

The Game Model between Government Subsidies Act and Green Supply Chain

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Abstract

In order to promote the development of green product market, the government will adopt fiscal subsidies to encourage enterprises and consumers. This paper builds the game model of the manufacturers and retailers from the aspect of green supply chain based on the government subsidies. Consider the green supply chain consisting of manufacturers and retailers, the influence of subsidy amount on the decision-making behaviors of the manufacturers, retailers and consumers respectively under the mode of government fiscal subsidies to manufacturers and consumers are studied. Analyze the influence of government subsidy on the decision-making behaviors of manufacturers, retailers and consumers through numerical simulation analysis, and further compare the difference between the manufacturer subsidy mode and consumer subsidy mode. The results indicate that: (1) the manufacturers and retailers will choose consumer subsidy mode; (2) the selection of subsidy mode by consumers is mainly influenced by the relative size of price sensitivity coefficient and subsidy sensitive coefficient.

Keywords: *Green supply chain; Subsidy per unit product; Product green degree; Government subsidy mode*

1. Introduction

The increasingly shortage of resources and environmental degradation today have increased the green industry demand, and the production and purchasing of green products have become the consensus of many enterprises and consumers. The manufacturing enterprises must strengthen the cooperation with suppliers and retailers and adopt the green supply chain management, in order to better develop and produce green products to provide more green products for the society [1]. The existing literatures [1] have considered this point, studied the game between the government and two green product manufacturers, but they did not consider retailers into the research category, nor study the government subsidy mode. Literature induction analysis shows that there are two kinds of government fiscal subsidy modes: subsidy of manufacturers for the R&D of green products and subsidy of consumers for the purchasing of green products. For instance, the Notice on Accelerating the Green Building in Xi'an Province in 2012 clearly stated that Xi'an citizen can choose the products with the "Green" mark when purchasing residential products, and enjoy the subsidy policy of "Subsidy for Green Building Purchase" [2]. Therefore, which government subsidy mode can bring more benefits for

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and be accepted by manufacturers, retailers and consumers in the supply chain is the problem the government should consider in fiscal subsidies. Based on which, this paper builds the game model of the manufacturers and retailers from the aspect of green supply chain. Analyze the influence of government subsidy on the decision-making behaviors of manufacturers, retailers and consumers through numerical simulation analysis, and further compare the difference between the manufacturer subsidy mode and consumer subsidy mode.

2. Government Subsidy Mode

2.1. SM Model of Government Subsidies for Manufacturers

To encourage manufacturers to develop and manufacture the green products with higher green degree, the government will make financial subsidy for the R&D costs and production costs of the manufacturer. For example, the Implementation Suggestions on Promoting the Development of Green Buildings in China jointly issued by the Ministry of Finance and Ministry of Housing and Urban-Rural Development of the People's Republic of China clearly stated to reward the building developers for green building construction; In the second half of 2011, the U.S. Department of Energy put forward the medium and long-term R&D strategy of energy technology in the Quadrennial Technology Review, which put the electric car as the priority of the recent energy technology R&D and investment; The Japanese government plans to invest 21 billion Yen in new-energy vehicle battery project within 7 years and increase the driving range on a single charge of Japanese electric vehicles by 3 times. The market demand function is:

$$D = a - bp + kg \quad (1)$$

The retailer's profit function is:

$$\Pi_r = (p - w - c_r)D = (p - w - c_r)(a - bp + kg) \quad (2)$$

Manufacturer's profits may be affected by government subsidies, and the manufacturer's profit function is:

$$\Pi_m = (u + w - c_m)D = (u + w - c_m)(a - bp + kg) \quad (3)$$

Explore the first-order derivative of P with formula (3), if the derivative=0, the product price made by retailers is:

$$p = \frac{a + kg + bw + bc_r}{2b} \quad (4)$$

Substitute formula (4) into formula (3), and the profit function of manufacturers is:

$$\Pi_m = \frac{(u + w - c_m)(a + kg - bw - bc_r)}{2} \quad (5)$$

Solve the first-order derivative of w with formula (5), if the derivative=0, the optimal wholesale price of manufacturers is:

$$w^m = \frac{a + kg - bc_r + bc_m - bu}{2b} \quad (6)$$

By substituting formula (6) into formula (4), the optimal market price of retailers in the mode of subsidy for manufactures is:

$$p^m = \frac{3a + 3kg + bc_r + bc_m - bu}{4b} \quad (7)$$

At this point, the consumers' actual payment price is equal to the market price of green products, that is

