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PRICING, QUALITY LEVEL AND GREENING DECISIONS FOR GREEN AND NON-GREEN PRODUCTS WITH GOVERNMENT INTERVENTIONS

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Abstract

Due to the environmental deterioration because of pollution and excessive consumption of natural resources, governments are driving efforts to limit pollution emissions and to encourage cleaner manufacturing. The most common interventions governments adopted are providing subsidy to green products and taxing non-green products. With the green consciousness improving gradually, consumers prefer to buy products based on greenness of products with price and quality level together. In order to investigate decision-making of retailer, green manufacturers and non-green manufactures in a two-echelon supply chain setting, in this paper, we formulate a Stackelberg game and derive the equilibrium solutions. Some managerial insights are given through numerical analysis as well. The findings show that both governments subsidy and taxation have an impact on strategy for the two-echelon supply chain, however, subsidy mechanism is more efficient. Moreover, retailer and manufacturers tend to make decisions to meet consumers' preferences, and the retailer is the most beneficial supply chain member in our scenario.

Keywords: green products, green supply chain management, government interventions, game theory

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1. Introduction

Environment protection and energy saving have attracted more and more attention from governments, countries and regions (Madani and Rasti-Barzoki, 2017). Considering the awareness of pollution and energy consuming, as the most powerful and significant roles in market, governments have proposed some policies and regulations to restrict carbon emissions and to encourage eco-friendly manufacturing (Hafezalkotob, 2017; Sheu and Chen, 2012; Seuring, 2013;). Governments usually adopt two kinds of approaches to achieve these goals, which are "cap-and-trade" and pollution taxation mechanisms. "Cap-and-trade" is a direct method to limit total carbon emissions by giving a cap of annual permits for companies. Companies can sell their unused credits to others in the market, which is what "trade" is.

Meanwhile, companies will be taxed if they emit a higher level of carbon than their credits allowed. Moreover, some governments give subsidies to green products as well in order to offset cleaning producing costs and to lead a cleaner life style. As a consequence, traditional supply chain has been changing to green supply chain under this pressure. According to Seuring and Müller (2008), the green products mentioned in our paper could be seen as all kinds of products that have or aim at an improved environmental and social quality.

With the aggravation of environmental pollution and frequently occurring of natural disasters (Hasan et al., 2017; Safayet et al., 2018; Ying et al., 2018), consumers' consciousness of environment

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protection is raising constantly. Therefore, despite guidance of governments, pressure for environmentally friendly products preference driven by consumers also leads manufacturers to increase their green investment (Ji et al., 2017). In order to attract consumers and gain market share, price and level of product quality strategies are critical and inevitable for manufacturers. A group of manufacturers, however, consider greening level of products as an element to their competition strategy, because more and more consumers prefer to buy green products according to survey of Adaman et al. (2011), even spending more money, with environmental consciousness gradually improving (Ji et al., 2017; Li and Chen, 2018).

According to these two aspects, green products and green supply chain management have become popular trends in practical and academic research. For example, the famous IT company HP focuses on low-carbon technologies deployment and green products innovation in these years to strengthen competitiveness and to improve social responsibility. Many researchers have studied the development of green supply chain management and sustainable supply chain management, and indicated the challenges of green supply chain and a development trend for future (de Oliveira et al., 2018; Seuring, 2013). Competition between green and non-green supply chain also has been explored widely by scholars (Jamali and Rasti-Barzoki, 2018; Nagurney and Yu, 2012), which provides decision-making supports for stakeholders in supply chain.

From what we introduced above, we find some managerial issues worth investigating. This study, therefore, comprehensively considering governmental interventions and consumers' preferences, exploring competition between green and non-green products manufacturers with a two-echelon supply chain setting, attempts to give answers to the following questions.

(1) How will retailers design prices of green and non-green products to maximize profit, respectively, considering preferences and choices of consumers?

(2) How could green and non-green products manufacturers decide their pricing, quality level and greening strategy, respectively, to reap maximum profits?

(3) What are the implications of government interventions, including both taxation and subsidy, for decisions of retailer and manufacturers?

(4) Is there any other parameters such as consumers' loyalty to green products influencing this competition strategy?

This paper is organized as follows. Recent and related literatures are briefly reviewed in Section 2. Section 3 describes the detailed problem, the model and solutions as well. Section 4 presents some analytical results and managerial insights through sensitivity analysis. We conclude this paper and provide some future research in Section 5.

