \geq 0$. Meanwhile, all remaining consumers are oblivious to green products because of price considerations or ignorance and disbelief, thus they only make the purchase decision if and only if $q_2 v - p_2 \geq 0$. Thus, the market demand of green products and profit functions of the retailer and manufacturer are as follows.

$$d_2^G = (1-\alpha)(1-\frac{p_2}{q_2}) + \alpha(1-\frac{p_2-\mu g}{q_2}) \quad (4)$$

$$\pi_{M_2}^G = (w_2 - c_2 + r_m g)d_2 \quad (5)$$

$$\pi_R^G = (p_2 - w_2 + r_n g)d_2 \quad (6)$$

Under Strategy D, similar to the G case, socially conscious customers with $v \geq p_2 - \mu g / q_2$ will purchase green products while non-socially conscious customers with $v \geq p_1 / q_1$ will purchase non-green products. We assume that socially responsible consumers would only purchase green products, and non-socially conscious consumers would only purchase non-green products. Thus, the market demand of green and non-green products, as well as the profit functions of the retailer and manufacturers are as follows:

$$d_1^D = (1-\alpha)(1-\frac{p_1}{q_1}) \quad (7)$$

$$d_2^D = \alpha(1-\frac{p_2-\mu g}{q_2}) \quad (8)$$

$$\pi_{M_1}^D = (1-\alpha)(w_1 - c_1)(1-\frac{p_1}{q_1}) \quad (9)$$

$$\pi_{M_2}^D = \alpha(w_2 - c_2 + r_m g)(1-\frac{p_2-\alpha\mu g}{q_2}) \quad (10)$$

$$\pi_R^D = (p_1 - w_1)d_1 + (p_2 - w_2 + r_n g)d_2 \quad (11)$$

Further, we define $\delta = q_2/q_1 (q_1 > q_2)$, $e_i = q_i - c_i (i = 1,2)$, and $\gamma = r_m + r_n$. The equilibrium results under three sourcing strategies are shown in Table 1. By comparing the retailer's optimal profits under Strategy N, G and D, we can get the decision rule for the retailer to choose suppliers, as shown in Proposition 1.

Proposition 1: *When* $0 < r_n < e_2(1+\sqrt{\delta})/g - \gamma$, *the retailer selects strategy N; When* $e_2(1+\sqrt{\delta})/g - \gamma < r_n < \sqrt{\alpha\mu^2 + e_1^2\delta/g^2} - r_m - e_2/g$, *the retailer selects strategy D; Otherwise, the retailer selects strategy G.*

From Proposition 1, we can see that when the retailer's responsibility is low, selling non-green products is more beneficial for the retailer. When the retailer's responsibility is high enough, it might sell green products only. Otherwise, the retailer will choose to sell both products.

Table 1 Game equilibrium without government subsidy

Strategy N	Strategy G	Strategy D
$p_1^{N*}=\frac{3q_1+c_1}{4}$	$p_2^{G*}=\frac{3\alpha\mu g+3q_2+c_2-g\gamma}{4}$	$p_1^{D*}=\frac{3q_1+c_1}{4}$, $p_2^{D*}=\frac{3\mu g+3q_2+c_2-g\gamma}{4}$
$w_1^{N*}=\frac{q_1+c_1}{2}$	$w_2^{G*}=\frac{\alpha\mu g+q_2+c_2+g(r_n-r_m)}{2}$	$w_1^{D*}=\frac{q_1+c_1}{2}$, $w_2^{D*}=\frac{\mu g+q_2+c_2+g(r_n-r_m)}{2}$
$d_1^{N*}=\frac{e_1}{4q_1}$	$d_2^{G*}=\frac{(\alpha\mu+\gamma)g+e_2}{4q_2}$	$d_1^{D*}=\frac{e_1}{4q_1}$, $d_2^{D*}=\frac{[(\mu+\gamma)g+e_2]\alpha}{4q_2}$
$\pi_{M_1}^{N*}=\frac{e_1^2}{8q_1}$	$\pi_{M_2}^{G*}=\frac{[\alpha\mu g+e_2+g\gamma]^2}{8q_2}$	$\pi_{M_1}^{D*}=\frac{(1-\alpha)e_1^2}{8q_1}$
$\pi_R^{N*}=\frac{e_1^2}{16q_1}$	$\pi_R^{G*}=\frac{[\alpha\mu g+e_2+g\gamma]^2}{16q_2}$	$\pi_{M_2}^{D*}=\frac{\alpha[\mu g+e_2+g\gamma]^2}{8q_2}$
		$\pi_R^{D*}=\frac{[\mu g+e_2+g\gamma]^2\alpha}{16q_2}+\frac{(1-\alpha)e_1^2}{16q_1}$

3. SUPPLIER SELECTION WITH GOVERNMENT SUBSIDY

In this section, we examine the scenario in which the government provides sales subsidies for green products. Suppose the retailer receives a subsidy φg from the government for each unit of green product sold in the market. Assume φg is a (weakly) increasing function of the product greenness g, which is common among existing government subsidy programs on green products [7].