$$p_r^m = p^m = \frac{3a + 3kg + bc_r + bc_m - bu}{4b}$$

By substituting formula (7) into formula (1), the best demand in the mode of subsidy for manufactures is:

$$D = \frac{a - bc_m - bc_r + kg + bu}{4} \quad (8)$$

By substituting formula (6) and formula (7) into formula (2) and formula (3), we can get the profits of retailers and manufactures in the mode of subsidy for manufactures are respectively:

$$\Pi_r^m = \frac{(7bc_r + bc_m + bu + kg - a)(3a - kg - bc_r + bc_m + bu)}{8b} \quad (9)$$

$$\Pi_m^m = \frac{(bu + a + kg - 3bc_m - bc_r)(3a - kg - bc_r + bc_m + bu)}{8b} \quad (10)$$

2.2. The SC Model of Government Subsidy for Consumers

Due to the high R&D and marketing costs, the market prices of green products are generally higher than normal products. Government subsidy for consumers is to compensate the green costs paid by the consumers in order to encourage consumers to buy the green products with higher green degree at lower prices. For example, the Chinese government has started the financial subsidies for the 10 major energy efficient and environmentally friendly products since 2009 [1]. In the new-energy automobile industry, the Notice on Sustainable Promotion and Application of New Energy Vehicles issued by the relevant national department in September 2013 specified the financial subsidy for the purchase of new energy vehicles by consumers from 2013 and 2013. The consumers will determine whether to buy the green products according to the amount of government subsidies. The more the government subsidies are, the consumers are more inclined to buy green products rather than ordinary products, and the market demand for green products will also increase. Thus, the market demand function is:

$$D = a - bp + \beta u + kg \quad (11)$$

The retailer's profit function is:

$$\Pi_r = (p - w - c_r)(a - bp + \beta u + kg) \quad (12)$$

The manufacturers' profit function is:

$$\Pi_m = (w - c_m)(a - bp + \beta u + kg) \quad (13)$$

Similarly, the retailers' market price can be obtained with the application of backward induction:

$$p = \frac{bw + bc_r + a + \beta u + kg}{2b} \quad (14)$$

By combining the formula (14) with the manufacturer's profit function, we can get that

$$\Pi_m = (w - c_m) \left(\frac{a + kg + \beta u - bw - bc_r}{2} \right) \quad (15)$$

By using the first order condition to formula (15), the manufacturer's optimal wholesale price is as

$$w^c = \frac{bc_m + \beta u + a + kg - bc_r}{2b} \quad (16)$$

The retailer's optimal market price under the mode of government subsidies for consumers is:

$$p^c = \frac{bc_r + 3a + 3\beta u + 3kg + bc_m}{4b} \quad (17)$$

Similarly, the actual price paid by consumers is:

$$p_r^c = \frac{bc_r + 3a + 3\beta u + 3kg + bc_m}{4b} - u = \frac{bc_r + 3a + 3\beta u + 3kg + bc_m - 4bu}{4b} \quad (18)$$

By bringing the formula (16) and formula (17) into the profit function, we can get the profits of retailers and manufacturers under the mode of government subsidies for consumers:

$$\Pi_r^c = \frac{(a + kg + \beta u - bc_r - bc_m)^2}{16b} \quad (19)$$

$$\Pi_m^c = \frac{1}{8b} (\beta u + a + kg - bc_r - bc_m)^2 \quad (20)$$

2.3. Theoretical Proposition and Proof

After the comparison and comprehensive analysis of the above two models, we can get the following theoretical propositions.

Proposition 1: regardless of the change in subsidies amount, $w^m < w^c$ and $p^m < p^c$ are always correct.

$$\begin{aligned} w^m - w^c &= \frac{a + kg - bc_r + bc_m - bu}{2b} - \frac{bc_m + \beta u + a + kg - bc_r}{2b} \\ &= \frac{-bu - \beta u}{2b} < 0 \end{aligned}$$

$$\begin{aligned} p^m - p^c &= \frac{3a + 3kg + bc_r + bc_m - bu}{4b} - \frac{bc_r + 3a + 3\beta u + 3kg + bc_m}{4b} \\ &= \frac{-bu - 3\beta u}{4b} < 0 \end{aligned}$$

The proposition suggests that the government subsidies for manufacturers may have significant effect, that is, the manufactures will try to take various measures to bring down the wholesale price of green products. But the subsidies for consumers have little influence on the fall of wholesale prices. The change of market prices can be analyzed in the same way.

Proposition 2: $\frac{\partial w^c}{\partial u} = \frac{\beta}{2b} > 0$, $\frac{\partial w^m}{\partial u} = -\frac{1}{2} < 0$. It indicates that in the SC model, the wholesale price increases with the increase of subsidy amount. But in the SM model, the wholesale price decreases with the increase of subsidy amount.

