ISSN: 2688-9323

Consumer Online Reviews-Based Green Products Strategy

Shanshan Xu

School of Economics and Management, Xidian University, Xi'an 710126, China.

240321165@qq.com

Abstract

To explore how to make the decision about the green product price, from the companies' perspective, we established a two-period model considering consumers' online reviews about green products. In the first period, consumers make purchase decisions without knowing the true greenness of the product. In the second period consumers learn about the true greenness of the product through online reviews and then make purchase decisions. Our findings show that companies with low costs for green production should report a higher degree of greenness, choose a higher first-period price, and target fewer consumers to achieve a higher profit. As for companies with low costs for green production, when the low cost is known by the consumers, they may reduce the greenness of the products. In addition, consumers' knowledge about companies will lead to a reduction in consumer surplus. Moreover, the total social welfare can be improved by improving consumers' intention to purchase green products.

Keywords

Green product, product strategy, online reviews, social welfare, hotlleing model.

1. Introduction

The development of human society is getting faster and faster, and environmental issues have become a major issue urgently to be solved on the road of sustainable development of society. At present, environmental protection (hereinafter referred to as "environmental protection") has become a major topic of social concern. Green development is the fundamental strategy to solve environmental protection problems[1]. Therefore, green products for environmental protection have appeared in the market, such can make the environment be avoided, controlled, reduced or reasonably affected during produced or used[2]. For example, Apple's charging cable is a product that meets environmental protection requirements. However, due to considerations such as price, many consumers will not choose to buy Apple's original data cable, but will choose alternatives. There are many similar situations, which have greatly affected the development of the green industry. Therefore, How to make decisions based on the market environment and consumers' preferences has become the core issue of this research. In addition, due to the development of online shopping platforms in recent years, the influence of online reviews on consumers has gradually increased, which has a certain impact on consumers' shopping behaviors. Therefore, we believe that it is necessary to combine consumers' information sharing for green products strategy research. Our paper use mathematical modeling methods to explore green products strategy and make recommendations for make recommendations for companies. While increasing product sales, they also help the development of green industry.

ISSN: 2688-9323

2. Literature Review

Recent years, green products have been gradually accepted by the society and the research on green products has become a hot topic in academic circles at home and abroad. Scholars at home and abroad have researched on green products from many perspectives. From the perspective of consumers, some scholars have researched from psychological awareness factors such as attitude, perception, responsibility and emotion[3-4], some scholars have researched based on family income[5], some scholars have researched from the reference group factors in the context of national co-governance[6]. Some scholars have researched the impact of consumer innovation on their green consumption[7], and some scholars have researched the pricing model of green products under the heterogeneous environmental preferences of consumers[8]. From the perspective of companies, because of the development of green industry will be affected by the decisions of upstream and downstream companies associated with it[9], many scholars at home and abroad have focused on the optimization of green product supply chains. They have analyzed the impact of government subsidies on green supply chain profits[10], the impact of tariffs on transnational green supply chains[11], and have explored the incentive effect of government subsidies on manufacturers to improve their green efforts, etc[12]. For companies themselves, some scholars have found that the company's green product production behavior requires government guidance and regulation[13], and some scholars have analyzed the impact of corporate managers' environmental awareness and innovation consciousness[14]. In addition, some scholars have explored green manufacturing, cleaner production[15], and low-carbon product design[16,17,18] , product remanufacturing[19] and the role of green product quality supervision systems[20]from the perspective of green products.

These existing studies provide ideas for the research of green products, but from the perspective of green product pricing, further exploration is needed. Our paper will research green product strategies based on customer information sharing.

3. Model

Our paper considers a monopoly market for new green products. It is assumed that the product quality meets the expectations of all consumers. At the same time, consumers can reflect on the greenness of the product (usually reflected by the energy efficiency label, hazardous substance content, carbon label and the degree of recyclability of waste products[21]. Our paper refers to the environmental friendly effect that can be experienced such as the energy-saving effect of air conditioners and the energy consumption of cars.) However, consumers cannot intuitively observe the true greenness of the product before purchasing the product. Monopoly companies face new consumers in two different sales periods: in the first period, after observing the company's first-period price, consumers make purchasing decisions based on the price and demand of the product. The first time consumers purchase the product, they will know the true greenness, and generate online reviews through social networking sites or purchase platforms to show the true greenness of the product to future consumers. Therefore, consumers in the second period will make purchasing decisions based on the true greenness of the product and the price of the second period.

In each period, there are new consumers entering the market. We standardize the total number of consumers in each period to one, and each consumer needs at most one product. The net utility obtained by consumers from purchasing products with known greenness is $U=ge-p$, that is, consumer surplus[22], where g represents the consumer ’s greenness sensitivity coefficient, which is the consumer ’s green preference, e is the product Greenness, and p is the price of the product. If the expected utility of the consumer is at least as large as

ISSN: 2688-9323

the expected utility of the external option, the consumer will purchase the product, the standardized utility of the external option will be zero, and consumers who do not purchase the product in the first period will withdraw from the market. Suppose there are two types of consumers[23], g_H represents consumers with high preference for green products, the fraction is a, and g_L represents consumers with low preference for green products, the fraction is $1-a$. And $g_H > g_L$ When the consumer surplus is at least 0, the consumer chooses to buy the product. So we believe that the consumer surplus of L-type is 0 regardless of whether the consumer chooses to buy the product.