Under strategy N, the supply chain is not affected by government subsidies. Under Strategy G, the demand of green products and the profit functions of the retailer and the green manufacturer are:

$$d_2^G=(1-\alpha)(1-\frac{p_2}{q_2})+\alpha(1-\frac{p_2-\mu g}{q_2}) \quad (12)$$

$$\pi_{M_2}^G=(w_2-c_2+r_m g)d_2 \quad (13)$$

$$\pi_R^G=(p_2-w_2+r_n g+\varphi g)d_2 \quad (14)$$

Under Strategy D, the demand of green and non-green products, as well as the profit functions of the retailer and manufacturers are:

$$d_1^D=(1-\alpha)(1-\frac{p_1}{q_1}) \quad (15)$$

$$d_2^D=\alpha(1-\frac{p_2-\mu g}{q_2}) \quad (16)$$

$$\pi_{M_1}^D=(1-\alpha)(w_1-c_1)(1-\frac{p_1}{q_1}) \quad (17)$$

$$\pi_{M_2}^D=\alpha(w_2-c_2+r_m g)(1-\frac{p_2-\alpha\mu g}{q_2}) \quad (18)$$

$$\pi_R^D=(p_1-w_1)d_1+(p_2-w_2+r_n g+\varphi g)d_2 \quad (19)$$

Table 2 shows the equilibrium results under three sourcing strategies when the government provides sales subsidies to the retailer. By comparing Table 2 with Table 1, we get Proposition 2.

Proposition 2: *Under the government subsidy policy, the wholesale price and the demand for green products are both higher than those in the benchmark case; But the retailing price for green products is lower than that in the benchmark case.*

Proposition 2 shows that the green manufacturer could increase marginal profit through endogenous product wholesale price decision under the government subsidies. Therefore, the green manufacturer has a free-riding behavior on the retailer. The retailer benefits from sales subsidies by decreasing retail price to boost demand for green products. By comparing the retailer's optimal profits under Strategy N, G and D in Table 2, we can get the decision rule for the retailer to choose suppliers, as shown in Proposition 3.

Table 2 Game equilibrium with government subsidy

Strategy N	Strategy G	Strategy D
$p_1^{N*}=\frac{3q_1+c_1}{4}$	$p_2^{G*}=\frac{3\alpha\mu g+3q_2+c_2-g\gamma-\varphi}{4}$	$p_1^{D*}=\frac{3q_1+c_1}{4}$, $p_2^{D*}=\frac{3\mu g+3q_2+c_2-g\gamma-\varphi g}{4}$
$w_1^{N*}=\frac{q_1+c_1}{2}$	$w_2^{G*}=\frac{\alpha\mu g+q_2+c_2+g(r_n-r_m)+\varphi g}{2}$	$w_1^{D*}=\frac{q_1+c_1}{2}$, $w_2^{D*}=\frac{\mu g+q_2+c_2+g(r_n-r_m)+\varphi g}{2}$
$d_1^{N*}=\frac{e_1}{4q_1}$	$d_2^{G*}=\frac{(\alpha\mu+\gamma+\varphi)g+e_2}{4q_2}$	$d_1^{D*}=\frac{e_1}{4q_1}$, $d_2^{D*}=\frac{[(\mu+\gamma+\varphi)g+e_2]\alpha}{4q_2}$
$\pi_{M_1}^{N*}=\frac{e_1^2}{8q_1}$	$\pi_{M_2}^{G*}=\frac{[\alpha\mu g+e_2+g\gamma+\varphi g]^2}{8q_2}$	$\pi_{M_1}^{D*}=\frac{(1-\alpha)e_1^2}{8q_1}$
		$\pi_{M_2}^{D*}=\frac{\alpha[\mu g+e_2+g\gamma+\varphi g]^2}{8q_2}$
$\pi_R^{N*}=\frac{e_1^2}{16q_1}$	$\pi_R^{G*}=\frac{[\alpha\mu g+e_2+g\gamma+\varphi g]^2}{16q_2}$	$\pi_R^{D*}=\frac{[\mu g+e_2+g\gamma+\varphi g]^2\alpha}{16q_2}+\frac{(1-\alpha)e_1^2}{16q_1}$

Proposition 3:
Under the government subsidies,

(a) When $0<r_n<e_2(1+\sqrt{\delta})/g-\gamma$ *, if* $0<\varphi<(\sqrt{e_1^2\delta}-e_2)/g-\mu-\gamma$ *, then the retailer selects strategy N whereas if* $(\sqrt{e_1^2\delta}-e_2)/g-\mu-\gamma<\varphi<(\sqrt{\alpha g^2\mu^2+\delta e_1^2}-e_1-g\gamma)/g$ *, then the retailer selects strategy D; Otherwise, the retailer selects strategy G.*

(b) When $e_2(1+\sqrt{\delta})/g-\gamma<r_n<\sqrt{\alpha\mu^2+e_1^2\delta/g^2}-r_m-e_2/g$ *, if* $0<\varphi<(\sqrt{\alpha g^2\mu^2+\delta e_1^2}-e_2-g\gamma)/g$ *, then the retailer selects strategy D; Otherwise, the retailer selects strategy G.*

(c) When $r_n>\sqrt{\alpha\mu^2+e_1^2\delta/g^2}-r_m-e_2/g$ *, whether the government subsidizes it or not, the retailer always chooses strategy G..*

From Proposition 3, we can see that when the retailer has low or moderate social responsibility, government subsidy could induce the retailer to shift its sourcing strategy from N to D, or from D to G. However, when the retailer' social responsibility is high enough, it would always choose to sell green products(G) even without government subsidy. It is obvious that the more green-conscious the retailer, the less the burden on the government.

