

Article

# Sustainable Product Strategy in Apparel Industry with Consumer Behavior Consideration

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Academic Editor: Bin Shen

Received: 19 April 2017; Accepted: 23 May 2017; Published: 31 May 2017

**Abstract:** The article attempts to analyze sustainable product strategy in apparel industry specifically addressing a firm that is considering launching a sustainable product partly made from recycled materials. There are two types of consumers under consideration, environmentally conscious and regular consumers, as they have different perceived values for the sustainable products. The article provides an analytical model aimed to identify conditions under which a firm could benefit from adopting sustainable product strategy. The level of sustainability is determined by the trade-off between profitability and costs occurred and if more consumers value sustainable products, the firm will increase its sustainable level and get a higher profit. This is because of a combination effect of an increasing marginal profit and demand expansion. Moreover, the model has been further extended to address a situation where the firm could manage consumer segmentation. Depending on parameter settings, the firm may target different consumer segments and there is always a threshold of cost for managing consumer segments. When converting regular consumers to be environmentally conscious is not costly, the firm will convert all consumers to be environmentally conscious with great efforts; otherwise, the firm will convert part of consumers to be environmentally conscious.

**Keywords:** sustainability; social responsibility; market segmentation; consumer behavior

## 1. Introduction

In the past few years, sustainability has got paramount attention in apparel industry, especially when consumers are emphasizing more on corporate social responsibility and environmental protection. According to WTO statistics, the global apparel demand reached 140.84 million tons in 2012. The increase in global market further emphasizes the importance of sustainability in apparel industry. Therein, sustainability becomes government concern [1], focus of academia [2] and a potential source of competitive advantage in industry [3,4]. Besides cost and performance, firms need to pay attention to sustainability [5]. Sustainable product strategy becomes a popular strategy, especially when consumers have more concerns about social responsibility and environmental protection.

From consumers' perspective, as they are paying more attention to corporate social responsibility and environmental protection, many consumers prefer to buy environment friendly products. Therefore, sustainable product strategy is considered by firms as a strategy to respond to government environmental regulations [6,7], and a competitive advantage to cater to consumers' preference to environment friendly products [8]. In this paper, we focus only on environmental sustainability because of our observation of some practices in apparel industry. In apparel industry, firms produce sustainable products with green materials and/or recycled materials in practice. Ensuring the usage of green materials or recycled material makes these products more environment friendly. For example, Jack Wolfskin used recycled materials in its apparel products [9], 71% of Nike footwear and apparel

products use recycled materials [10]. Furthermore, Wilson Staff is going to introduce the first golf bag made from 100% recycled materials [11]. These practices help firms to enhance their images, telling consumers that they care about environmental sustainability by using some recycled materials in producing products. To do so, firms will make advertisement to emphasize their attention to protect environment, or mark some information about recycled materials in their products' labels.

On the one hand, firms could increase their images and better meet the demands from customers who prefer the sustainable products through launching sustainable products. On the other hand, producing sustainable products could increase firms' costs. There is a trade-off between the pros and cons of adopting a sustainable product strategy. Therefore, designing an appropriate sustainable product becomes critical to firms. It is important for firms to understand under what conditions they should launch a sustainable product. Furthermore, a firm needs to determine the optimal sustainable level to balance between the cost and benefit of such strategy. Our paper addresses this issue by constructing an analytical framework.

In this paper, we investigate the sustainable product strategy in apparel industry, taking consumers' purchase behavior into account. Specifically, we consider that a firm could produce sustainable product, which is made from recycled materials in part. Such strategy increases the firm's production cost, but also increases environmentally conscious consumers' perceived value of the product. We first consider a situation where all consumers are environmentally conscious, who give a higher value of sustainable product than a regular product without recycled materials. We find that the optimal sustainable level depends on the comparison between the profitability and cost of the sustainable product. When adopting sustainable product strategy, the firm has incentive to charge a higher price due to two effects: additional cost effect and extra consumer surplus effect. Moreover, although a sustainable product has a higher cost than a regular product, it also has higher marginal profit because of its high price. Therein, the firm is better off to adopt sustainable product strategy when consumers are environmentally conscious.

We then consider a market consisting of two consumer segments, environmentally conscious consumers and regular consumers. Environmentally conscious consumers get positive additional utilities from sustainable products, while regular consumers may have some doubts about the quality of the sustainable products, and therein they obtain non-positive additional utility from sustainable products. The firm has to balance the pros and cons to determine its sustainable level. The firm adopts sustainable product strategy only when the expected additional consumer utility of a sustainable product is positive. The firm should adopt a higher sustainable level when more consumers are environmentally conscious. We identify two driving forces of adopting sustainable product strategy: demand expansion effect and profitability effect.

We further extend our study to consider managing consumer segmentation. The firm could convert some regular consumers to be environmentally conscious by some efforts. Such efforts include advertisement, organizing some activities to promote environmental protection, and so on. We find that there is a threshold of the effort cost coefficient. When the cost coefficient is lower than the threshold, the firm aims to convert all consumers to be environmentally conscious; otherwise, there is an optimal consumer segmentation degree. The optimal segmentation degree is jointly determined by the sustainable level, profitability and cost.

## 2. Literature Review

Our paper relates to the literature from two perspectives: consumers' preferences to sustainable products and firms' sustainable strategies.

There are a few studies investigating consumers' attitude to sustainable products. Schwepker and Cornwell [12] point out that consumer purchasing decisions for sustainable products are often based on their environmental attitudes. Akehurst et al. [13] suggest that consumers with higher ecological conscious will have higher intention to purchase green products. Some studies show that consumers are willing to pay a premium to environment friendly products [14–16]. Bei and Simpson [17] suggest

that green consumers could obtain psychological benefits from buying an environment friendly product. This indicates that consumers who care about environment protection may get a higher surplus from an environment friendly product than from a regular product. Guagnano [18] shows that over 86% of the consumers are willing to pay a higher price for a common household good made from recycled materials. Ali and Amir [19] find that if a firm produces more green products, consumers have an intention to buy more from the firm. D'Souza et al. [20] show that some consumers will buy green products even if the products are of lower quality than the alternative products. Meanwhile, these consumers would look for environmental information on labels. This indicates that firms should write down the environmental information about the products in the labels. The above studies indicate that consumers who care about environment protection prefer to buy sustainable products. However, most of the studies are empirical studies, mainly focusing on the issue from consumers' perspective. There is a lack of analytical investigation about how consumers' preferences would affect firms' strategies.

From firms' perspective, good responses to consumers' preference on sustainable product are critical to attract consumers and gain higher profits. Chan [21] shows that consumers would translate their environment concern into their consumption. Therefore, improving consumers' environmental conscious will lead to consumers' environment friendly behaviors and prefer to buy environmental friendly products. Chan [22] indicates that consumers' attitude toward green products are largely affected by ecological effect, therein a firm can improve consumers' attitude toward green products by advertisement. Cherian and Jacob [23] find out that companies are starting to educate the masses that how sustainable products are beneficial to consumers. Tsarenko et al. [24] show that retailers could improve environmentally conscious consumption with adoption of sustainable business practices. Galbreth and Ghosh [25] investigate a model of horizontal competition with consideration of consumers' awareness of sustainability. They consider two firms' product have different sustainable levels. The two key influencing factors are: each individual consumer's unique level and the general level of awareness. Guo et al. [26] investigate that how consumers' purchase behavior affects the firms' sourcing strategy to promote sustainability. Differing from these studies that sustainable level is exogenously given, we specifically address the product design (i.e., a firm needs to determining the optimal level of a product with consideration of consumers' preference).

### 3. Model Setting

We have considered a firm in apparel industry adopting sustainable product strategy. There are two types of products: sustainable product and regular product. Sustainable products are defined as products made from recycled materials in part (or all) in this paper. Regular products are those without recycled materials. The firm decides its sustainable product strategy, followed by pricing decision. Consumers make purchase decisions based on their individual surplus. In the following, we will describe the modeling setting from perspectives of the firm and the consumers.