Proposition 3: $\frac{\partial p^c}{\partial u} = \frac{3\beta}{4b} > 0$, $\frac{\partial p^m}{\partial u} = -\frac{1}{4} < 0$. It indicates that in the SC model, the market prices of green products increase with the increase of subsidy amount. But in the SM model, the market prices of green products decrease with the increase of subsidy amount.

Proposition 4: $b > \beta, p_r^m > p_r^c$ and $b < \beta, p_r^m < p_r^c$.

$$p_r^m - p_r^c = \frac{3a + 3kg + bc_r + bc_m - bu}{4b} - \frac{bc_r + 3a + 3\beta u + 3kg + bc_m - 4bu}{4b}$$

$$= \frac{3bu}{4b} - \frac{3\beta u}{4b} = \frac{3u(b - \beta)}{4b}$$

It is clear that $b > \beta, p_r^m > p_r^c$, and $b < \beta, p_r^m < p_r^c$.

If the price sensitivity of consumers is strong, that is, the price change of green products has a great effect on consumer purchase behavior, the retailers will take into account the consumers of the psychological response, thus greatly reduce the market price of green products to promote the consumers to buy more green products.

Proposition 5: (1) $\frac{\partial p_r^m}{\partial u} = -\frac{1}{4} < 0$. As the government increases subsidies to manufacturers, the actual price paid by consumers is falling. It shows that government subsidies enable manufacturers to reduce costs, so that consumers can get benefits.

(2) $\frac{\partial p_r^c}{\partial u} = \frac{3\beta - 4b}{4b}$, when $3\beta > 4b$, $\frac{\partial p_r^c}{\partial u} > 0$; when $3\beta < 4b$, $\frac{\partial p_r^c}{\partial u} < 0$. When government subsidizes consumers, whether the consumers can get benefits mainly depends on the relative sizes of β and b .

Proposition 6: (1) $\frac{\partial^2 \Pi_r^m}{\partial u^2} = \frac{b}{4} > 0$, $\frac{\partial^2 \Pi_m^m}{\partial u^2} = \frac{b}{4} > 0$, $\frac{\partial^2 \Pi_r^c}{\partial u^2} = \frac{\beta}{16b} > 0$, $\frac{\partial^2 \Pi_m^c}{\partial u^2} = \frac{\beta}{4b} > 0$.

Therefore, whether in SC model or SM model, the profits of manufacturers and retailers increase with the increase of amount of subsidies. Therefore, government subsidy is favorable for both manufacturers and retailers.

(2) $\Pi_r^c > \Pi_r^m$, $\Pi_m^c > \Pi_m^m$. It can be seen that the manufacturer's profit in SC model has been larger than the one in SM model; the retailer's profit in SC model has also been greater than the one in SM model. Therefore, with the same amount of government subsidies, the mode of subsidies for consumers can bring more profits to both manufacturers and retailers than the mode of subsidies for manufacturers. Manufacturers and retailers are more willing to accept the mode of subsidies for consumers instead of the mode of subsidies for manufacturers.

3. Numerical Experiment

The numerical experiment is conducted in order to better analyze the interaction relationship between parameters. The assignment for main parameters is as follows: $a = 500$, $\beta = 13$, $b = 11$, $k = 17$, $c_r = 22$, $c_m = 31$.

3.1. The Influence of Amount of Government Subsidies on the Wholesale Prices of Green Products

From Figure 1, it can be seen that, in the mode of subsidies for consumers, the wholesale price will rise with the increase of the amount of subsidies. In the mode of

subsidies for manufacturers, the wholesale price will gradually decline. From further comparison it can be seen that, no matter how much the amount of subsidies are, the wholesale price in SC model is always higher than the one in SM model. Therefore, after receiving the government subsidy, the manufacturers will try every means, such as strengthening the R&D and technological innovation as well as purchasing environmental protection raw materials, to lower the wholesale price in order to encourage retailers to wholesale more green products. Therefore, both the conclusions of Proposition 1 and Proposition 2 are correct.

3.2. The Influence of Amount of Government Subsidies on the Market Prices of Green Products

Figure 2, shows that in the SM model, the market prices of products decrease with the increase of subsidy amount. In the SC model, the market prices of green products increase with the increase of subsidy amount, which is totally consistent with the conclusion of Proposition 3.