The marginal green cost of a company is ke^2[24], where k represents the green-cost-efficiency of the company. In order to simplify the analysis, we do not consider the cost impact caused by other factors such as quality, but only consider the cost impact brought by the company's green production. In terms of green-cost-efficiency, assuming that there are two types of companies, we use $i \in \{1,2\}$ to label the type of companies. k_1 represents green-cost-efficient companies, that is, companies with low cost for green production, the probability is b. k_2 represents green-cost-inefficient companies, that is, companies with high cost for green production, the probability is 1-b. For any given degree of greenness, the marginal green cost of a type 1 company is low.

The total social welfare is the sum of total consumer surplus and corporate profits[22], that is $W=U+\pi$, where U is consumer surplus and π is corporate profit.

The sequence of the game is as follows. First nature decides the type of company(i), then the company chooses the greenness level e_i for its products, and set its first period price $p^{(1)}_i$. In the first period, consumers neither observed the greenness of the product nor its cost, and will purchase the product with expected utility. After the purchase, the first-period customers will learn the true greenness, and will generate online reviews through social networking sites or purchase platforms to show later consumers the true greenness of the product. In the second period, the company chooses the price p $p^{(2)}_i$, and the consumer in the second period will make purchasing decisions.

The key notations used are shown in table 1.

Table 1: Key Notations

Symbol	Description
i	The company's type, i=1 for the green-cost-efficient firm, and i=2 for the green-cost-inefficient firm
j	The consumer's type,$j=H$ *or* L
g_j	j-type consumer greenness sensitivity coefficient, that is, the green preference of j-type consumers
a	The probability that the consumer is of H type
b	The prior probability of the firm being green-cost-efficient
$p^{(t)}_i$	The price of the type i company's product at period t, t=1, 2
e_i	Greenness of i-type products
k_i	The type i company's green-cost-efficiency
$C_i(e_i)$	The type i company's unit variable cost of green production, $C_i(e_i)=k_i e_i^2$
π_i	The type i company's total profit
Sep	Separation equilibrium
N	Consumer demand
U	Consumer Surplus
W	Social welfare

ISSN: 2688-9323

4. Analysis

4.1. Product Strategy

4.1.1. Product Strategy of Companies under Consumers' Known Green-Cost-Efficiency

We assume that the green-cost-efficiency (k_i) of a company is well-known. Under equilibrium, the company will choose a certain degree of greenness and price. Consumers in the second period will know the true greenness of the product from the consumers in the first period, and the willingness to pay for products with zero greenness will be zero, and products with zero greenness will have zero profit in the second period. Therefore, consumers sharing information will motivate companies to increase the greenness of their products. In order to maximize their profits, companies will provide a greenness that is lower than expected to deceive first-period consumers for benefits, and weigh the benefits of selling higher-greenness products to informed second-period consumers. In the first period, consumers can reasonably infer the greenness of the companies from the price in the first period. So in the first period, consumers will make purchasing decisions based on their reasonable inference of the company's greenness from the price.

In our model, the company first declares the greenness and announces the price, and then the consumer decides whether to believe the greenness declared by the company at the current price of the company. Consumers will trust it only if the company cannot increase the total profit for both periods by reducing the greenness below the declared greenness. Therefore, our model is to find the most reliable greenness and price combination.

The company's optimization goal is following, and Lemma 1 shows the results.

$$\max_{p^{(1)},p^{(2)},e}\left\{\left(p^{(1)}-ke^2\right)N^{(1)}\left(p^{(1)}\right)+\left(p^{(2)}-ke^2\right)N^{(2)}\left(p^{(2)},e\right)\right\} \quad (1)$$

Lemma 1: When the green-cost-efficiency of a company is well known, its optimal greenness and price are as follows:

(1) When $\frac{g_L}{g_H}\geq\max\left\{\sqrt{\frac{(1+a)a}{2}},\frac{4a}{1+3a}\right\}$,companies will target both types of consumers in both periods, and, $e_i=\frac{g_L}{4k_i}$, $p_i^{(1)}=p_i^{(2)}=\frac{{g_L}^2}{4k_i}$, $\pi_i=\frac{3g_L^2}{8k_i}$

(2) When $\frac{g_L}{g_H}<\sqrt{\frac{2a^2}{1+a}}$,companies will target H-type consumers in both periods, and, $e_i=\frac{g_H}{4k_i}$, $p_i^{(1)}=p_i^{(2)}=\frac{{g_H}^2}{4k_i}$, $\pi_i=\frac{3ag_H^2}{8k_i}$

(3) When $\sqrt{\frac{(1+a)a}{2}}<\frac{g_L}{g_H}<\max\left\{\sqrt{\frac{(1+a)a}{2}},\frac{4a}{1+3a}\right\}$,Companies will target H-type consumers in the first period and both types of consumers in the second period and, $e_i=\frac{g_L}{2(1+a)k_i}$, $p_i^{(1)}=\frac{g_Lg_H}{2(1+a)k_i}$, $p_i^{(2)}=\frac{{g_L}^2}{2(1+a)k_i}$, $\pi_i=\frac{g_L\left(g_L+2ag_H\right)}{4(1+a)k_i}$

The company's target decisions is shown as follows.