2. Literature review

Studies related to this paper can be divided to three categories: competition among supply chains (hereinafter referred to as SCs), competition among green supply chains (hereinafter referred to as GSCs) and government interventions in GSCs. A brief review is provided as follows.

2.1. Competition among SCs

Many investigators have maintained that competition level in market is shifting from competition between independent firms to competition between supply chains (de Oliveira et al., 2018; Huang et al., 2012; Nazifa and Ramachandran, 2019; Olugboyega, 2017). In the field of research on competition among SCs, the most researchers mainly concentrate on competition for pricing strategy of SCs (Huang et al., 2016; Panda et al., 2015). Mahmoodi and Eshghi (2014) explored price competition of three scenarios (both centralized, both decentralized, one centralized and the other decentralized) in duopoly supply chains with stochastic demand, and the effect of competition and demand uncertainty intensity on the Nash equilibria are discussed as well. Moreover, a number of other factors, such as delivery lead time (Yang et al., 2017), information sharing (Bian et al., 2016) and shelf space (Reisi et al., 2019), have been investigated with price together in SCs competition research. However, we find that quality level is another key factor being discussed in this research field. Li and Chen (2018) examined pricing timing choices when two manufacturers in supply chain produce quality differentiated products. Chakraborty et al. (2019) studied how two competing manufacturers and a retailer in a supply chain can obtain benefits by collaborative product quality improvement strategies, and pointed out that cost-sharing contracts result in both higher quality improvement levels and higher profits for stakeholders. Moverover, scholars have also tended to investigate dual-channel or multi-channel supply chains competition. Lan et al. (2018) analysed competition and cooperation of a three-tier supply chain in which a manufacturer distributes products via two different distributors to a retailer whose demand is uncertain, and derived the optimal ordering strategy of retailer, the optimal pricing policy of two distributors and the manufacturer, respectively. Pi et al. (2019) modelled price and service quality competition and derived the optimal strategies for dual-channel supply chain with demand disruption, and found that each retailer benefits from channel's demand disruption.

2.2. Competition among GSCs

With regard to competition among GSCs, there is a rich body of literature discussing it (de Oliveira et al., 2018; Li et al., 2016; Nagurney and Yu, 2012;

Seuring, 2013), which mainly focus on two streams of greenness. One stream is about greening investment and green product producing, and the other is related to reverse logistics and close-loop supply chain. For the first category, considering the development of e-commerce, Jamali and Rasti-Barzoki (2018) examined the pricing and the degree of greenness of a product in competition with a non-green product under two dual-channel supply chains, and solutions are derived two different scenarios: centralized and decentralized. Yang et al. (2019) studied the green investment of two competing manufacturers based on price and quality competition, and analysed how green investment influences products' quality level. Rahmani and Yavari (2019) investigated the demand disruption management in a dual-channel supply chain producing and selling green products in centralized and decentralized cases. Raza and Govindaluri (2019) studied mathematical models for single channel coordination that integrate price differentiation and demand leakage aspects for the two-product case of green and regular products for both integrated and decentralized channels. For the second aspect, Mondal et al. (2019) considered pricing and greening strategy in a closed-loop green supply chain with both forward and reverse dual-channels, and the equilibria for channel members and the whole supply are derived under both centralized and decentralized scenarios. Shen et al., (2019) built analytical models to explore the optimal advertising and pricing decisions for a green product in the presence of a non-green product substitute in the circular economy setting.

2.3. Government intervention in GSCs

As the indispensable role in market, governments have put forward some regulation and legislation to encourage GSC management. Researchers have acknowledged that recognizing influence of government interventions on GSCs is a critical point to GSC research area (Giri et al., 2019; Hafezalkotob, 2017, 2018a,b; Sinayi and Rasti-Barzoki, 2018; Sun et al., 2019; Yang and Xiao, 2017; Yu et al., 2018). Sheu and Chen (2012) explored the effects of governmental financial intervention on GSC competition using a three-stage game-theoretic model, and indicated that green taxation and subsidy should be adopted to ensure the green profits. Madani and Rasti-Barzoki (2017) developed a GSCs competition model, in which the government is the leader and two competing GSC and non-GSC are followers, to discuss the pricing, greening strategy and government tariff policy. For a online to offline close-loop supply chain, Zand et al. (2019) explored the effects of activities dominated by governments with the goal of maximizing social welfare on members' optimal strategy and profits under the "cap-and-trade" mechanism, and they found that government interventions have positive contributions.