#### 3.1. Firm

Sustainable product strategy is reflected by the extent to which recycled materials are used in producing a product. We have defined sustainable level as  $\theta$  ( $0 \leq \theta \leq 1$ ) which is the percentage of recycled materials used over the total materials in producing a product. For instance, a shoes manufacturer could claim that 10% materials used in producing a pair of shoes is recycled materials. It is noted that  $\theta$  reflects the extent to which the firm adopts sustainable product strategy. As shown by previous research, firm can gain support from consumers and reduce the implementation constraints by sharing production information [27]. Therefore, we assume that this percentage  $\theta$  is revealed by firms to consumers. Therein, consumers' surplus could be affected by such information. Then,  $c$  ( $0 < c < 1$ ) is denoted as the unit cost of regular product. In order to make products with recycled materials, the firm must improve its technology and production process, which will cause some additional production cost. We define the unit cost of sustainable product as  $c_r = (1 + b\theta^2/2)c$ , where

$b > 0$  is cost coefficient for additional cost of sustainable product. If  $\theta = 0$ , the product is a regular product and its unit product cost is  $c$ . With a higher percentage of recycled materials, the firm has a higher production cost.

### 3.2. Consumers

Consumers make their purchase decision based on their individual utility. Denote by  $v_i$  the  $i$ th consumer's perceived value for a regular product, which is assumed to follow a uniform distribution  $v_i \sim U[0, 1]$ . The total market size is assumed to be 1. As we mentioned, the information about recycled materials is revealed by the firm. Therefore, consumers are able to access to this information. It is showed that consumers' recognition is very important for firms to adopt sustainable supply chain management [28]. Therefore, the information about sustainable product will affect consumers' utility, positively or negatively. We assume there are two consumer segments. A fraction  $r \in [0, 1]$  of consumers are assumed to be environmentally conscious, who have a positive feeling of sustainable products. We refer  $r$  as the segmentation degree in this paper. The environmentally conscious consumers obtain an additional homogenous utility  $a$  for a sustainable product, and  $a > 0$ . This positive additional utility captures the sensitivity of environmentally conscious consumers to the sustainable products. It also indicates the profitability of sustainable products. The remaining consumers (a fraction  $1 - r$  of total consumers) are referred to as "regular consumers", who have doubts about the quality of sustainable product. Therefore, regular consumers may devalue sustainable products and receive a non-positive utility  $-d$  for a sustainable product, and  $d \geq 0$ . Therefore, an environmentally conscious consumer's perceived value for a sustainable product is  $v_{ri} = v_i + a\theta$ ; and a regular consumer's perceived value for a sustainable product is  $v_{ri} = v_i - d\theta$ . When  $d = 0$ , regular consumers are insensible to sustainable product. A consumer's utility of purchasing a product is the difference between her perceived value and product price, i.e.,  $U_i = v_{ri} - p$ . Consumers will buy the product only when they get positive utility. Each consumer will buy one product at most. Moreover,  $q$  denotes the product demand, and  $\pi$  denotes the firm's profit throughout this paper. All proofs are provided in the Appendix A.

## 4. Model Analyses

### 4.1. Benchmark Case (B)

We first consider a benchmark case where the firm produces regular products only. We use subscript "B" to represent the variables in benchmark case (which is referred as Case B in this paper). The firm prices the regular products as  $p_B$ . A consumer's utility of purchasing the product is  $U_i = v_i - p_B$ . Therefore, the product demand is  $q_B = 1 - p_B$ . The firm aims at maximizing its profit by determining the product price, as below:

$$\text{Max } \pi_B = p_B(1 - p_B) - c(1 - p_B) \quad (1)$$

The first term in Equation (1) is the total sales revenue for the firm, and the second term is the total product cost. We can then derive the optimal price is  $p_B^* = (1 + c)/2$  and the firm's optimal profit is  $\pi_B^* = (1 - c)^2/4$ . The corresponding product demand is  $q_B^* = (1 - c)/2$ .

### 4.2. Sustainable Strategy with Homogenous Consumers (O)

We now consider a situation where all consumers are environmentally conscious, i.e.,  $r = 1$ . We use subscript "O" to represent the variables in this case (which is referred as Case O in this paper). The firm first determines its sustainable level  $\theta$  to maximize its profit. This causes some additional cost when firm produces its products. Note that sustainable level relates to product design and production process, it is therefore a middle-term decision and will not be changed frequently. Conditional on the sustainable level  $\theta$ , the firm makes pricing decision and put the products into the market. Observing

the sustainable level  $\theta$  and product price  $p_O$ , consumers make their purchase decisions based on their utilities. A consumer's utility is  $U_i = v_i + a\theta - p_O$ . Consumers who have a perceived value  $v_i > p_O - a\theta$  will buy the product. Accordingly, we can derive the market demand is  $q_O = 1 + a\theta - p_O$ . The firm's profit maximization problem is formulated as below

$$\begin{aligned} \text{Max } \pi_O(p_O, \theta) &= (p_O - c_r)q_O = [p_O - (1 + \frac{b\theta^2}{2})c](1 + a\theta - p_O) \\ \text{s.t. } &(1 + \frac{b\theta^2}{2})c < p_O < 1 + a\theta \end{aligned} \quad (2)$$

It is noted that when product price is lower than the production cost, the firm gets negative revenue. When product price is higher than the upper bond of consumers' utility, the product demand becomes zero. Therefore, to eliminate trivial results, we only focus on the case  $p_O \in ((1 + b\theta^2/2)c, 1 + a\theta)$ .

**Proposition 1.** *In a market where all consumers are environmentally conscious, the firm's optimal sustainable level  $\theta_O^*$ , product price  $p_O^*$  and profit  $\pi_O^*$  are as follows:*

- (i) If  $a \geq bc$ ,  $\theta_O^* = 1$ ,  $p_O^* = \frac{1}{2}[1 + a + (1 + \frac{b}{2})c]$  and  $\pi_O^* = \frac{1}{4}[1 + a - (1 + \frac{b}{2})c]^2$
- (ii) If  $a < bc$ ,  $\theta_O^* = \frac{a}{bc}$ ,  $p_O^* = \frac{1}{2}[\frac{3a^2}{2bc} + c + 1]$  and  $\pi_O^* = \frac{1}{4}[\frac{a^2}{2bc} - c + 1]^2$

Recall that  $a$  is the additional utility obtained from a sustainable product by environmentally conscious consumers,  $b$  is cost coefficient for additional cost of sustainable product, and  $c$  is unit cost of regular product. Proposition 1 suggests that the optimal sustainable level depends on the comparison between the profitability and cost of sustainable products. When consumers give a very high value for the sustainable products, sustainable products lead to a higher profit margin. When the extra profit extracted from environmentally conscious consumers could completely offset the additional cost occurred, the firm will produce its products with only recycled materials. In addition, when the unit production cost is very low, or the additional production cost of sustainable products is very limited, the sustainable products' profit margin increases and the firm will set the sustainable level to its upper bound, i.e.,  $\theta_O^* = 1$ . Otherwise, the firm sets its sustainable level as  $\theta_O^* = a/bc$ , with consideration of both profitability and additional cost effect of sustainable products. It is noted that when all consumers are environmentally conscious, the firm is better off to adopt a positive sustainable level.

With comparison between the cases with and without sustainable product strategy, we can obtain Lemma 1 and Lemma 2.

**Lemma 1.** *Adoption of sustainable product strategy leads to a higher product price.*

Compared with the case without sustainable product strategy, the firm will increase the product price after adopting sustainable product strategy. This is due to two reasons. First, to produce sustainable products, the firm needs to do additional efforts for recycling process, redesign the product and refining the producing process. All these additional efforts cause additional cost. Therefore, the firm has incentive to increase the product price to offset the additional cost. Second, observing that consumers give a higher value to sustainable products, the firm could strategically increase the product price to extract the additional consumer surplus for sustainable products. As a result, the product price increases when the firm adopts the sustainable product strategy.

**Lemma 2.** *In a market with only environmentally conscious consumers, the firm gains a higher profit by adopting sustainable product strategy.*

As discussed before, adoption of sustainable product strategy leads to additional cost and a higher price. Therefore, the marginal profit becomes a key in determining the benefit of sustainable product strategy. We denote  $s$  as the marginal profit for a product. For a regular product, the marginal profit is  $s_B = p_B - c = (1 - c)/2$ . For a sustainable product, the marginal profit is  $s_O = [a^2/2bc + 1 - c]/2$

when  $a < bc$ ; otherwise,  $s_O = [1 + a - (1 + b/2)c]/2$ . Denote  $\Delta s_{OB} = s_O - s_B$ . We can prove that  $\Delta s_{OB} > 0$ , suggesting that the marginal profit of a sustainable product is higher than a regular product. The reason for the increase of marginal profit is that consumers are willing to pay a premium for sustainable products. Meanwhile, a higher perceived value will expand product demand by attracting some customers with low value of regular products. Therefore, the firm will be better off when adopting sustainable product strategy when consumers value sustainability.