ISSN: 2688-9323

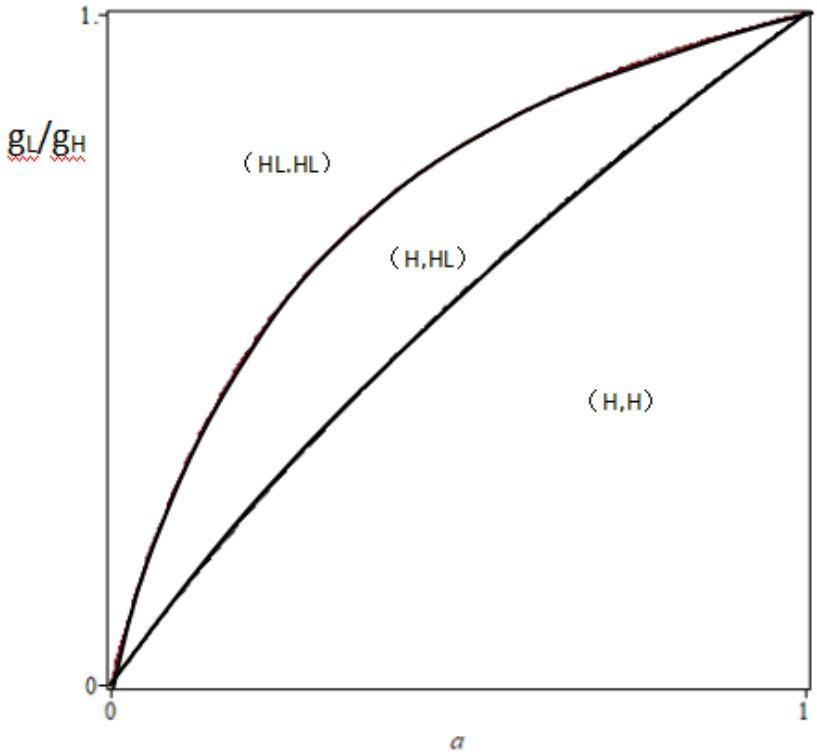

Fig. 1: Company's Target Decisions

According to Lemma 1, the following Corollaries can be directly obtained:

Corollary 1: If a company's green-cost-efficiency is well-known, its target decision will not depend on its green-cost-efficiency regardless of whether its greenness can be observed before buying.

Corollary 2: In equilibrium, the price of the first period of the company is not lower than that of its second period.

4.1.2. Product Strategy of Companies under Consumers' Unknown Green-Cost-Efficiency

We consider a more realistic situation, where the green-cost-efficiency and greenness choices of a company are private information. Different types of companies will announce different prices in the first period, so that the price indicates the greenness of the product. At the same time, different types of companies will target different consumers in the first period. So no matter which type of company do not want to be considered as another type of company. We assume $N_{1,sep}^{(1)}=1$, $N_{2,sep}^{(1)}=a$,then $p_{1,sep}^{(1)}<p_{2,sep}^{(1)}$. According to the Lemma 1, the unbiased conditions for different parameter areas are following:

$$\frac{g_L}{g_H}>\sqrt{\frac{(1+a)a}{2}} \tag{1}$$

If $p_{1,sep}^{(1)}<p_{2,sep}^{(1)}$, then

$$\pi_{1\to 2}=ap_{2,sep}^{(1)}+\frac{g_L^2}{4(1+a)k_1}<p_{1,sep}^{(1)}+\frac{g_L^2}{8k_1}=\pi_{1,sep},\ \pi_{2\to 1}=p_{1,sep}^{(1)}+\frac{g_L^2}{8k_2}<ap_{2,sep}^{(1)}+\frac{g_L^2}{4(1+a)k_2}=\pi_{2,sep},$$

so $\frac{(a-1)g_L^2}{8(1+a)k_2}<ap_{2,sep}^{(1)}-p_{1,sep}^{(1)}<\frac{(a-1)g_L^2}{8(1+a)k_1}$.

ISSN: 2688-9323

But because of $\frac{(a-1)g_L^2}{8(1+a)k_2} > \frac{(a-1)g_L^2}{8(1+a)k_1}$, $\frac{(a-1)g_L^2}{8(1+a)k_2} < ap_{2,sep}^{(1)} - p_{1,sep}^{(1)} < \frac{(a-1)g_L^2}{8(1+a)k_1}$ is invalid.