As listed above, price and quality level are important criteria while consumers considering whether to buy a product. Greenness of products is the new preference for consumers when they make decisions. This paper, therefore, contributes to the literature by comprehensively considering consumers' preferences on price, quality level and greenness, developing a game-theoretical approach to explore competition between green and non-green products. Also, we consider effects of both taxation and subsidy government interventions, which are powerful factors affecting the market, to answer questions mentioned in Section 1.

3. Methodology

3.1. Problem description

Fig. 1 is provided to show our problem. There are government, two manufacturers, one retailer and consumers in the market. One of two manufactures would like to increase green investment to produce green products, and the other is the non-green products manufacturer. The green products and non-green products are homogenous; therefore, these two manufacturers have a competition for market share with each other.

There is one retailer in this supply chain, who sell both green products and non-green products to consumers. Consumers choose products based on price, level of quality and greenness. Moreover, government taxes non-green products and provides subsidy to green products based on greenness. In this competing supply chain, retailer needs to decide the optimal pricing strategy for green products and non-green products, respectively, with the goal of maximizing profit.

To obtain the maximum profit, manufacture 1 (green products manufacturer) and manufacture 2 (non-green products manufacturer) will consider the pricing and level of quality strategy, in addition, manufacture 1 will decide the greenness of products as well.

3.2. Notation and modelling

Table 1 shows the notation definition of the model. We firstly formulate demand function based on consumers' choice preferences. Similar to Xie (2016); Wang et al. (2017); Zhou et al. (2017), we express linear demand functions for green and non-green products as Eqs. (1, 2), respectively.

$$D_1 = \rho m - \alpha_1 (p_1 - t_s\theta_1) + \alpha_2 (p_2 + t_t) + \beta_1 q_1 - \beta_2 q_2 + \gamma\theta_1 \tag{1}$$

$$D_2 = (1-\rho)m - \alpha_1 (p_2 + t_t) + \alpha_2 (p_1 - t_s\theta_1) + \beta_1 q_1 - \beta_2 q_2 \tag{2}$$

ρ is the loyalty of consumers to green products, where $0 \le \rho \le 1$. α_1 and α_2 are sensitivity coefficient of own price and competitor's price to demand, and β_1 and β_2 have the similar meanings for quality level.

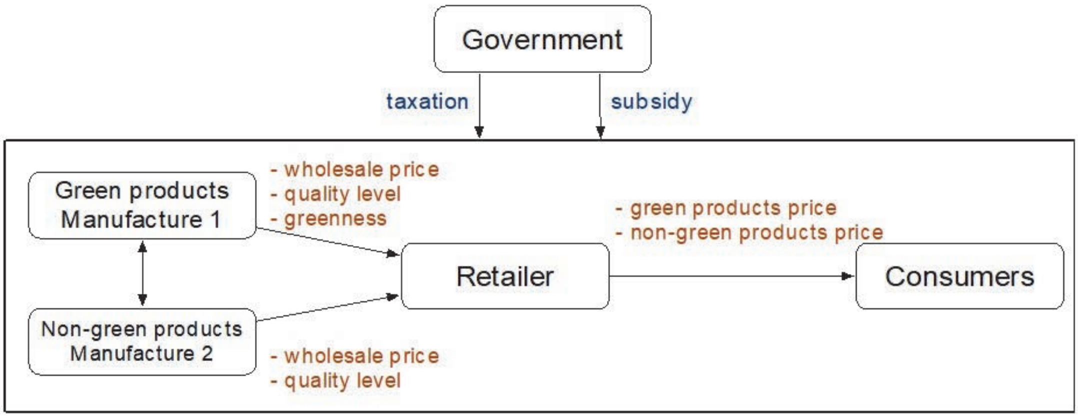


Fig. 1. Explanation of the game

Table 1. Notation definitions of the model

Notation	*Definition*
Sets	
I	set of manufacturers, $i \in I$, where $i=1$ represents green products manufacture, $i=2$ represents non-green products manufacture
Parameters	
ρ	consumers' loyalty to green products
m	the whole market size for two products
α_1	the price elasticity of demand
α_2	the cross price sensitivity
β_1	the quality level elasticity of demand
β_2	the cross quality level sensitivity
γ	the expansion effectiveness coefficient of greenness of green products to demand
t_s	unit government subsidy per greenness of green products
t_t	unit government tax per non-green products unit
c_i	unit manufacturing cost of products i, $i \in I$
τ	the cost coefficient of quality level per product unit
μ	the cost coefficient of green investment per green product unit
Decision variables	
p_i	unit price retailer charged to consumers for product i, $i \in I$
w_i	unit wholesale price manufacturers charged to retailer for product i, $i \in I$
q_i	quality level decided by manufacture i for product i, $i \in I$
θ_1	greenness decided by manufacture 1 for green products