### 4.3. Market with Two Consumer Segments (T)

We examine a situation where two consumer segments coexist in the market, i.e.,  $0 < r < 1$ . We use subscript "T" to represent the variable in this case (which is referred as Case T in this paper).

A fraction  $r$  of consumers are environmentally conscious, and the remaining are regular consumers. To facilitate the presentation,  $r$  is referred to as segmentation degree in this paper. Similar to the case with homogenous consumers, the firm first determines its sustainable level  $\theta$ , followed by the pricing decision. Then, consumers make their purchase decisions based on their utilities. The sequential events are shown in Figure 1. An environmentally conscious consumer gets utility  $U_i = v_i + a\theta - p_T$  by purchasing the product; and a regular consumer gets utility  $U_i = v_i - d\theta - p_T$  by purchasing the product. The total market demand is derived as  $q_T(\theta, p_T) = r(1 + a\theta - p_T) + (1 - r)(1 - d\theta - p_T)$ . Thus, the firm's profit maximization problem is formulated as

$$\begin{aligned} \text{Max } \pi_T(\theta, p_T) &= [p_T - c_r]q_T = [p_T - (1 + \frac{b\theta^2}{2})c][r(1 + a\theta - p_T) + (1 - r)(1 - d\theta - p_T)] \\ \text{s.t. } &(1 + \frac{b\theta^2}{2})c < p_T < 1 + a\theta \end{aligned} \tag{3}$$

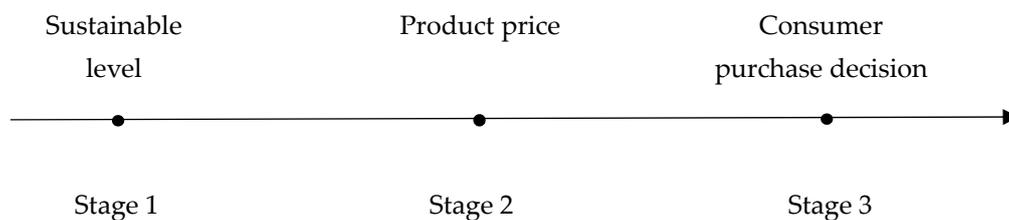


Figure 1. Sequential events in Case T.

Similar to Case O, the product price should be higher than the cost to ensure the firm a positive revenue. Further, the product should be lower than the upper bound of regular consumers' perceived value, so that both environmentally conscious consumers and regular consumers coexist in the market. Therefore, we only examine the case  $p_T \in ((1 + b\theta^2/2)c, 1 - d\theta)$ . The optimal decisions of the firm are provided by Proposition 2.

**Proposition 2.** In a market with two consumer segments, the firm's optimal sustainable level  $\theta_T^*$ , product price  $p_T^*$  and profit  $\pi_T^*$  are as follows,

- (i) If  $ar - (1 - r)d \geq bc$ ,  $\theta_T^* = 1$ ,  $p_T^* = \frac{1}{2}[r(1 + a) + (1 + \frac{b}{2})c + (1 - r)(1 - d)]$  and  $\pi_T^* = \frac{1}{4}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c]^2$ ;
- (ii) If  $0 < ar - (1 - r)d < bc$ ,  $\theta_T^* = \frac{ar - (1 - r)d}{bc}$ ,  $p_T^* = \frac{3[ar - (1 - r)d]^2 + 2bc(1 + c)}{4bc}$  and  $\pi_T^* = \frac{1}{4}[\frac{(ar + dr - d)^2}{2bc} + 1 - c]^2$ ;
- (iii) If  $ar - (1 - r)d \leq 0$ ,  $\theta_T^* = 0$ ,  $p_T^* = \frac{1}{2}(1 + c)$  and  $\pi_T^* = \frac{1}{4}(1 - c)^2$ .

In a market with two consumer segments, the sustainable product strategy affects environmentally conscious consumers and regular consumers in different ways. For environmentally conscious consumers, sustainable products increase their perceived values and attract consumers who give

a high value of sustainability. Such effects offer the firm incentive to increase product price. On the other hand, regular consumers may prefer regular products than sustainable products, due to their purchasing habit and concerns about quality of sustainable product. For example, some consumers may concern the durability of a pair of shoes made from recycled materials. Thus, sustainable products may reduce regular consumers' willing to pay and lead to a reduction of demand. The firm has to balance the two effects in adopting the sustainable product strategy. Note that  $ar$  is the expected positive consumer utility of a sustainable product, while  $-(1-r)d$  is the expected negative consumer utility of a sustainable product. Therefore, the value of  $ar - (1-r)d$  is the expected additional consumer utility of a sustainable product. Only when a sustainable product gains a positive expected additional consumer utility (i.e.,  $ar - (1-r)d > 0$ ), the firm considers adopting sustainable product strategy. Otherwise, the firm will only produce regular products, which is Case (iii) in Proposition 2.

When the expected additional consumer utility is positive, the firm needs to determine sustainable level. Specifically, the firm will have to make a trade-off between the profitability and cost of sustainable products. When the profit brought by the sustainable products is very high, or the additional cost required to adopt sustainable product strategy is very limited, the firm will set sustainable level as high as possible, leading to  $\theta_T^* = 1$ . Otherwise, the firm will set the sustainable level as  $\theta_T^* = [ar - (1-r)d]/bc$  to get the optimal profit. Therefore, we have Corollary 1.

**Corollary 1.** *When  $ar - (1-r)d > 0$ , the firm can increase its profit by adopting sustainable product strategy.*

Lemma 3 addresses the effect of segmentation degree  $r$  on product demand and firm's profit.

**Lemma 3.** *When  $ar - (1-r)d > 0$ , the product demand is increasing in  $r$ ; the firm's profit is increasing in  $r$ .*

Lemma 3 indicates that when the firm is better off to adopt the sustainable product strategy, the firm's demand is increasing in segmentation degree, i.e.,  $r$ . This is because that with a larger value of  $r$ , more consumers are willing to pay a higher price for the product and, therefore, the demand is expanded. In addition, we find that the firm's profit is also increasing in segmentation degree,  $r$ . This is because that with a larger value of  $r$ , more consumers value sustainability, and therein the expected positive utility of a sustainable product increases. Meanwhile, as fewer consumers are regular consumers, the expected negative utility of a sustainable product decreases. As a result, with an increase of  $r$ , the expected utility of a sustainable product increases. Therefore, the firm's profit increases due to a combination of demand expansion effect and utility increase effect.

**Lemma 4.** *When  $0 < ar - (1-r)d < bc$ , we have*

- (i) the firm's optimal sustainable level  $\theta_T^*$  is increasing in  $r$ ;
- (ii) the firm's optimal sustainable level  $\theta_T^*$  is decreasing in  $b$ ;
- (iii) the firm's optimal sustainable level  $\theta_T^*$  is decreasing in  $c$ .

Lemma 4 shows that when the sustainable product's profitability is moderate, the firm will adopt a higher sustainable level  $\theta_T^*$  as more consumers become environmentally conscious. This indicates that the market acceptability of the sustainable products increases. The sustainable level is also affected by the product cost parameters  $b$  and  $c$ . Note that the additional unit cost of a sustainable product is  $bc\theta^2/2$ . As the firm needs to balance the trade-off between the profit brought by the sustainable products and the corresponding costs occurred, a higher additional cost will dampen the firm's incentive to adopt the sustainable product strategy.

To better understand the driving forces of sustainable product strategy, we let  $D = ar - (1-r)d$ , which is the expected additional consumer utility of a sustainable product. We have Lemma 5.