$\pi_{i\to j}$ indicates that the *i*-type company is recognized as a *j-type* company.

$$\sqrt{\frac{2a^2}{1+a}} < \frac{g_L}{g_H} < \sqrt{\frac{(1+a)a}{2}} \tag{2}$$

If $p_{1,sep}^{(1)} < p_{2,sep}^{(1)}$,then

$\pi_{1\to 2} = ap_{2,sep}^{(1)} + \frac{ag_H^2}{8k_1} < p_{1,sep}^{(1)} + \frac{g_H^2}{8k_1} = \pi_{1,sep}$, $\pi_{2\to 1} = p_{1,sep}^{(1)} + \frac{g_H^2}{8k_2} < ap_{2,sep}^{(1)} + \frac{ag_H^2}{8k_2} = \pi_{2,sep}$,

so $\frac{g_L^2 - ag_H^2}{8k_2} < ap_{2,sep}^{(1)} - p_{1,sep}^{(1)} < \frac{g_L^2 - ag_H^2}{8k_1}$.

But because of $\frac{g_L^2 - ag_H^2}{8k_2} > \frac{g_L^2 - ag_H^2}{8k_1}$, $\frac{g_L^2 - ag_H^2}{8k_2} < ap_{2,sep}^{(1)} - p_{1,sep}^{(1)} < \frac{g_L^2 - ag_H^2}{8k_1}$ is invalid.

$$\frac{g_L}{g_H} < \sqrt{\frac{2a^2}{1+a}} \tag{3}$$

If $p_{1,sep}^{(1)} < p_{2,sep}^{(1)}$,then

$\pi_{1\to 2} = ap_{2,sep}^{(1)} + \frac{ag_H^2}{8k_1} < p_{1,sep}^{(1)} + \frac{a^2 g_H^2}{4(1+a)k_1} = \pi_{1,sep}$, $\pi_{2\to 1} = p_{1,sep}^{(1)} + \frac{a^2 g_H^2}{4(1+a)k_2} < ap_{2,sep}^{(1)} + \frac{ag_H^2}{8k_2} = \pi_{2,sep}$,

so $\frac{a(a-1)g_H^2}{8(1+a)k_2} < ap_{2,sep}^{(1)} - p_{1,sep}^{(1)} < \frac{a(a-1)g_H^2}{8(1+a)k_1}$.

But because of $\frac{a(a-1)g_H^2}{8(1+a)k_2} > \frac{a(a-1)g_H^2}{8(1+a)k_1}$, $\frac{a(a-1)g_H^2}{8(1+a)k_2} < ap_{2,sep}^{(1)} - p_{1,sep}^{(1)} < \frac{a(a-1)g_H^2}{8(1+a)k_1}$ is invalid.

From the above derivation, we can get $N_{1,sep}^{(1)} = a$, $N_{2,sep}^{(1)} = 1$, $p_{1,sep}^{(1)} > p_{2,sep}^{(1)}$,that is, a green-cost-efficient company always chooses higher prices and sells to fewer consumers.

In a separation equilibrium, the prices of company will fall in the second period. In order to be separated from green-cost-inefficient companies, green-cost-efficient companies need to increase their prices in the first period to target fewer consumers, but in the second period, because their high greenness is already widely known, they can target more consumers .

To sum up:

Proposition 1: In any discrete equilibrium, a green-cost-efficient company will choose a higher first-period price and target fewer consumers than a green-cost-inefficient company.

In the first period, there is a moral hazard for both types of companies, and both can benefit by providing a greener level than consumers believe. However, from the perspective of the second-period profit, due to the lower marginal cost structure, the green-cost-efficient company will have more incentives to provide higher greenness. Because if both types of companies choose the same greenness that is lower than consumers' expectations, the gradual increase in greenness will increase the profit of green-cost-efficient companies higher than that of green-cost-inefficient companies.

To sum up:

Proposition 2: green-cost-efficient companies will choose a higher degree of greenness than green-cost-inefficient companies and green-cost-efficient companies will obtain higher profits than green-cost-inefficient companies.

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In any equilibrium, green-cost-inefficient companies will not imitate green-cost-inefficient companies, because the former must choose a higher degree of greenness. For a green-cost-inefficient company, if it is still considered green-cost-inefficient after the deviation, it is unreasonable to deviate from its optimal greenness and price strategy. Therefore, for a green-cost-inefficient company, whether its green-cost-efficiency is known , He will choose the same strategy.

$$\frac{g_L}{g_H} \geq \max\left\{\sqrt{\frac{(1+a)a}{2}}, \frac{4a}{1+3a}\right\} \tag{4}$$

When the green-cost-efficiency of the company are known, the company targets two types of consumers in the first period, then $e_1 = \frac{g_L}{4k_i}$. When the green-cost-efficiency of the company are unknown, $N_{1,sep}^{(1)} = a$， $N_{2,sep}^{(1)} = 1$, that is, green-cost-efficient companies will target smaller markets to distinguish themselves from green-cost-inefficient companies. At this point, $e_{1,\ sep} = \frac{g_L}{2(1+a)k_i}$ then $e_{1,\ sep} > e_1$.

$$\frac{g_L}{g_H} < \sqrt{\frac{2a^2}{1+a}} \tag{5}$$

When the green-cost-efficiency of the company are known, companies will target H-type consumers in both periods, then $e_1 = \frac{g_H}{4k_i} = e_{1,\ sep}$.

$$\sqrt{\frac{(1+a)a}{2}} < \frac{g_L}{g_H} < \max\left\{\sqrt{\frac{(1+a)a}{2}}, \frac{4a}{1+3a}\right\} \tag{6}$$

Companies will target H-type consumers in the first period and two types of consumers in the second period, then $e_1 = \frac{g_L}{2(1+a)k_i} = e_{1,\ sep}$.