In these formulations, $\alpha_1 \le \alpha_2$ and $\beta_1 \le \beta_2$, which represent the impact of self-price and self-quality greater than competitor's price and quality. π_r is the profit of retailer, which is equal to the sum of profits of green and non-green products (Eq. 3).

$$\pi_r = (p_1 - w_1)D_1 + (p_2 - w_2)D_2 \tag{3}$$

We describe the total cost of manufacturers for quality guarantee as $\frac{1}{2}\tau q_i^2$, where $\tau \ge 0$. Similar cost function also used by by Desai et al. (2001); Matsubayashi and Yamada (2008); Ghosh and Shah (2012). In the same way, we consider the green investment cost of green products manufacturer as $\frac{1}{2}\mu\theta_1^2$, where $\mu \ge 0$, which is suggested by Ghosh and Shah (2015); Basiri and Heydari (2017). π_{M_1} and π_{M_2} are profit of green product manufacturer and non-green manufacturer, respectively, which are expressed as Eqs. (4- 5).

$$\pi_{M_1} = (w_1 - c_1)D_1 - \frac{1}{2}\tau q_1^2 - \frac{1}{2}\mu\theta_1^2 \tag{4}$$

$$\pi_{M_2} = (w_2 - c_2)D_2 - \frac{1}{2}\tau q_2^2 \tag{5}$$

This game can be solved as a two-stage Stackelberg game (Rahmani and Yavari, 2019) where two manufacturers are leaders and the retailer is follower. In the first stage of game, two manufacturers decide their wholesale price, quality level, and the green manufacture decide the greenness degree of products as well. In the second stage, retailers decide prices of two kinds of products based on consumers' choices. As usual in such a model, the solution is derived backwards, which is calculating equilibrium prices of retailer first and then getting the equilibria of two manufacturers by substituting the equilibrium prices. Using the retailer's profit function (Eq. 3), the second stage pricing solutions for retailer is calculated from the first order condition $\frac{\partial \pi_r}{\partial p_1} = 0$ and $\frac{\partial \pi_r}{\partial p_2} = 0$. We can derive the equilibrium prices as Eqs. (6, 7). Substituting the prices solution p_1^* and p_2^* to Eqs. (1, 2), we can obtain D_1^* and D_2^*. As leader of this Stackelberg game, two manufacturers make decisions with the reaction of retailer. The first stage problem, therefore, expressed as Eqs. (8-9).

$$p_1^* = \frac{(\alpha_1^2-\alpha_2^2)(w_1+t_s\theta_1)+(\alpha_1\beta_1-\alpha_2\beta_2)q_1-(\alpha_1\beta_2-\alpha_2\beta_1)q_2+(\alpha_1-\alpha_2)\rho m+\alpha_2 m+\alpha_1\gamma\theta_1}{2(\alpha_1^2-\alpha_2^2)} \tag{6}$$

$$p_2^* = \frac{(\alpha_1^2-\alpha_2^2)(w_2 - t_t)+(\alpha_1\beta_1-\alpha_2\beta_2)q_2-(\alpha_1\beta_2-\alpha_2\beta_1)q_1+(\alpha_2-\alpha_1)\rho m+\alpha_1 m+\alpha_2\gamma\theta_1}{2(\alpha_1^2-\alpha_2^2)} \tag{7}$$

$$\max \pi_{M_1}(w_1,q_1,\theta_1)=(w_1-c_1)D_1-\frac{1}{2}\tau q_1^2-\frac{1}{2}\mu\theta_1^2 \tag{8}$$