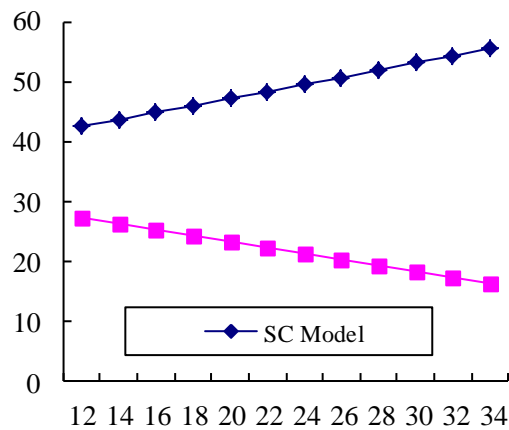


Figure 1. The Influence of Government Subsidy Amount on the Wholesale Prices of Green Products

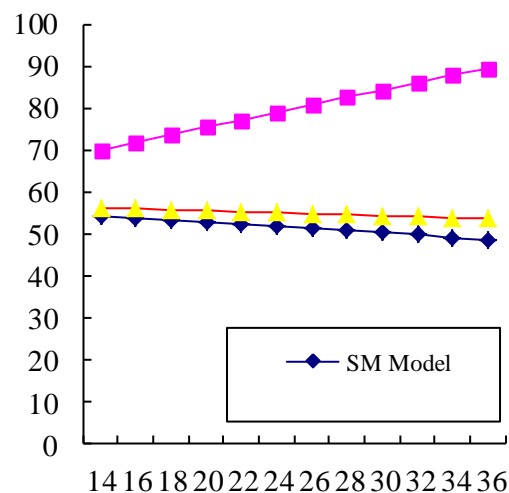


Figure 2. The Influence of Government Subsidy Amount on the Market Prices of Green Products

In addition, by comparing the SC model and SM model, it can be found that the actual price paid by consumers in SC model is higher than the one in SM model. This is because $b < \beta, p_r^m < p_r^c$ according to Proposition 2. But when $b=11 < \beta=13$, the actual price paid by consumers in SC model is higher than the one in SM model, which just verifies Proposition 4. Because the actual price paid by consumers is higher in the SC model, consumers are more willing to accept the mode of government subsidy for manufactures.

Besides, it can be seen from the figure that, in SC model, the actual price paid by consumers gradually declines with the increase of the amount of subsidies. Because the assignment in this time is that $3\beta=39 < 4b=44$, the conclusion of the second part in Proposition 5 can be verified. In the SM model, the actual price paid by consumers is equal to the market price of the green product. Figure 2 shows that the actual price paid by consumers decreases with the government subsidy, which can be verified in the first part of Proposition 5. Based on the above analysis, it can be seen that both the government subsidies for manufacturers and consumers can play a role in regulating and make consumers satisfied.

3.3. The Influence of Government Subsidy Amount on the Profits of Manufacturers and Retailers

In Figure 3, with the increase of amount of government subsidies, both the profits of manufacturers and retailers in SM model are increasing and the difference between the two profits is smaller. In SC model, the profits of manufacturers and retailers also increase with the increase of subsidy amount, but the difference between the two profits is larger and is gradually become bigger. Therefore, the conclusion of the first part of Proposition 6 is correct.

In addition, the profit of manufacturers in SC model is greater than the one in SM model; the profit of retailers in SC model is also greater than the one in SM model. Therefore, the conclusion of the second part of Proposition 6 is correct, that is, manufacturers and retailers are more willing to accept the mode of subsidies for consumers.

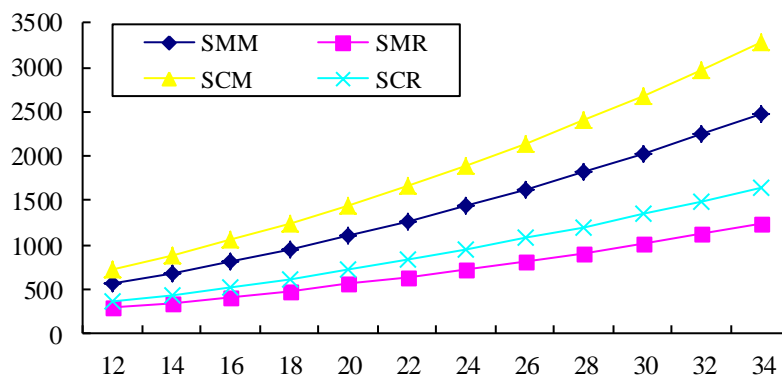


Figure 3. The Influence of Government Subsidy Amount on the Profits of Manufacturers and Retailers