In the first period, the greenness of the product is unobservable, so it will not directly affect demand. Higher greenness will bring higher marginal costs to the company, which means that it will reduce the company's first-period profit. Therefore, a higher first-period sales volume will enable companies to reduce the greenness of their products, because the unit cost savings brought by the reduced greenness will result in higher unit sales revenue. In addition, for each level of sales in the first period, when the total profit of the companies in the two periods is maximized, there is a corresponding best greenness level and the best second period price. In other words, there is a one-to-one negative correlation between the equilibrium greenness of the companies and the unit sales in the first period.

If consumers do not know the green-cost-efficiency of the companies, then the green-cost-efficient companies need to target fewer customers in the first period. In contrast, when green-cost-efficient companies' products are known to consumers, green-cost-efficient companies will be able to target more customers in the first period. Because of the negative correlation between the unit's first-period unit sales and its optimal greenness, under equilibrium, the companies will choose a lower level of greenness.

To sum up:

Proposition 3:In any separation equilibrium, if an green-cost-efficient company is known in advance to be highly effective, it will provide an equilibrium greenness no higher than the unknown.

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4.2. Social Welfare Maximization

4.2.1. Social Welfare Maximization under Consumers' Known Green- Cost-Efficiency

According to Lemma 1, when the green-cost-efficiency of a company is well known, consumer surplus and social welfare are as follows:

$$\frac{g_L}{g_H} \geq \max\left\{\sqrt{\frac{(1+a)a}{2}}, \frac{4a}{1+3a}\right\} \tag{7}$$

$$\overline{U} = a\left(\frac{b}{k_1}+\frac{1-b}{k_2}\right)\frac{g_L(g_H-g_L)}{2}, W = a\left(\frac{b}{k_1}+\frac{1-b}{k_2}\right)\frac{g_L(g_H-g_L)}{2}+\frac{3g_L^2}{8k_1}+\frac{3g_L^2}{8k_2}$$

$$\frac{g_L}{g_H} < \sqrt{\frac{2a^2}{1+a}} \tag{8}$$

$$\overline{U} = 0, W = \frac{3ag_H^2}{8k_1}+\frac{3ag_H^2}{8k_2}$$

$$\sqrt{\frac{(1+a)a}{2}} < \frac{g_L}{g_H} < \max\left\{\sqrt{\frac{(1+a)a}{2}}, \frac{4a}{1+3a}\right\} \tag{9}$$

$$\overline{U} = a\left(\frac{b}{k_1}+\frac{1-b}{k_2}\right)\frac{g_L(g_H-g_L)}{2(1+a)}$$

$$W = a\left(\frac{b}{k_1}+\frac{1-b}{k_2}\right)\frac{g_L(g_H-g_L)}{2(1+a)}+\frac{g_L(g_L+2ag_H)}{4(1+a)k_1}+\frac{g_L(g_L+2ag_H)}{4(1+a)k_2}$$

According to Lemma 1, the following inferences can be directly obtained:

Corollary 3:When consumers know the green-cost-efficiency, the higher the proportion of H-type consumers is, the greater the total social welfare will be.

Corollary 4:When consumers know the green-cost-efficiency, the higher consumers' preferences for green products is, the greater the total social welfare will be.

4.2.2. Social Welfare Maximization under Consumers' Unknown Green- Cost-Efficiency

The separation equilibrium, green-cost-efficient and green-cost-inefficient companies do not want to deviate from another type of price and target different consumer groups. At the same time, the greenness of the products selected by the company is negatively related to the first period sales. then:

(1) Green-cost-efficient companies do not want to deviate

$$\pi_{1,sep} > \pi_{1\to 2} \Leftrightarrow ap_{1,sep}^{(1)}+\frac{g_L^2}{4(1+a)k_1} > p_{2,sep}^{(1)}+\frac{g_L^2}{8k_1}$$

(2) Green-cost-inefficient companies do not want to deviate

$$\pi_{2,sep} > \pi_{2\to 1} \Leftrightarrow p_{2,sep}^{(1)}+\frac{g_L^2}{8k_2} > ap_{2,sep}^{(1)}+\frac{g_L^2}{4(1+a)k_1}$$

(3) Green-cost-efficient companies target H-type consumers

$$g_L e_{1,sep} \leq p_{1,sep}^{(1)} \leq g_H e_{1,sep} \Leftrightarrow \frac{e_L^2}{2(1+a)k_1} \leq p_{1,sep}^{(1)} \leq \frac{e_L e_H}{2(1+a)k_1}$$

(4) Green-cost-efficient companies target two types of consumers

$$p_{2,sep}^{(1)} = \frac{g_L^2}{4k_i}$$

ISSN: 2688-9323

In summary, Figure 2 is obtained. The shaded area represents (1)-(3), so $p_{2,\ sep}^{(1)} = \frac{g_L^{\ 2}}{4k_i}$ must cross the shadow area, then $\underline{K} = \frac{4a}{1+3a} < \frac{k_1}{k_2} < \frac{4ag_H + (1-a)g_L}{2(1+a)g_L} = \overline{K}$.