$$\max \pi_{M_2}(w_2,q_1)=(w_2-c_2)D_2-\frac{1}{2}\tau q_2^2 \tag{9}$$

Under the Nash assumption that the competitor's decision variables are fixed, the first order conditions for this problem is $\frac{\partial\pi_{M_1}}{\partial p_1}=0$, $\frac{\partial\pi_{M_1}}{\partial q_1}=0$, $\frac{\partial\pi_{M_1}}{\partial\theta_1}=0$, $\frac{\partial\pi_{M_2}}{\partial p_2}=0$ and $\frac{\partial\pi_{M_2}}{\partial q_2}=0$. From the above sections, we can derive the analytical solutions of equilibria w_1^*, w_2^*, q_1^*, q_2^*, θ_1^*, p_1^*, p_2^*, D_1^*, D_2^*, π_r^*, $\pi_{M_1}^*$ and $\pi_{M_2}^*$, however, the expressions look too complicated because of containing too much parameters. It seems to make no sense to managerial insights by exploring the analytical solutions; therefore, we use the numerical analysis to discuss the equilibrium and impacts of parameters in the following section.

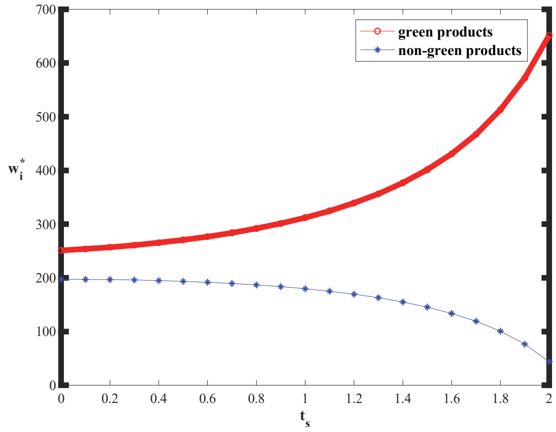
4. Numerical analysis

4.1. Impacts of government interventions

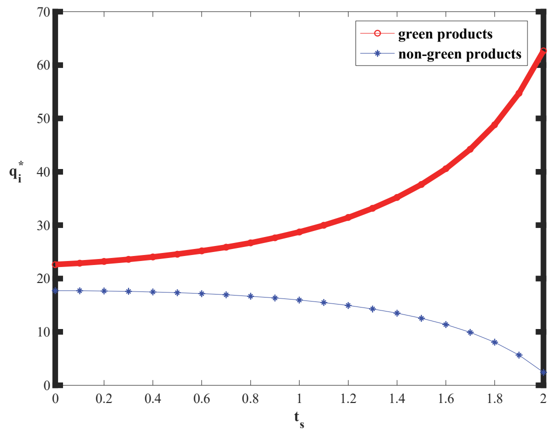
Government interventions play an important role in this competing supply chain, therefore, we first use numerical methods where $\rho=0.6$, $m=2400$, $\alpha_1=5$, $\alpha_2=4$, $\beta_1=3$, $\beta_2=2$, $\gamma=2$, $t_s=0.6$, $t_t=20$, $c_1=25$, $c_2=20$, $\tau=15$, $\mu=10$, according to our investigation and observation on facts, to investigate the effect of government interventions (including subsidy and taxation) on stakeholders' profits, decisions of retailer and manufacturers, respectively.

Impact of subsidy. Government subsidy is a key factor that has effects on both retailer and manufacturers' decisions, which can be seen from Figs. 2- 4. Fig. 2 shows the effects of subsidy on equilibrium wholesale prices, equilibrium quality levels and equilibrium greening decisions, respectively.

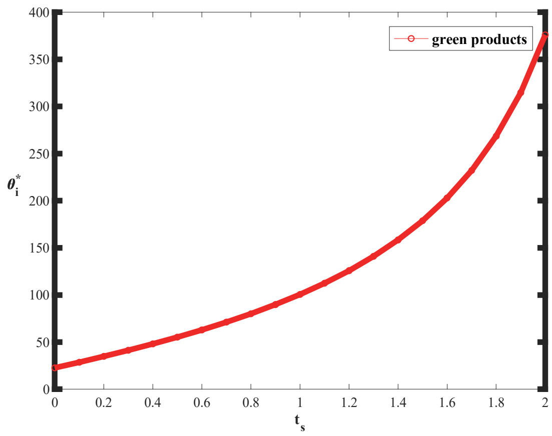
We could conclude that green manufacture will increase price, quality and greenness of products with subsidy going up, however, non-green manufacture will make opposite decisions. This is because government subsidy to green products strengthens green manufacture's competitiveness.