4. Conclusion

In order to guide the development of green product market, the government will adopt financial subsidies to encourage enterprises and consumers. This paper studies the influence of change in subsidy amount on the decision-making behaviors of manufacturers and retailers when respectively adopting financial subsidy for

manufacturers and consumers. The results indicate that (1) after receiving the government subsidy, the manufactures will strengthen the R&D and technical innovation to lower the wholesale price; (2) the actual price paid by consumers can be influenced by price sensitivity coefficient b and the subsidy sensitivity coefficient β . When $b < \beta, p_r^m < p_r^c$, consumers tend to choose the mode of government subsidy for manufactures. When $b < \beta, p_r^m < p_r^c$, consumers tend to choose the mode of government subsidy for consumers. (3) the actual price paid by consumers decreases with the increase of subsidy amount, indicating that both government subsidies for consumers and manufactures can play a regulatory role; (3) both in the modes of subsidies for manufacturers and subsidies for consumers, the profits of manufacturers and retailers gradually increase with the increase of subsidy amount and the increase of green degree, indicating that the government subsidies are favorable for manufacturers and retailers; (4) Manufacturers and retailers are more willing to accept the mode of subsidies for consumers. This paper analyzes the game under complete information. In the future, we can also study the game under incomplete information, and further explore the government subsidies for to R&D and investment.

Acknowledgements

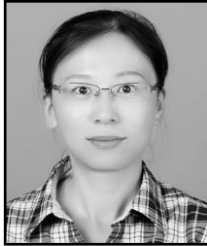
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References

- [1] Y. Liang and X. Wang, "Developing a new perspective to study the health of survivors of Sichuan earthquakes in China: a study on the effect of post-earthquake rescue policies on survivors' health-related quality of life", *Health Research Policy and Systems*, vol. 11, no. 41, (2013), pp.1-12. DOI:10.1186/1478-4505-11-41.
- [2] J. Hu and Z. Gao, "Modules identification in gene positive networks of hepatocellular carcinoma using Pearson agglomerative method and Pearson cohesion coupling modularity", *Journal of Applied Mathematics*, vol. 2012, (2012).
- [3] Y. Geng, J. Chen, R. Fu, G. Bao and K. Pahlavan, "Enlighten Wearable Physiological Monitoring systems: On-Body RF Characteristics Based Human Motion Classification Using a Support Vector Machine", (2015), pp. 99, 1-16.
- [4] X. Song and Y. Geng, "Distributed Community Detection Optimization Algorithm for Complex Networks", *Journal of Networks*, vol. 9, no. 10, (2014), pp. 2758-2765.
- [5] K. Pahlavan, P. Krishnamurthy and Y. Geng, "Localization Challenges for the Emergence of the Smart World", *Access, IEEE*, vol. 3, no. 1, (2015), pp. 1-11.
- [6] J. He, Y. Geng, Y. Wan, S. Li and K. Pahlavan, "A cyber physical test-bed for virtualization of RF access environment for body sensor network", *Sensors Journal, IEEE*, vol. 13, no. 10, (2013), pp. 3826-3836.
- [7] Z. Lv, A. Tek and F. Da Silva, "Game on, science-how video game technology may help biologists tackle visualization challenges", *PloS one*, vol. 8, no. 3, (2013), pp. 57990.
- [8] T. Su, W. Wang and Z. Lv, "Rapid Delaunay triangulation for randomly distributed point cloud data using adaptive Hilbert curve", *Computers & Graphics*, vol. 54, (2016), pp. 65-74.
- [9] J. Hu, Z. Gao and W. Pan, "Multiangle Social Network Recommendation Algorithms and Similarity Network Evaluation", *Journal of Applied Mathematics*, vol. 2013, (2013).
- [10] S. Zhou, L. Mi, H. Chen and Y. Geng, "Building detection in Digital surface model", 2013 IEEE International Conference on Imaging Systems and Techniques (IST), (2012) October.
- [11] J. He, Y. Geng and K. Pahlavan, "Toward Accurate Human Tracking: Modeling Time-of-Arrival for Wireless Wearable Sensors in Multipath Environment", *IEEE Sensor Journal*, vol. 14, no. 11, (2014), November, pp. 3996-4006.

- [12] Z. Lv, A. Halawani and S. Fen, "Touch-less Interactive Augmented Reality Game on Vision Based Wearable Device", *Personal and Ubiquitous Computing*, vol. 19, no. 3, (2015), pp. 551-567.
- [13] G. Bao, L. Mi, Y. Geng, M. Zhou and K. Pahlavan, "A video-based speed estimation technique for localizing the wireless capsule endoscope inside gastrointestinal tract", 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), (2014) August.

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