**Lemma 5.** *When  $ar - (1 - r)d > 0$ , the firm's optimal price is increasing in  $D$ ; the product demand is increasing in  $D$ ; the marginal profit is increasing in  $D$ ; and the firm's profit is increasing in  $D$ .*

It is noted that  $D$  reflects the profitability of the sustainable products. A higher profitability promotes the firm to adopt sustainable product strategy, and therefore offers the firm incentive to increase its price. Lemma 5 also shows that higher profitability leads to product demand expansion. Recall that  $D = ar - (1 - r)d$ . An increase in profitability could be caused by three possible reasons: a larger  $a$ , a larger  $r$ , or a smaller  $d$ . An increase in  $a$  encourages more environmentally conscious consumers to purchase the sustainable product. A larger value of  $r$  indicates that more consumers value sustainability and, therefore, the product demand in segment of environmentally conscious consumers will increase. A smaller  $d$  increases the perceived value of regular consumers for the sustainable products. Therefore, there is less reduction of product demand in segment with regular consumers. As a result, higher profitability leads to demand expansion. Further, higher profitability increases the marginal profit and firm's profit.

The main influential factors determining the implementation of sustainable product strategy are profitability, costs and demand expansion effects. In Lemma 6, we investigate the cost effects.

**Lemma 6.** *When  $ar - (1 - r)d > 0$ , we have:*

- (i) when  $b > \frac{2}{3}$ ,  $\sqrt{\frac{2bc^2}{3}} \leq D < bc$ , the optimal price  $p_T^*$  is decreasing in the unit regular cost  $c$ ;
- (ii) otherwise, the optimal price  $p_T^*$  is increasing in the unit regular cost  $c$ .

It is noted that the cost to produce a sustainable product increases with a higher unit regular cost  $c$ . It is intuitive that the firm has incentive to increase its product price to cover the increase in cost. However, interestingly and surprisingly, there exists a situation where the optimal price will decrease as the cost increases.

Comparing with the case of homogenous consumers (i.e., Case O) and the case with two consumer segments (i.e., Case T), we have Lemma 7.

**Lemma 7.** *With comparison between Case O and Case T, we find:*

- (i) the optimal price in Case T is less than that in Case O, i.e.,  $p_T^* < p_O^*$ ;
- (ii) the marginal profit in Case T is less than that in Case O, i.e.,  $s_T < s_O$ ;
- (iii) the product demand in Case T is less than that in Case O, i.e.,  $q_T < q_O$ .

With a comparison between Case O and Case T, Lemma 7 reveals the impact of consumer type on the firm's decisions. On the one hand, the environmentally conscious consumers offer the firm incentive to invest more in sustainability, as more consumer surplus will be created. Therein, the firm has incentive to adopt a high sustainable level and increase the product price. On the other hand, regular consumers may have some doubts about quality of sustainable products. Some regular consumers' utility is reduced by a higher price and the reduced perceived value. The firm has to take such demand reduction of regular consumers into account. Thus, the firm will charge a lower price in a market with two consumer segments than that in a market with homogeneously environmentally conscious consumers. Lemma 7 also shows that compared with Case O, the marginal profit of sustainable products is also reduced.

#### 4.4. Consumer Segmentation (S)

Thus far, our discussions hinge on the assumption that the segmentation degree is given, i.e.,  $r$  is exogenously given. Now we consider a situation where the firm could do some efforts to increase consumers' awareness about environmental protection. Specifically, the firm could convert some regular consumers to be environmentally conscious by advertisement, organizing some activities to

promote environmental protection, and so on. We use subscript “S” to represent the variables in this case (which is referred as Case S in this paper).

We consider a market where all consumers are regular consumers. The firm plans to launch a type of sustainable products. With some advertisement, a fraction  $r$  of consumers will value the firm’s sustainable products and convert to be environmentally conscious, while the remaining will stay as regular consumers. In other words, the firm could manage consumer segmentation degree through its effort. The cost of effort is denoted by a quadratic function  $c_M = Mr^2/2$ , where  $M > 0$  is a cost parameter. A larger value of  $M$  indicates higher cost for the consumer segmentation effort. Further, we assume the sustainable level  $\theta$  is a given parameter in this case. The sequential events are shown in Figure 2.

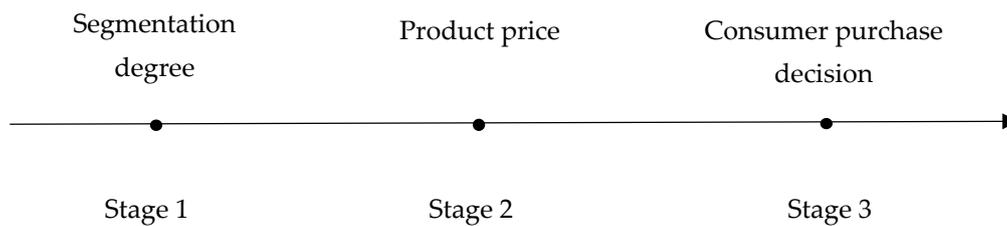


Figure 2. Sequential events in Case S.

With a given sustainable level  $\theta$ , the firm first determines the consumer segmentation degree  $r$ . Then, the firm makes pricing decision. With observation of the sustainable level  $\theta$ , the consumers make their purchase decisions. Similarly, an environmentally conscious consumer gets utility  $U_i = v_i + a\theta - p_S$  for a product, while a regular consumer obtains utility  $U_i = v_i - d\theta - p_S$ . The firm aims at maximizing its profit. Similar to Case O, we focus on the range  $p_S \in ((1 + b\theta^2/2)c, 1 + a\theta)$ . The profit is computed by subtracting the total production cost and the cost of additional effort from the total sales revenue. We can formulate the problem as:

$$\begin{aligned} \text{Max } \pi_S(p_S, r) &= [p_S - (1 + \frac{b\theta^2}{2})c][r(1 + a\theta - p_S) + (1 - r)(1 - d\theta - p_S)^+] - \frac{1}{2}Mr^2 \\ \text{s.t. } &(1 + \frac{b\theta^2}{2})c < p_S < 1 + a\theta \end{aligned} \quad (4)$$

Propositions 3 and 4 characterize the firm’s optimal decisions under different situations.

**Proposition 3.** *Given the sustainable level  $\theta$  for sustainable products, when  $a\theta \geq 1 - 2d\theta - (1 + b\theta^2/2)c$ , only environmentally conscious consumers will buy the products; specifically, the firm’s optimal consumer segmentation degree  $r$ , the optimal product price and the optimal profit are given as follows:*

When

$$M > \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4},$$

then we have

$$r_S^* = \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4M}, \quad p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \text{ and } \pi_S^* = \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^4}{32M};$$

When

$$M \leq \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4}$$

then,  $r_S^* = 1$ ,  $p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c]$  and  $\pi_S^* = \frac{1}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{M}{2}$ .

**Proposition 4.** Given the sustainable level  $\theta$  for sustainable products, when  $a\theta < 1 - 2d\theta - (1 + b\theta^2/2)c$ , both environmentally conscious consumers and regular consumers will buy the products; specifically, the firm's optimal consumer segmentation degree  $r$ , the optimal product price and the optimal profit are given as follows:

When

$$M > \frac{(a\theta + d\theta)[1 + a\theta - (1 + \frac{b\theta^2}{2})c]}{2},$$

then

$$r_S^* = \frac{(a\theta + d\theta)[1 - d\theta - (1 + \frac{b\theta^2}{2})c]}{2[M - \frac{(a\theta + d\theta)^2}{2}]},$$

$$p_S^* = \frac{1}{2}[1 - d\theta + (1 + \frac{b\theta^2}{2})c] + \frac{(a\theta + d\theta)^2(1 - d\theta - c - \frac{b\theta^2}{2})c}{2M - (a\theta + d\theta)^2} \text{ and}$$

$$\pi_S^* = \frac{M[1 - d\theta - (1 + \frac{b\theta^2}{2})c]^2}{4[2M - (a\theta + d\theta)^2]};$$

When

$$M \leq \frac{(a\theta + d\theta)[1 + a\theta - (1 + \frac{b\theta^2}{2})c]}{2},$$

then,  $r_S^* = 1$ ,  $p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c]$  and  $\pi_S^* = \frac{1}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{M}{2}$ .