(a)



(b)



(c)

Fig. 2. Effect of subsidy on manufacturers' decisions: (a) Effects on wholesale price; (b) Efeects on level of quality; (c) Effects on greenness

Moreover, from Fig. 3, the retailer will increase price of green products dramatically with subsidy going up, however, retailer will not tend to reduce price of non-green products even the wholesale price is lower.

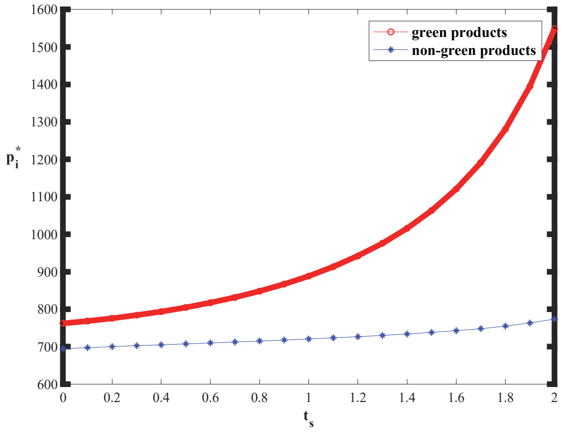


Fig. 3. Effect of subsidy on retailer's decisions

This means that retailer would like to obtain more or maintain profits through squeezing manufacturers' profits. We could obtain the same conclusion from Fig. 4 that retailer is the most beneficial member under this scenario.

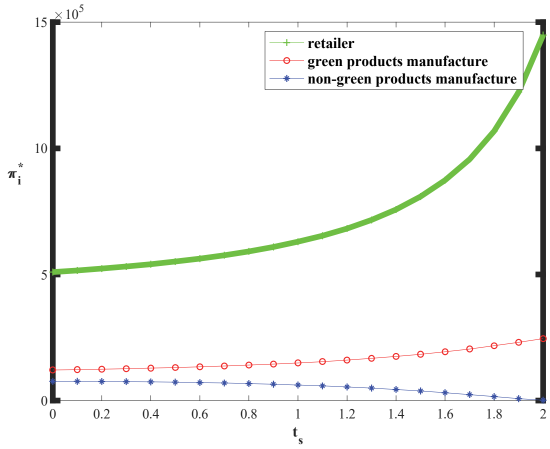


Fig. 4. Effect of subsidy on profits

Impact of taxation. Taxing non-green products influences the market as well, but may not be as sensitive as subsidy Figs. 5-7. The same as Fig. 2, Fig. 5 shows effects of taxation on manufactures' decisions.

However, the different point is manufactures just increase or decrease their prices, quality levels and greenness slightly with taxation going up. The retailer will take a lower pricing strategy with a higher taxation in order to avoid tax and to maximize profit (Fig. 6). Even though, retailer will lose profit as well with increasing taxation, but this descend range is less than non-green manufacture (Fig. 7). Comparing effect of subsidy and taxation, it is illustrated that both these two government interventions make sense in the market. However, subsidy may play a more positive and significant role to encourage green manufacturing and improving products' quality level.