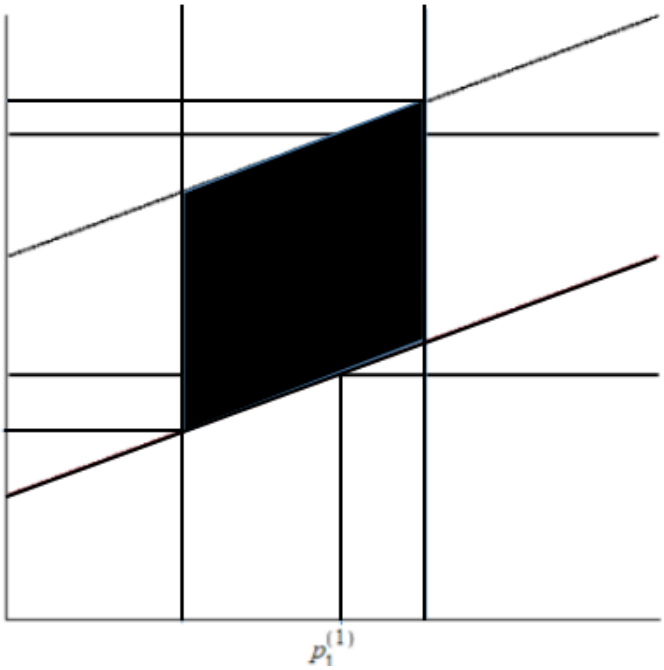

Fig. 2 Get the shadow

This separation equilibrium corresponds to the largest first-period price. When $\frac{(1+3a)g_L^2}{8(1+a)k_2} = \frac{g_L g_H}{2(1+a)k_1}$, $\frac{k_1}{k_2} = \frac{4ag_H}{(1+3a)g_L}$. So when $\underline{K} = \frac{4a}{1+3a} < \frac{k_1}{k_2} < \frac{4ag_H}{(1+3a)g_L}$, $p_{1,sep}^{(1)} = \frac{(1+3a)g_L^2}{8(1+a)k_2}$, when $\frac{4ag_H}{(1+3a)g_L} < \frac{k_1}{k_2} < \frac{4ag_H + (1-a)g_L}{2(1+a)g_L} = \overline{K}$, $p_{1,sep}^{(1)} = \frac{g_L g_H}{2(1+a)k_1}$. Of all possible separation equilibrium, this is the most advantageous for green-cost-efficient companies. In this equilibrium, $\frac{g_L}{g_H} \geq \max\left\{\sqrt{\frac{(1+a)a}{2}}, \frac{4a}{1+3a}\right\}$, it means that the proportion of L-type consumers is very high, so some companies will provide services to this type of consumers in the first period, which allows green-cost-efficient companies to target themselves by targeting different consumer groups to distinguish from green-cost-inefficient companies. The second condition requires that the two types of companies are neither too different nor too similar. The lower limit ensures that green-cost-inefficient companies do not want to deviate from their best goals to imitate green-cost-efficient companies, while the upper limit ensures that green-cost-efficient companies are willing to sacrifice some market share to distinguish them from green-cost-inefficient companies.

So when $\frac{g_L}{g_H} \geq \max\left\{\sqrt{\frac{(1+a)a}{2}}, \frac{4a}{1+3a}\right\}$ and $\underline{K} = \frac{4a}{1+3a} < \frac{k_1}{k_2} < \frac{4ag_H + (1-a)g_L}{2(1+a)g_L} = \overline{K}$, there is a separation equilibrium. The consumer surplus of H-type consumers at this time is as follows:

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Table 2: Consumer surplus of *H*-type consumers

$\underline{K}=\frac{4a}{1+3a}<\frac{k_1}{k_2}<\frac{4ag_H}{(1+3a)g_L}$	$\frac{4ag_H}{(1+3a)g_L}<\frac{k_1}{k_2}<\frac{4ag_H+(1-a)g_L}{2(1+a)g_L}=\overline{K}$
$U^{(1)}=ag_L\left(\left(\frac{bg_H}{2(1+a)k_1}-\frac{b(1+3a)g_L}{8a(1+a)k_1}\right)+\frac{(1-b)(g_H-g_L)}{4k_2}\right)$	$U^{(1)}=\frac{a(1-b)(g_H-g_L)}{4k_2}$
$U^{(2)}=ag_L(g_H-g_L)\left(\frac{b}{2(1+a)k_1}+\frac{(1-b)}{4k_2}\right)$	$U^{(2)}=ag_L(g_H-g_L)\left(\frac{b}{2(1+a)k_1}+\frac{(1-b)}{4k_2}\right)$
$U=ag_L\left(b\left(\frac{(2g_H-g_L)}{2(1+a)k_1}-\frac{(1+3a)g_L}{8a(1+a)k_2}\right)+\frac{(1-b)(g_H-g_L)}{2k_2}\right)$	$U=ag_L(g_H-g_L)\left(\frac{b}{2(1+a)k_1}+\frac{(1-b)}{2k_2}\right)$