It is interesting to find that the firm will target different consumer segments depending on parameter settings. As demonstrated in Proposition 3, when the environmentally conscious consumers get a very high additional utility from sustainable products, the firm will forego the regular consumers and target only environmentally conscious consumers. It means that the firm will set a very high price at which the regular consumers will not buy the products due to non-positive utility. This high price enables the firm to extract high surplus from environmentally conscious consumers. Under this situation, there is a threshold of cost parameter  $M$  in determining the segmentation degree  $r$ . When managing segmentation cost is higher than the threshold, the firm will convert a fraction of regular consumers to environmentally conscious consumers, i.e.,  $0 < r_S^* < 1$ ; otherwise, the firm will make great efforts to convert all consumers to environmentally conscious consumers, i.e.,  $r_S^* = 1$ .

Proposition 4 shows that when the additional utility from sustainable products obtained by the environmentally conscious consumers is not very high, the firm will set a mediate price to capture potential demand in the two consumer segments. Under this situation, the firm will get revenue from both the environmentally conscious consumers and the regular consumers. Similarly, there is a threshold of cost parameter  $M$  under, which the firm will convert all consumers to be environmentally conscious; otherwise, the firm will convert a fraction of consumers to be environmentally conscious.

## 5. Conclusions

In recent years, sustainable product strategy has been receiving an increasing amount of attention in apparel industry, as both firms and consumers have emphasized the importance of corporate social responsibility and environmental protection. In this paper, we provide an analytical model to demonstrate the fact that the firm may benefit from adoption of sustainable product strategy while the consumers may also get greater surplus.

Firstly, we have constructed a base model without sustainable product strategy as a benchmark case. Consequently, we have built up a model with homogenous consumers who value sustainability. It is proven that as long as the consumers are environmentally conscious, the firm can increase its profit by using sustainable product strategy. The optimal sustainable level depends on the trade-off between the profitability and cost. Secondly, we have extended our analysis to a model where two consumer segments exist: environmentally conscious consumers and regular consumers. This model

reveals that as the expected additional utility from a sustainable product is positive, the firm should produce sustainable products; otherwise, the firm should only produce regular products. A higher segmentation degree has a demand expansion effects. As more consumers come to value sustainability, the firm itself will choose to increase the sustainable level of the products and will gain a higher profit. Moreover, we have identified the three influencing factors in determining sustainable product strategy—profitability, cost and demand expansion.

Furthermore, we have considered a situation where the firm could manage consumer segmentation with some degree of effort. As a result, we have finally reached the sustainable level. Depending on the profitability that comes from environmentally conscious consumers, the firm will target different consumer segments. When the additional utility that comes from the sustainable products used by environmentally conscious consumers is very high, the firm will forego the regular consumers and only target the environmentally conscious consumers. Contrarily, the firm will earn revenues from the two consumer segments. Moreover, we have identified that there is a threshold of the managing consumer segmentation cost efficiency. When the cost for managing consumer segmentation is sufficiently high, the firm will convert a part of the regular consumers to environmentally conscious customers; otherwise, the firm will need a considerable amount of effort to convert all consumers into environmentally conscious ones.

In summary, the main contributions of our paper are as follows: First, we partly fill the gap between the firms' practices in apparel industry and the analytical research in academia. Although we have observed a few implementations of sustainable strategy, there is a lack of research on quantitatively investigating the mechanism of how a firm's sustainable product strategy is affected by the consumers' preference to sustainable product. In particular, some firms in apparel industry launch sustainable products that are made from recycled materials. Our analytical model could formulate such practice in apparel industry. Second, the existing studies on sustainability mainly focus only on consumers' attitude to sustainable products. Most of these studies are empirical studies. These studies do not consider firms' responses to consumers' emerging preference. Our research extends the current literature by building up an analytical framework in addressing how consumers' attitude to environment friendly products affects firms' strategies. Third, our research set sustainability level as an endogenous decision, with consideration of consumers' purchase behavior. This differs from the existing studies on sustainable strategy that assume the sustainability level is given. With our model, we could solve the optimal sustainable level, identify the influential factors and determine the extent to which consumers' attitude would affect a firm's strategy.

As a conclusion for our paper, we want to point out some limitations and further research directions. Firstly, we have considered a monopolistic market type. We expected that consumers may have more options in a competitive market. Therefore, the firm's incentive to adopt sustainable product strategy may be affected. Secondly, we assumed that the firm only focused on the economic aspect when adopting sustainable product strategy. In fact, the firm also considered some non-economic aspects when it implements a strategy i.e., branding, reputation, innovation, etc. All these factors will play some direct or indirect roles in the firm's strategy when launching a new sustainable product. Accordingly, we await and encourage some future studies that can take these factors into account.

**Acknowledgments:** The authors thank the academic editor Prof. Shen and two referees for the helpful comments. This work was supported in part by the National Natural Science Foundation of China (No. 71571043, 71332007 and 71572034).

**Author Contributions:** Liu Yang designed the research and formulated the model. Shaozeng Dong provided the solutions and carried out the analysis.

**Conflicts of Interest:** The authors declare no conflict of interest.

### Appendix A

#### Proof of Proposition 1.

Firm’s profit in Case O is given by

$$\text{Max } \pi_O(p_O, \theta) = (p_O - c_r)q_O = [p_O - (1 + \frac{b\theta^2}{2})c](1 + a\theta - p_O)$$

where  $0 \leq \theta \leq 1$  and  $(1 + \frac{b\theta^2}{2})c < p_O < 1 + a\theta$ ,  $\pi_O(p_O, \theta)$  is a function of  $p_O$  and  $\theta$ . Firstly, we solved the first-order conditions of  $\pi_O(p_O, \theta)$  on  $p_O$ , and reached the result  $p_O(\theta) = \frac{1}{2}[a\theta + (1 + \frac{b\theta^2}{2})c + 1]$ . Since  $\frac{\partial^2 \pi_O(p_O, \theta)}{\partial p_O^2} = -2 < 0$ , we only need to show that  $(1 + \frac{b\theta^2}{2})c < p_O(\theta) < 1 + a\theta$ . Because  $1 + a\theta > (1 + \frac{b\theta^2}{2})c$ , we can prove that  $p_O(\theta)$  abides by this condition. When substituting  $p_O(\theta)$  into the firm’s profit function, we have  $\pi_O(\theta) = \frac{1}{4}[a\theta - (1 + \frac{b\theta^2}{2})c + 1]^2$ . We proceed by solving the first-order conditions of  $\pi_O(\theta)$  on the  $\theta$ , and have

$$\theta_{O1} = \frac{a - \sqrt{a^2 - 2bc^2 + 2bc}}{bc}; \theta_{O2} = \frac{a}{bc}; \theta_{O3} = \frac{a + \sqrt{a^2 - 2bc^2 + 2bc}}{bc}, \text{ and } \theta_{O1} < \theta_{O2} < \theta_{O3}$$

**Table A1.** Monotonicity judging table of  $\pi_O(\theta)$ .

$\theta$	$(-\infty, \theta_{O1})$	$\theta_{O1}$	$(\theta_{O1}, \theta_{O2})$	$\theta_{O2}$	$(\theta_{O2}, \theta_{O3})$	$\theta_{O3}$	$(\theta_{O3}, +\infty)$
$\pi_O^{(1)}(\theta)$	-	0	+	0	-	0	+
$\pi_O(\theta)$	$\searrow$	Min	$\nearrow$	Max	$\searrow$	Min	$\nearrow$

We notice that  $\theta_{O1} = \frac{a - \sqrt{a^2 - 2bc^2 + 2bc}}{bc} = \frac{a - \sqrt{a^2 + 2bc(1-c)}}{bc} < \frac{a - \sqrt{a^2}}{bc} = 0$ .

In order to get the optimal solutions, we have considered this question from two perspectives.

- (i)  $a \geq bc$ . In this case,  $\pi_O(\theta)$  is monotone increasing in  $\theta(0 \leq \theta \leq 1)$ . Thus, when  $\theta_O^* = 1$ , then  $\pi_O^* = \frac{1}{4}[a - (1 + \frac{b}{2})c + 1]^2$ , and  $p_O^* = \frac{1}{2}[a + (1 + \frac{b}{2})c + 1]$ .
- (ii)  $a < bc$ . In this case, we notice that  $\theta_{O2} = \frac{a}{bc} < 1$ , and we have  $\theta_{O3} - 1 = \frac{a + \sqrt{a^2 - 2bc^2 + 2bc}}{bc} - 1 > 0$ . By combining the cases of  $\pi_O(\theta)$  in Table A1, when  $\theta_O^* = \frac{a}{bc}$ , the firm will get optimal profit  $\pi_O^* = \frac{1}{4}[\frac{a^2}{2bc} - c + 1]^2$  and will set the optimal price as  $p_O^* = \frac{1}{2}[\frac{3a^2}{2bc} + c + 1]$ .