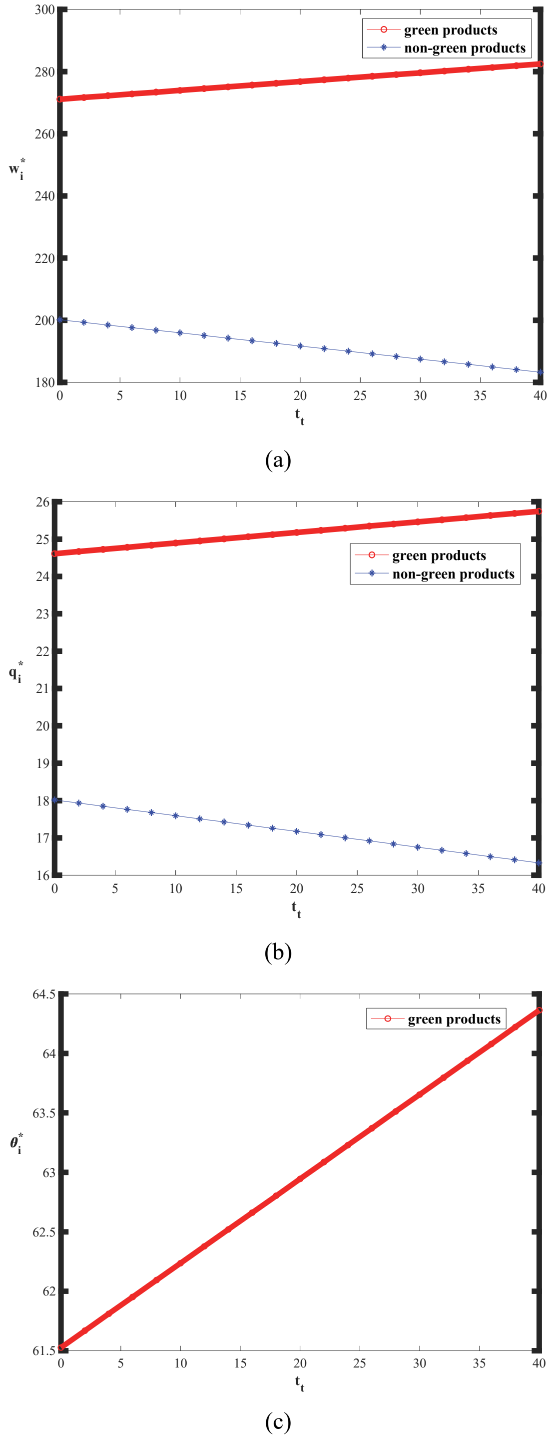


Fig. 5. Effect of taxation on manufacturers' decisions: (a) Effects on wholesale price; (b) Effects on level of quality; (c) Effects on greenness

4.2. Impact of consumers' loyalty to green products and demand sensitivity coefficients

Consumers' loyalty to green products ρ and demand sensitivity coefficients α_1, α_2, β_1, β_2, γ also important non-governmental factors in profits and decision making. We illustrate Table 2 to show these effects, where $m = 2400$, $t_s = 0.6$, $t_t = 20$, $c_1 = 25$, $c_2 = 20$, $\tau = 15$, $\mu = 10$.

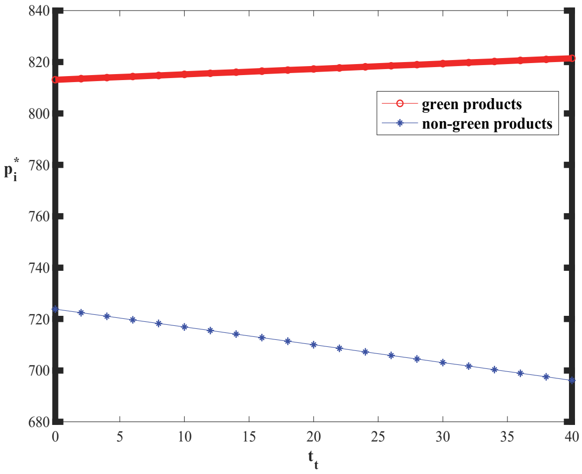


Fig. 6. Effect of taxation on retailer's decisions

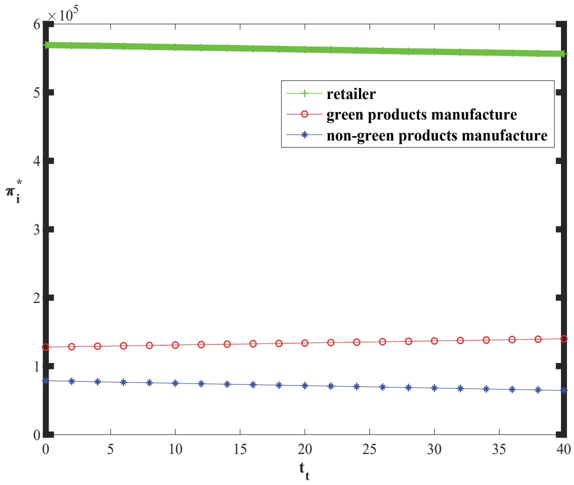


Fig. 7. Effect of taxation on profits

From Table 2, loyalty to green products and the demand sensitivity coefficients have an impact on profits and decision-making in supply chain. Firstly, ρ and γ both reflect consumers' consciousness of environmental protection and greening awareness; however, they have some different insights to supply chain members. When consumers' loyalty to green products decreases, green manufacturer would like to reduce wholesale price to fight for market share, however, non-green manufacturer will increase their wholesale price to narrow the gap with the price of green manufacturer. Besides, when consumers become less sensitive to the greenness of products, both two manufactures will reduce their wholesale prices and quality levels. This is because the competition between two manufactures or two kinds of products becomes weak.