4. NUMERICAL EXAMPLES

In this section, we use numerical examples to illustrate the influence of the retailer's social responsibility on its supplier selection strategy and the role of government subsidies. The parameter values are set as α=0.31 , $c_2=0.16$, $c_1=0.11$, $g=0.6$, $\mu=0.06$, $q_1=0.18$, $q_1=0.57$, and $r_m=0.06$.

4.1. Influence of the Retailer's Social Responsibility

As shown in Figure 1a depicts the optimal profits with different levels of the retailer's social responsibility. We can see that when the retailer's social responsibility is sufficiently low ($r_n\le 0.27$), it chooses strategy N. When $0.27<r_n<0.34$, the retailer shifts it's strategy from N to D. When $r_n>0.34$, the retailer's strategy shifts from D to G. Figure 1b and Figure 1c describe the optimal price paths and demand curves. We can see that the entry of green products into the market will not affect the retailing price and demand of non-green products. When the two products coexist in the market, the green product's price is higher than that under strategy G. It also implies that due to the existence of non-green products, the retailer will choose to increase the margin profit of green products to improve revenue. However, the retailer will choose to lower prices to stimulate demand and get a higher profit under strategy G.

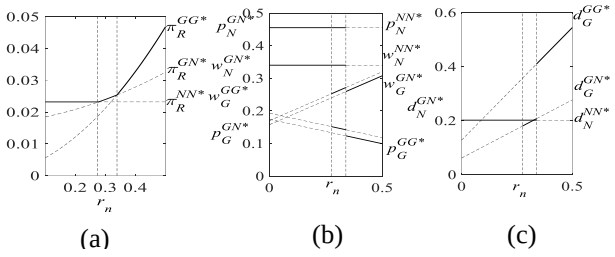

Figure 1 Influence of the retailer's social responsibility

4.2. Role of Government Subsidy

To further analyse the role of government subsidy, we chose three different levels of the retailer's social responsibility. As shown in Figure 2a, when the retailer's social responsibility $r_n = 0.25$, the retailer will chooses strategy N. If government subsidies $\varphi < 0.027$, the retailer will continue to choose to sell only non-green products. If the government subsidy $0.027 < \varphi < 0.24$, the retailer shifts its strategy from N to D. When the government subsidy is high enough $(\varphi > 0.24)$, the retailer will choose to sell only green products. Figure 2b shows the impact of government subsidies on retailer strategies when $r_n = 0.3$. The retailer will choose to sell both products under no government subsidy. When government subsidies $\varphi < 0.2$, the retailer still chooses to sell both products. If the government subsidy $0.2 < \varphi < 0.24$, supplier selection strategy shifts from strategy D to strategy G. Figures 2c shows that when the retailer's social responsibility is relatively high $(r_n = 0.4)$, the retailer chooses to sell only green products, and government subsidies serve to increase demand for green products.

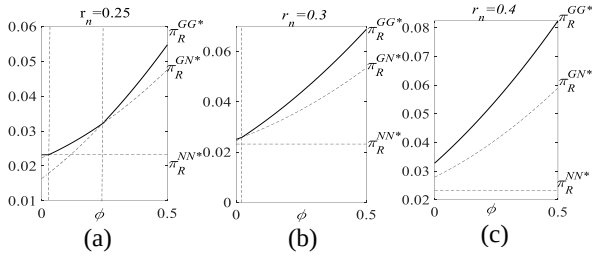

Figure 2 Influence of government subsidy on the retailer's profit

5. CONCLUSION

In this paper, we develop a game model where the supply chain consists of a green manufacturer, a non-green manufacturer and a common retailer. Both the retailer and the green manufacturer consider environmental impact as well as profit maximization and the retailer should determine its sourcing strategy. First, we identify thresholds of social responsibility for the retailer to make sourcing strategy without government subsidy. We show that the retailer would not select green supplier when it has a relatively low social responsibility. We explore the effect of government support, namely sales subsidies, on the retailer's supplier selection. The result shows that government subsidies always stimulate the market demand for green products. When the retailer has low or moderate social responsibility, government subsidy could induce the retailer to shift its sourcing strategy from N to D, or from D to G. However, when the retailer' social responsibility is high enough, it would always choose to sell green products(G) even without government subsidy. The game theory method adopted in this paper can also be applied to supply chain bargaining strategy and the heat loss optimization problem of electric vehicle motor based on game theory.

ACKNOWLEDGMENT

This work was supported by the National Natural Science Foundation of China (Grant Nos. 71571102 and 71771123), and the Jiangsu Province Postgraduate Research Innovation and Practice Project(KYCX20_0390).

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