#### Proof of Lemma 1.

If  $a \geq bc$ , the price difference between Case B and Case O is presented as

$$\Delta p_{OB}^* = p_O^* - p_B^* = \frac{1}{2}[a + (1 + \frac{b}{2})c + 1] - \frac{1}{2}(1 + c) = \frac{1}{2}[a + \frac{bc}{2}] > 0.$$

If  $a < bc$ , the price difference between Case B and Case O is presented as

$$\Delta p_{OB}^* = p_O^* - p_B^* = \frac{1}{2}[\frac{3a^2}{2bc} + c + 1] - \frac{1}{2}(1 + c) = \frac{3a^2}{4bc} > 0$$

Therefore, it is evident that  $p_O^* > p_B^*$  for the two above cases.

#### Proof of Lemma 2.

If  $a \geq bc$ , the profit difference between Case B and Case O is presented as

$$\Delta \pi_{OB}^* = \pi_O^* - \pi_B^* = \frac{1}{4}[a - (1 + \frac{b}{2})c + 1]^2 - \frac{1}{4}(1 - c)^2 = \frac{1}{4}[1 + a - (1 + \frac{b}{2})c + 1 - c](a + \frac{bc}{2}) > 0$$

If  $a < bc$ , the difference profit between Case B and Case O is presented as

$$\Delta\pi_{OB}^* = \pi_O^* - \pi_B^* = \frac{1}{4} \left[ \frac{a^2}{2bc} - c + 1 \right]^2 - \frac{1}{4} (1 - c)^2 = \frac{a^2}{8bc} \left[ \frac{a^2}{2bc} + 2(1 - c) \right] > 0$$

Thus,  $\Delta\pi_{OB}^* = \pi_O^* - \pi_B^* > 0$ , i.e.,  $\pi_O^* > \pi_B^*$ .

**Proof of Proposition 2.**

In case T, firm’s profit function is given by

$$Max \pi_T(\theta, p_T) = [p_T - c_r]q_T = [p_T - (1 + \frac{b\theta^2}{2})c][r(1 + a\theta - p_T) + (1 - r)(1 - d\theta - p_T)]$$

where  $0 \leq \theta \leq 1$  and  $(1 + \frac{b\theta^2}{2})c < p_T < 1 + a\theta$ . In this case, we have considered that these two consumer segments are in the market, so  $(1 + \frac{b\theta^2}{2})c < p_T < 1 - d\theta$ . We have solved the first-order conditions of  $\pi_T(p_T, \theta)$  on  $p_T$ , and got the price

$$p_T(\theta) = \frac{1}{2} [r(1 + a\theta) + (1 + \frac{b\theta^2}{2})c + (1 - r)(1 - d\theta)].$$

Consequently, we can prove that  $(1 + \frac{b\theta^2}{2})c < p_T(\theta) < 1 - d\theta$ , and substitute  $p_T(\theta)$  into the Equation (3), resulting in

$$\pi_T(\theta) = \frac{1}{4} [1 + ar\theta - (1 - r)d\theta - (1 + \frac{b\theta^2}{2})c]^2.$$

We solve the first-order conditions of  $\pi_T^*(\theta)$  on  $\theta$ , and we have

$$\theta_{T1} = \frac{ar - (1 - r)d - \sqrt{[ar - (1 - r)d]^2 + 2bc(1 - c)}}{bc}, \theta_{T2} = \frac{ar - (1 - r)d}{bc} \text{ and } \theta_{T3} = \frac{ar - (1 - r)d + \sqrt{[ar - (1 - r)d]^2 + 2bc(1 - c)}}{bc}.$$

Having in view the conditions in this case, we have  $\theta_{T1} < \theta_{T2} < \theta_{T3}$ ;

$$\theta_{T1} = \frac{ar - (1 - r)d - \sqrt{[ar - (1 - r)d]^2 + 2bc(1 - c)}}{bc} < \frac{ar - (1 - r)d - |ar - (1 - r)d|}{bc} \leq 0;$$

$$\theta_{T3} = \frac{ar - (1 - r)d + \sqrt{[ar - (1 - r)d]^2 + 2bc(1 - c)}}{bc} > \frac{ar - (1 - r)d + |ar - (1 - r)d|}{bc} \geq 0$$

**Table A2.** Monotonicity judging table of  $\pi_T^*(\theta)$ .

$\theta$	$(-\infty, \theta_{T1})$	$\theta_{T1}$	$(\theta_{T1}, \theta_{T2})$	$\theta_{T2}$	$(\theta_{T2}, \theta_{T3})$	$\theta_{T3}$	$(\theta_{T3}, +\infty)$
$\pi_T^{(1)}(\theta)$	-	0	+	0	-	0	+
$\pi_T(\theta)$	$\searrow$	Min	$\nearrow$	Max	$\searrow$	Min	$\nearrow$

Additionally, we will discuss the optimal solution from three perspectives:

- (i)  $ar - (1 - r)d \geq bc$ . In this case  $\pi_T^*(\theta)$  is monotone increasing in  $\theta$  ( $0 \leq \theta \leq 1$ ). As a result, when  $\theta_T^* = 1$ , then  $\pi_T^* = \frac{1}{4} [1 + ar - (1 - r)d - (1 + \frac{b}{2})c]^2$ , and  $p_T^* = \frac{1}{2} [r(1 + a) + (1 + \frac{b}{2})c + (1 - r)(1 - d)]$ .
- (ii)  $0 < ar - (1 - r)d < bc$ . In this case, we have  $0 < \theta_{T2} = \frac{ar - (1 - r)d}{bc} < 1$  and  $\theta_{T3} - 1 = \frac{ar - (1 - r)d + \sqrt{[ar - (1 - r)d]^2 + 2bc(1 - c)}}{bc} - 1 > 0$ . Combining the cases in Table A2, we can learn that when  $\theta_T^* = \frac{ar - (1 - r)d}{bc}$ , then  $\pi_T^* = \frac{1}{4} \left[ \frac{(ar + dr - d)^2}{2bc} + 1 - c \right]^2$ ,  $p_T^* = \frac{3[ar - (1 - r)d]^2 + 2bc(1 + c)}{4bc}$ .

- (iii)  $ar - (1 - r)d \leq 0$ . From the conditions of this case, we have  $\theta_{T2} = \frac{ar - (1-r)d}{bc} \leq 0$  and  $\theta_{T3} - 1 = \frac{ar - (1-r)d + \sqrt{[ar - (1-r)d]^2 + 2bc(1-c)}}{bc} - 1 > 0$ . In this case, when  $\theta_T^* = 0$ , then  $\pi_T^* = \frac{1}{4}(1 - c)^2$ ,  $p_T^* = \frac{1}{2}(1 + c)$ .

### Proof of Corollary 1.

If  $ar - (1 - r)d \geq bc$ , the profit difference between Case T and Case B is presented as

$$\Delta\pi_{TB} = \pi_T^* - \pi_B^* = \frac{1}{4}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c + 1 - c][ar - (1 - r)d - \frac{bc}{2}] > 0$$

If  $0 < ar - (1 - r)d < bc$ , the profit difference between Case T and Case B is presented as

$$\Delta\pi_{TB} = \pi_T^* - \pi_B^* = \frac{(ar + dr - d)^2}{8bc} [\frac{(ar + dr - d)^2}{2bc} + 2(1 - c)] > 0$$

Thus,  $\Delta\pi_{TB} = \pi_T^* - \pi_B^* > 0$ , i.e.,  $\pi_T^* > \pi_B^*$ .