When the green-cost-efficiency of the companies can be observed, we also calculate the expected consumer surplus $\overline{U}=a\left(\frac{b}{k_1}+\frac{1-b}{k_2}\right)\frac{g_L(g_H-g_L)}{2}$ Comparing the two types of consumer surplus, it can be concluded that when $\frac{k_1}{k_2}<\frac{4a((1-a)g_H+ag_L)}{(1+3a)g_L}=r^*$ and consumers know the green-cost-efficiency of the companies, their consumer surplus will be lower than when they do not know.

We found that, known green-cost-efficiency, the company could target more consumers and produce less green products. Although expanding the market is good for consumers, lower product greenness is not good. Therefore, when consumers have more information about the companies, it may be detrimental to the consumers. When the two types of companies have significantly different green-cost-efficiency, the negative impact of lower product greenness will dominate the positive impact of market expansion, so consumers' understanding of green-cost-efficiency will reduce their surplus. In addition, we find that $\partial r^*/\partial g_H > 0$, which means that as g_H increases, consumers' understanding of the green-cost-efficiency of the companies is more likely to reduce total consumer surplus.

To sum up:

Proposition 4: When $\frac{k_1}{k_2}<\frac{4a((1-a)g_H+ag_L)}{(1+3a)g_L}$ and consumers know the green-cost-efficiency of the companies, consumer surplus would be lower than they don't know.

By observing the consumer surplus in different periods of each type of companies, we find that, under equilibrium, green-cost-efficient companies always produce greener products than green-cost-inefficient companies, and choose higher price in each period. In the second period, the greenness of the product become well known, and both types of companies target the same consumer market. When both types of companies target only H-type consumers, consumers will receive zero surplus, but when both types of companies target both types of consumers, L-type consumers will receive zero surplus. And H-type consumers can get some positive surplus, and increase with the increase of greenness. Therefore, as *b* increases, the expected greenness of the product will increase, and consumer surplus expectations for the second period will increase. In contrast, in the first period, consumers do not understand greenness, and green-cost-efficient companies will choose higher prices and target fewer consumers to indicate their greenness (higher than the greenness of green-cost-inefficient companies). Our paper shows that when *k1 / k2* is relatively large, that is, the two types of companies have similar green-cost-efficiency, and a larger *b* has a negative impact on total consumer surplus because there is a higher expected prices and smaller market coverage, that

ISSN: 2688-9323

is, in this case, a more green-cost-efficient market will lead to a reduction in total consumer surplus.

To sum up:

Proposition 5: When expected green-cost-efficiency in the market increases, total consumer surplus decreases

When consumers know the green-cost-efficiency of a company, consumer surplus will be lower than when they don't know, and as the expected green- cost-efficiency in the market increases, the total consumer surplus will decrease, caused by consumers 'product strategy that companies will target H-type consumption. In order to maximize the total social welfare, it is necessary to increase consumer surplus without affecting corporate income. Because $U=ge-p$, when H -type consumers' preference for green products is higher, that is, the g_H is larger, the consumer surplus will be larger, which will affect the overall social welfare.

To sum up:

Proposition 6: When consumers don't know the green-cost-efficiency, the higher consumers' preference for green products is, the greater the total social welfare will be.

5. Conclusion

By researching the strategy of green products based on customer information sharing, we found that consumers do not observe the greenness of the company's products beforehand, nor do they know the green green-cost-efficiency of the company, these two asymmetric information dimensions affect the company's best product strategy. We found that green-cost-efficient companies will choose a higher degree of greenness than green-cost-inefficient companies, choose higher first-period prices, and target fewer consumers, but green-cost-efficient companies will Get higher profit than green-cost-inefficient ones. However, when consumers don't know that a company is green-cost-efficient, a green-cost-efficient company may actually provide a higher degree of greenness. At the same time, consumers' understanding of the green-cost-efficiency of the companies will reduce consumer surplus, and when the expected green-cost-efficiency in the market increases, the total consumer situation may worsen. In this case, increasing consumer preferences for green products, That is, increasing the willingness of consumers to buy green products will increase total social welfare.

From the above conclusions, we can find that, on the one hand, in order to obtain higher profits, companies can improve their green-cost-efficiency through developing their technological level, and target different types of consumers at different periods to formulate product strategies. On the other hand, in order to improve social welfare, the government should provide technical support to green companies, and by increasing their green-cost-efficiency, encourage them to produce greener products. At the same time, the government should also come forward to guide green consumption and increase the promotion of green products. We have confirmed that the higher the consumer's preference for green products is, the greater the total social welfare will be. Therefore, it is necessary to increase the public's intention for green products to improve the total social welfare.