The competitiveness of green products is not too obvious anymore. Secondly, α_1 and α_2 represent consumers' sensitivity to self-price and competitor's price. From the numerical results, it is found that two manufactures will make decisions to the same trend with the price sensitivity coefficients changing.

For instance, two manufactures both would like to decrease their wholesale prices if consumers become more sensitive to prices. Thirdly, we find the same pattern with the quality sensitivity coefficients β_1 and β_2. Retailer and manufacturers, therefore, need to make decisions flexibly to meet preferences of consumers.

5. Conclusions

In recent years, a group of legislation and regulations related to environmental pollution has been published. We investigate the impact of two types of government interventions, including subsidy and taxation, on strategy making in a competing green supply chain.

Considering a two-echelon supply chain setting, in this paper, we explore the decision-making of retailer, green manufacture and non-green manufacture with government interventions. Specifically, the retailer need to decide prices of green products and non-green products charged to consumers. Besides, two manufactures would like to make decisions on wholesale price, level of quality, respectively, and the green manufacture decides the greenness of products as well. We develop a Stackelberg game to analyse this problem and derive the equilibrium solutions. Also, we conduct the numerical analysis to obtain some managerial insights.

Government interventions are significant and powerful factors influencing the decisions. Both retailer and green manufacturer gain more profits with subsidy increasing, and the profit of retailer grows dramatically. However, only profit of green manufacture goes up slightly if government raises taxes, and retailer and non- green manufacture both lose benefits. In order to encourage cleaner producing and to improve products quality guarantee, we find that providing subsidy would play a more major role than taxation mechanism.

With regard to pricing, quality level and greening strategy for retailer and two manufactures, it is best to be flexible to make decisions based on consumers' preferences. Consumers' loyalty to green products, sensitivity to price, quality level and greenness level are all parameters that effect decision-making process. Another finding is that the retailer is the most beneficial supply chain member in our scenario, where the retailer always tend to obtain profits through meeting consumers' preferences and squeezing manufacturers' benefits.

A final suggestion for further research is considering uncertain demand instead of direct demand function for scenario considered in this paper and comparing the conclusions with the obtained findings of this paper, and exploring strategies in different supply chain structure settings.

Table 2. Effects of changes in the consumers' loyalty degree and the demand sensitivity coefficient on SC

ρ	α_1	α_2	β_1	β_2	γ	p_1^*	p_2^*	w_1^*	w_2^*	q_1^*	q_2^*	θ_1^*	π_r^*	$\pi_{M_1}^*$	$\pi_{M_2}^*$
0.60	5	4	3	2	2	817.3	710.0	276.8	191.7	25	17	63	5.63	1.34	0.72
0.30	5	4	3	2	2	732.1	771.7	215.9	245.9	19	23	48	5.43	0.77	1.24
0.90	5	4	3	2	2	902.5	648.2	337.6	137.6	31	12	78	5.92	2.07	0.34
0.60	6	4	3	2	2	455.0	361.8	213.3	140.4	19	12	53	2.17	0.90	0.42
0.60	7	4	3	2	2	325.0	241.3	175.2	110.4	15	9	47	1.20	0.66	0.28
0.60	5	3	3	2	2	474.0	367.5	240.7	158.3	22	14	54	1.98	0.98	0.46
0.60	5	2	3	2	2	353.5	244.9	214.1	132.7	19	11	47	0.98	0.76	0.31
0.60	5	4	4	2	2	842.3	731.2	284.9	196.9	35	24	65	5.98	1.39	0.74
0.60	5	4	5	2	2	879.8	763.5	296.9	204.8	45	31	68	6.54	1.46	0.78
0.60	5	4	3	1	2	830.8	723.6	280.6	195.6	26	18	64	5.83	1.38	0.75
0.60	5	4	3	3	2	804.3	696.9	273.1	187.9	25	17	62	5.43	1.30	0.68
0.60	5	4	3	2	1	783.8	691.7	263.4	190.3	24	17	48	5.24	1.27	0.70
0.60	5	4	3	2	3	865.7	737.9	295.7	194.6	27	17	81	6.23	1.45	0.74

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