### Proof of Lemma 3.

If  $ar - (1 - r)d \geq bc$ , the product demand and firm's optimal profit are given by

$$q_T^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c] \text{ and } \pi_T^* = \frac{1}{4}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c]^2.$$

Moreover, we have

$$\frac{dq_T^*}{dr} = a + d > 0 \text{ and } \frac{d\pi_T^*}{dr} = \frac{a + d}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c] > 0.$$

If  $0 < ar - (1 - r)d < bc$ , the product demand and firm's optimal profit are given by

$$q_T^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2} \text{ and } \pi_T^* = \frac{1}{4}[\frac{(ar + dr - d)^2}{2bc} + 1 - c]^2.$$

Consequently, we have

$$\frac{dq_T^*}{dr} = \frac{a + d}{2bc}[ar - (1 - r)d] > 0 \text{ and } \frac{d\pi_T^*}{dr} = \frac{a + d}{2bc}[ar - (1 - r)d][\frac{(ar + dr - d)^2}{2bc} + 1 - c] > 0.$$

Therefore, when  $ar - (1 - r)d > 0$ , the product demand is increasing in  $r$ , and the firm's profit is also increasing in  $r$ .

### Proof of Lemma 4.

When  $0 < ar - (1 - r)d < bc$ , the firm's optimal sustainable level is given by

$$\theta_T^* = \frac{ar - (1 - r)d}{bc}$$

We calculate  $\theta_T^*$  first derivative of  $r, b, c$  respectively, and we have

$$\frac{\partial\theta_T^*}{\partial r} = \frac{a + d}{bc} > 0, \frac{\partial\theta_T^*}{\partial b} = -\frac{ar - (1 - r)d}{b^2c} < 0 \text{ and } \frac{\partial\theta_T^*}{\partial c} = -\frac{ar - (1 - r)d}{bc^2} < 0.$$

**Proof of Lemma 5.**

If  $ar - (1 - r)d \geq bc$ , the firm's optimal price, product demand, marginal profit and firm's profit are given by

$$p_T^* = \frac{1}{2}[1 + ar - (1 - r)d + (1 + \frac{b}{2})c], q_T^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c], \\ s_T^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c] \text{ and } \pi_T^* = \frac{1}{4}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c]^2.$$

Since  $D = ar - (1 - r)d$ , these functions can be written as

$$p_T^* = \frac{1}{2}[1 + D + (1 + \frac{b}{2})c], q_T^* = \frac{1}{2}[1 + D - (1 + \frac{b}{2})c], \\ s_T^* = \frac{1}{2}[1 + D - (1 + \frac{b}{2})c] \text{ and } \pi_T^* = \frac{1}{4}[1 + D - (1 + \frac{b}{2})c]^2.$$

As a result,

$$\frac{dp_T^*}{dD} = \frac{1}{2} > 0, \frac{dq_T^*}{dD} = \frac{1}{2} > 0, \frac{ds_T^*}{dD} = \frac{1}{2} > 0 \text{ and } \frac{d\pi_T^*}{dD} = \frac{1}{2}[1 + D - (1 + \frac{b}{2})c] > 0.$$

Similarly, if  $0 < ar - (1 - r)d < bc$ , then we can write the firm's optimal price, product demand, marginal profit and firm's profit as

$$p_T^* = \frac{3D^2}{4bc} + \frac{1+c}{2}, q_T^* = \frac{D^2}{4bc} + \frac{1-c}{2}, s_T^* = \frac{D^2}{4bc} + \frac{1-c}{2} \text{ and } \pi_T^* = \frac{1}{4}(\frac{D^2}{2bc} + 1 - c)^2.$$

and we have

$$\frac{dp_T^*}{dD} = \frac{3D}{2bc} > 0, \frac{dq_T^*}{dD} = \frac{D}{2bc} > 0, \frac{ds_T^*}{dD} = \frac{D}{2bc} > 0 \text{ and } \frac{d\pi_T^*}{dD} = \frac{D}{2bc} \left[ \frac{D^2}{2bc} + 1 - c \right] > 0.$$

In conclusion, when  $ar - (1 - r)d > 0$ , the firm's optimal price is increasing in  $D$ ; the product demand is increasing in  $D$ ; the marginal profit is increasing in  $D$ ; and the firm's profit is increasing in  $D$ .

**Proof of Lemma 6.**

When  $ar - (1 - r)d \geq bc$ , the optimal price is given by

$$p_T^* = \frac{1}{2}[1 + ar - (1 - r)d + (1 + \frac{b}{2})c].$$

Consequently, we have  $\frac{dp_T^*}{dc} = 1 + \frac{b}{2} > 0$

When  $0 < ar - (1 - r)d < bc$ , the optimal price is given by

$$p_T^* = \frac{3[ar - (1 - r)d]^2}{4bc} + \frac{1+c}{2}.$$

We can also write the equation as:  $p_T^*$  as  $p_T^* = \frac{3D^2}{4bc} + \frac{1+c}{2}$ , and we have  $\frac{dp_T^*}{dc} = \frac{1}{2} - \frac{3D^2}{4bc^2}$ .

If  $b \leq \frac{2}{3}$ ,  $\frac{dp_T^*}{dc} = \frac{1}{2} - \frac{3D^2}{4bc^2} > 0$

If  $b > \frac{2}{3}$ ,

when  $\sqrt{\frac{2bc^2}{3}} \leq D < bc$ ,  $\frac{dp_T^*}{dc} = \frac{1}{2} - \frac{3D^2}{4bc^2} < 0$ ;

when  $0 < D < \sqrt{\frac{2bc^2}{3}}$ ,  $\frac{dp_T^*}{dc} = \frac{1}{2} - \frac{3D^2}{4bc^2} > 0$ .

Therefore, when  $ar - (1 - r)d > 0$ , if  $b > \frac{2}{3}$ ,  $\sqrt{\frac{2bc^2}{3}} \leq D < bc$ , the optimal price is decreasing in  $c$ ; otherwise, the optimal price is increasing in  $c$ .

**Proof of Lemma 7.**

When  $ar - (1 - r)d \geq bc$ , the optimal price, marginal profit and product demand are given by

$$p_T^* = \frac{1}{2}[1 + ar - (1 - r)d + (1 + \frac{b}{2})c], s_T^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c] \text{ and } q_T^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c].$$

in Case T, and

$$p_O^* = \frac{1}{2}[a + (1 + \frac{b}{2})c + 1], s_O^* = \frac{1}{2}[1 + a - (1 + \frac{b}{2})c] \text{ and } q_O^* = \frac{1}{2}[1 + a - (1 + \frac{b}{2})c]$$

in Case O. Then, we have

$$\begin{aligned} \Delta p_{TO} &= p_T^* - p_O^* = \frac{1}{2}[1 + ar - (1 - r)d + (1 + \frac{b}{2})c] - \frac{1}{2}[a + (1 + \frac{b}{2})c + 1] = \frac{r-1}{2}(a + d) < 0 \\ \Delta s_{TO} &= s_T^* - s_O^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c] - \frac{1}{2}[1 + a - (1 + \frac{b}{2})c] = \frac{r-1}{2}(a + d) < 0 \\ \Delta q_{TO} &= q_T^* - q_O^* = \frac{1}{2}[1 + ar - (1 - r)d - (1 + \frac{b}{2})c] - \frac{1}{2}[1 + a - (1 + \frac{b}{2})c] = \frac{r-1}{2}(a + d) < 0. \end{aligned}$$

When  $0 < ar - (1 - r)d < bc \leq a$ , the optimal price, marginal profit and product demand are given by

$$p_T^* = \frac{3[ar - (1 - r)d]^2}{4bc} + \frac{1 + c}{2}, s_T^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2} \text{ and } q_T^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2}.$$

in Case T, and

$$p_O^* = \frac{1}{2}[a + (1 + \frac{b}{2})c + 1], s_O^* = \frac{1}{2}[1 + a - (1 + \frac{b}{2})c] \text{ and } q_O^* = \frac{1}{2}[1 + a - (1 + \frac{b}{2})c].$$

in Case O. As a result, we have

$$\begin{aligned} \Delta p_{TO} &= p_T^* - p_O^* = \frac{3[ar - (1 - r)d]^2 - 2abc - b^2c^2}{4bc} < 0 \\ \Delta s_{TO} &= s_T^* - s_O^* = \frac{[ar - (1 - r)d]^2 - abc}{4bc} + \frac{bc - a}{2} < 0 \\ \Delta q_{TO} &= q_T^* - q_O^* = \frac{[ar - (1 - r)d]^2 - abc}{4bc} + \frac{bc - a}{2} < 0 \end{aligned}$$