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Appendix 1

Lemma 1 Proves:

We assume that consumers are completely rational and they have the same and correct expectations of product greenness when observing prices. There are p_H and p_L equal to the maximum willingness of *H*-type and *L*-type consumers to pay, and $p_H >> p_L$, that is, the *H*-type consumer's willingness to pay is higher than *L*-type consumers under any greenness. p_H and p_L are for illustrative purposes only, and specific values are not discussed. We will discuss greenness choices for companies targeting two types or only *H*-type consumers in the first period and pricing decisions in the second period.

When $p^{(1)}_i = p_H$, the profit of the companies is:

$$\pi_i = a\left(p_H - k_i e_i^2\right) + \begin{cases} a\left(g_H e_i - k_i e_i^2\right) & \text{target H-type in the second period (1)} \\ g_L e_i - k_i e_i^2 & \text{target both types of in the second period (2)} \end{cases}$$

$$e_i = \frac{g_H}{4k_i}, \pi_i = ap_H + \frac{ag_H^2}{8k_i} \tag{1}$$

$$e_i = \frac{g_L}{2(1+a)k_i}, \pi_i = ap_H + \frac{g_L^2}{4(1+a)k_i} \tag{2}$$

When $p^{(1)}_i = p_L$, the profit of the companies is :

$$\pi_i = \left(p_L - k_i e_i^2\right) + \begin{cases} a\left(g_H e_i - k_i e_i^2\right) & \text{target H-type in the second period (3)} \\ g_L e_i - k_i e_i^2 & \text{target both types of in the second period (4)} \end{cases}$$

$$e_i = \frac{ag_L}{2(1+a)k_i}, \pi_i = ap_H + \frac{a^2 g_L^2}{4(1+a)k_i} \tag{3}$$

$$e_i = \frac{g_L}{4k_i}, \pi_i = ap_L + \frac{g_L^2}{8k_i} \tag{4}$$

So when companies target *H*-type consumers in the first period:

(1) When $\frac{g_L}{g_H} > \sqrt{\frac{(1+a)a}{2}}$, companies target both types of consumers in the second period, then $e_i = \frac{g_L}{2(1+a)k_i}, \pi_i = ap_H + \frac{g_L^2}{4(1+a)k_i}$.

(2) When $\frac{g_L}{g_H} < \sqrt{\frac{(1+a)a}{2}}$, companies target *H*-type of consumers in the second period, then $e_i = \frac{g_H}{4k_i}, \pi_i = ap_H + \frac{ag_H^2}{8k_i}$.

when companies target both types of consumers in the first period:

ISSN: 2688-9323

(3) When $\frac{g_L}{g_H} > \sqrt{\frac{2a^2}{1+a}}$,companies target both types of consumers in the second period, then $e_i = \frac{g_L}{4k_i}, \pi_i = p_L + \frac{g_L^2}{8k_i}$.

(4) When $\frac{g_L}{g_H} < \sqrt{\frac{2a^2}{1+a}}$,companies target *H*-type of consumers in the second period, then $e_i = \frac{ag_L}{2(1+a)k_i}, \pi_i = p_H + \frac{a^2 g_L^2}{4(1+a)k_i}$.

According to the consumer residual function, *U=ge-p*, in the first period, companies can choose $g_H e$ as the pricing to target *H*-type consumers, or $g_L e$ as the pricing to target both types of consumers.

$$\frac{g_L}{g_H} > \sqrt{\frac{(1+a)a}{2}} \tag{5}$$

Companies target both types of consumers in the second period. If companies target *H*-type consumers in the first period, $e_i = \frac{g_L}{2(1+a)k_i}$. If companies target both types of consumers in the first period, $e_i = \frac{g_L}{4k_i}$. Then, $p_H = \frac{g_L g_H}{2(1+a)k_i}$, $p_L = \frac{g_L^2}{4k_i}$. Comparing these two corresponding profits, we can conclude that when $\frac{g_L}{g_H} < \frac{4a}{1+3a}$,companies target *H*-type consumers in the first period, while companies target two types of consumers in the first period.

$$\frac{g_L}{g_H} < \sqrt{\frac{2a^2}{1+a}} \tag{6}$$

Companies target H-type consumers in the second period, If companies target *H*-type consumers in the first period, $e_i = \frac{g_H}{4k_i}$. If companies target both types of consumers in the first period, $e_i = \frac{ag_L}{2(1+a)k_i}$. Then, $p_H = \frac{g_H^2}{4k_i}$, $p_L = \frac{ag_L g_H}{2(1+a)k_i}$, Comparing these two corresponding profits, we can conclude that companies target *H*-type consumers in the first period.

$$\sqrt{\frac{2a^2}{1+a}} < \frac{g_L}{g_H} < \sqrt{\frac{(1+a)a}{2}} \tag{7}$$

Companies target the same types of consumers in both periods. If companies target *H*-type consumers in the first period, $e_i = \frac{g_H}{4k_i}$. If companies target both types of consumers in the first period, $e_i = \frac{g_L}{4k_i}$. Then, $p_H = \frac{g_H^2}{4k_i}$, $p_L = \frac{g_L^2}{4k_i}$. Comparing these two corresponding profits, we can conclude that companies target *H*-type consumers in the first period.