When  $a < bc$ , the optimal price, marginal profit and product demand are given by

$$p_T^* = \frac{3[ar - (1 - r)d]^2}{4bc} + \frac{1 + c}{2}, s_T^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2} \text{ and } q_T^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2}$$

in Case T, and

$$p_O^* = \frac{1}{2}[\frac{3a^2}{2bc} + c + 1], s_O^* = \frac{1}{2}[\frac{a^2}{2bc} + 1 - c] \text{ and } q_O^* = \frac{1}{2}[\frac{a^2}{2bc} + 1 - c].$$

in Case O. Then, we have

$$\begin{aligned} \Delta p_{TO} &= p_T^* - p_O^* = \frac{3[ar - (1 - r)d]^2 + 2bc(1 + c)}{4bc} - \frac{1}{2}[\frac{3a^2}{2bc} + c + 1] = \frac{3[ar - (1 - r)d]^2 - 3a^2}{4bc} < 0 \\ \Delta s_{TO} &= s_T^* - s_O^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2} - \frac{1}{2}[\frac{a^2}{2bc} + 1 - c] = \frac{[ar - (1 - r)d]^2 - a^2}{4bc} < 0 \\ \Delta q_{TO} &= q_T^* - q_O^* = \frac{[ar - (1 - r)d]^2}{4bc} + \frac{1 - c}{2} - \frac{1}{2}[\frac{a^2}{2bc} + 1 - c] = \frac{[ar - (1 - r)d]^2 - a^2}{4bc} < 0 \end{aligned}$$

Eventually we know that the optimal price, marginal profit and product demand in Case T are less than that in Case O.

**Proof of Proposition 3.**

In Case S, firm's profit function is given as

$$\begin{aligned} \text{Max } \pi_S(p_S, r) &= [p_S - (1 + \frac{b\theta^2}{2})c][r(1 + a\theta - p_S) + (1 - r)(1 - d\theta - p_S)^+] - \frac{1}{2}Mr^2 \\ \text{s.t } &\begin{cases} (1 + \frac{b\theta^2}{2})c < p_S < 1 + a\theta \\ 0 \leq r \leq 1 \end{cases} \end{aligned}$$

We consider that  $p_S \geq 1 - d\theta$ . Because regular consumers will not buy sustainable products, there are only environmentally conscious consumers in the market and  $r > 0$ . Firm's profit function can be shown as

$$\begin{aligned} \text{Max } \pi_S(p_S, r) &= [p_S - (1 + \frac{b\theta^2}{2})c]r(1 + a\theta - p_S) - \frac{1}{2}Mr^2 \\ \text{s.t } &\begin{cases} (1 + \frac{b\theta^2}{2})c < p_S < 1 + a\theta \\ 0 < r \leq 1 \end{cases} \end{aligned}$$

When solving the first-order conditions of  $\pi_S(p_S, r)$  on  $p_S$ , we have

$$p_S = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c].$$

From the model setting, we can prove that  $(1 + \frac{b\theta^2}{2})c < p_S < 1 + a\theta$ . Since  $\frac{d^2\pi_S(p_S, r)}{dp_S^2} = -2r < 0$ , when  $\frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \geq 1 - d\theta$ , and when substituting  $p_S$  into firm's profit function, we have  $\pi_S(r) = \frac{r}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{Mr^2}{2}$ . By solving the first-order conditions of  $\pi_S(r)$  on  $r$ , we have  $r_S = \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4M}$ . Because  $0 < r \leq 1$ , we need to compare  $r_S$  and 1. Since  $\frac{d^2\pi_S(r)}{dr^2} = -M < 0$ ,

If  $M > \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4}$ , then

$$\pi_S^* = \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^4}{32M}, p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \text{ and } r_S^* = \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4M}.$$

If  $M \leq \frac{[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2}{4}$ , then

$$\pi_S^* = \frac{1}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{M}{2}, p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \text{ and } r_S^* = 1.$$

**Proof of Proposition 4.**

Similar to the proof of Proposition 3, when  $p_S < 1 - d\theta$ , the firm's profit function in Case S can be shown as

$$\begin{aligned} \text{Max } \pi_S(p_S, r) &= [p_S - (1 + \frac{b\theta^2}{2})c][r(1 + a\theta - p_S) + (1 - r)(1 - d\theta - p_S)] - \frac{1}{2}Mr^2 \\ \text{s.t } &\begin{cases} (1 + \frac{b\theta^2}{2})c < p_S < 1 + a\theta \\ 0 \leq r \leq 1 \end{cases} \end{aligned}$$

Solve the first-order conditions of  $\pi_S(p_S, r)$  on  $p_S$ , and we have

$$p_S(r) = \frac{1}{2}[r(1 + a\theta) + (1 + \frac{b\theta^2}{2})c + (1 - r)(1 - d\theta)].$$

From pre-conditions, we can prove  $(1 + \frac{b\theta^2}{2})c < p_S(r) < 1 + a\theta$ . Since  $\frac{d^2\pi_S(p_S, r)}{dp_S^2} = -2$ , when  $p_S(r) < 1 - d\theta$ , substitute  $p_S(r)$  into firm's profit function, and we have

$$\text{Max } \pi_S(r) = \frac{1}{4}[r(1 + a\theta) + (1 - r)(1 - d\theta) - (1 + \frac{b\theta^2}{2})c] - \frac{Mr^2}{2}.$$

From this equation, we can calculate  $\frac{d^2\pi_S(r)}{dr^2} = \frac{(a\theta + d\theta)^2}{2} - M$

(i) If  $M > \frac{(a\theta + d\theta)^2}{2}$ , we have

$$r_S = \frac{(a\theta + d\theta)[1 - d\theta - (1 + \frac{b\theta^2}{2})c]}{2[M - \frac{(a\theta + d\theta)^2}{2}]}$$

from the first-order condition of  $\pi_S(r)$  on  $r$ . Because  $0 < r \leq 1$ , we need to compare  $r_S$  and 1.

When  $M > \frac{(a\theta + d\theta)[1 + a\theta - (1 + \frac{b\theta^2}{2})c]}{2}$ , then

$$\pi_S^* = \frac{M[1 - d\theta - (1 + \frac{b\theta^2}{2})c]^2}{4[2M - (a\theta + d\theta)^2]}, p_S^* = \frac{1}{2}[1 - d\theta + (1 + \frac{b\theta^2}{2})c] + \frac{(a\theta + d\theta)^2(1 - d\theta - (1 + \frac{b\theta^2}{2})c)}{2M - (a\theta + d\theta)^2}$$

and  $r_S^* = \frac{(a\theta + d\theta)[1 - d\theta - (1 + \frac{b\theta^2}{2})c]}{2[M - \frac{(a\theta + d\theta)^2}{2}]}$ .

When  $M \leq \frac{(a\theta + d\theta)[1 + a\theta - (1 + \frac{b\theta^2}{2})c]}{2}$ , then

$$\pi_S^* = \frac{1}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{M}{2}, p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \text{ and } r_S^* = 1.$$

(ii) If  $M = \frac{(a\theta + d\theta)^2}{2}$ , firm's profit function can be shown as

$$\text{Max } \pi_S(r) = \frac{1}{4}[1 - d\theta - (1 + \frac{b\theta^2}{2})c]^2 + \frac{r(a\theta + d\theta)}{2}[1 - d\theta - (1 + \frac{b\theta^2}{2})c].$$

From this equation, we know that  $\pi_S(r)$  is increasing in  $r$ . Thus, in this situation, firm's optimal profit, price and segmentation degree are given by

$$\pi_S^* = \frac{1}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{M}{2}, p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \text{ and } r_S^* = 1.$$

(iii) If  $M < \frac{(a\theta + d\theta)^2}{2}$ , we have

$$\frac{d^2\pi_S(r)}{dr^2} = \frac{(a\theta + d\theta)^2}{2} - M > 0 \text{ and } r = \frac{(a\theta + d\theta)[1 - d\theta - (1 + \frac{b\theta^2}{2})c]}{2[M - \frac{(a\theta + d\theta)^2}{2}]} < 0.$$

Firm's optimal profit, price and segmentation degree are given by

$$\pi_S^* = \frac{1}{4}[1 + a\theta - (1 + \frac{b\theta^2}{2})c]^2 - \frac{M}{2}, p_S^* = \frac{1}{2}[1 + a\theta + (1 + \frac{b\theta^2}{2})c] \text{ and } r_S^* = 1.$$

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