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Monopoly Pricing and Eco-Labeling Signaling

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Abstract

Environmental friendly products are one kind of credence goods which is impossible to observe its 'ethical quality'. It is difficult for consumers to distinguish between ethical and conventional firms. Then an eco-label from a third-party certifier is suspected to be an effective ethical quality signal that develops consumer trusts. This study, a monopoly signaling game, aims to find the firm equilibrium prices. It also objects to obtain the necessary conditions that make the eco-certification effective, under the conditions that conventional goods may be labeled and eco-friendly goods sometimes fail to be labeled. The results show that although prices fail to signal ethical quality in this case, an eco-label can be an indication of ethical characteristic. Namely, separating equilibrium which only an eco-friendly firm asks for label exists when an application cost is sufficiently high and the accuracy of labeling is large enough.In contrast, when the application fee is low, both types of firm may want to compete for a label.

Keywords: eco-label, quality signaling, monopoly, credence goods
JEL Classifications: C72; D21; D82; L15

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1. Introduction

As concerns on environmental problems and human rights are increasing around the world, many consumers turn to be green consumers who prefer eco-friendly or ethical products to normal ones (Cherian & Jacob, 2012; Dahm et al., 2009; Paço et al., 2013). Eco-friendly goods are produced and can be disposed with less harm methods to an environment, e.g. organic food and recycled paper. Moreover, the production of ethical goods like fair trade products as well as cruelty free cosmetics is less baleful to society.

Despite the fact that a number of consumers who prefer ethical goods, especially young consumers, are increasing, they still struggle to transform their attitudes to actual purchase behaviors. Credence characteristic of green products is one of the reasons behind this situation. Ethical qualities are not revealed to consumers though they had consumed the products (Nelson, 1970). Consumer purchase decisions, therefore, depend on their own trust to the companies. With this characteristic, quality signaling is essential for ethical companies to attract more customers. Advertising and self-proclaiming are popular signaling but customers often doubt its reliability (Atkinson & Kim, 2015). Thus, eco-certification from a third partyis more interesting to firms. The ethical label pinpoints that the products are produced and managed by environmentally desired technologies which meet the certifier standard. Besides, it is better than self-declaration as it eliminates a duplication of certification costs according to Auriol and Schilizzi (2003). There are many famous eco-labels which have different specific purposes provided by trustworthy organizations around the world, mainly in developed countries, such as USDA Organic, Fair Trade USA Certified, Dolphin-Safe and The Blue Angels.

Various theoretical models are developed to confirm the usefulness of an eco-label. Unsurprisingly, perfectly accurate eco-label is the fruitful ethical quality signal (Auriol & Schilizzi, 2003; Baltzer, 2012; Bonroy & Constantatos, 2008; Bottega & De Freitas, 2009; Fanelli, 2008; Ibanez & Stenger, 2000; Zago & Pick, 2004). Nevertheless, eco-labels are rarely perfect owing to the expensive monitoring costs. Then the question about the effectiveness of an imperfect eco-certification arises because consumers might not take an uncertain label into account when they purchase.

However, plenty of researches still supported the benefits of an imperfect certification. For example, the eco-label provides information about product ethical qualities (Giannakas, 2002; McCluskey, 2000). Additionnally, De and Nabar (1991), Strausz (2010), Mason (2006), and Mason (2011) studied a competitive market model with an uncertain eco-certification. Environmental friendly firm may fail to be awarded a label and conventional firms may not. Only a pooling equilibrium exists in De and Nabar (1991) model. While, Strausz (2010) model which consumer behavior is included showed that a separating equilibrium that only the high-quality firms apply for certification exists. The more expensive test cost or the higher monitoring accuracy lead the conventional firms to stay unlabeled. In addition, green technology becomes more preferable (Mason, 2006). Anania and Nisticò (2004) concluded that the ethical firms prefer an imperfect to non-monitoring when firms are risk averse.

Separating equilibrium also exists in a monopoly model of Pavlinović (2013), but only type II error (brown firm may be labelled) is considered there. Furthermore, in a duopoly setting, eco-labeling decreases the pollution level (Ibanez & Grolleau, 2008). In this case, an eco-label as well as a separating equilibrium exist in some certification fees, yet a pooling equilibrium does not exist. Moreover, an eco-label is welfare enhancing

compared with an absence of eco-label (Bottega & De Freitas, 2013). In Grover and Bansal (2015) Cournot game, if the chance of green firm passing the test is high enough, the minimum test cost for a separating equilibrium equals to zero thanks to the higher profit of the conventional firm from product differentiation.

It seems clear that most existing studies focus on perfect competitive market which firms have no market power to set their own price. Thus, the price signaling is not allowed. Furthermore, a study with the monopoly setting did not include the chance of having type I error. Additionally, the cost of certification is given. It may not capture all possible behaviors of the firm in real life. Therefore, this research aims to answer the effectiveness of an imperfect certification as ethical quality signaling and provide the implications to certifiers. The setting is based on a signaling game between a monopolist firm and consumers. A firm tries to send a quality signal through a label and price.

Consumer beliefs are updated by using Bayesian inference. Unlike the study of Pavlinović (2013), this model includes both type I and type II errors in the certification system which never done before. In addition, this model is also adopted vertical product differentiation idea. Consumers vary in term of their willingness to pay for green products but not for normal goods since it defines the size of demand for ethical goods.

This study is divided in to 6 parts. The first part presents the structures of the model and other assumptions. The second and third parts show the firm optimal price strategy and the eco-labeling equilibria including their necessary conditions, respectively. The forth part expresses the numerical examples of the model and the result discussion. The fifth part provides the conclusions, policy implications and a discussion of the role of eco-labels. Besides, limitation and further study are presented in the final part.

2. Model

2.1 Players

There are 3 players which are nature, a producer, and consumers. Nature only assigns a type of the producer or firm at the beginning of the game. A monopoly firm can be green or brown with positive probability λ and 1-λ, respectively. The firm observes own type and it is private information. Products of each type vary on discrete ethical qualities, q_g for a green firm and q_b for a brown firm, where $q_g > q_b$. Both types of firms carry constant unit cost equal to c_g and c_b, respectively, where $c_b < c_g$. In addition, the model is simplified by assuming $c_b = q_b$ so as to make brown firm obtains only zero profit in the full information case. Firm profit (π_i)- as follows:

$$\pi_i = d_i(p_i - c_i) \tag{1}$$

; where $i \in \{b, g\}$ indicates type of products.

Moreover, take-it-or-leave-it strategy is applied in this model. In the final stage, each consumer chooses over purchasing a product or not purchasing anything. They have the homogenous willingness to pay for brown products, which is equal to one. Nonetheless, consumers are different in willingness to pay for green products, represented by θ. It is assumed to be uniformly distributed with a unit mass and $\theta \in [1, \bar{\theta}]$. Thus, if consumers access full information of firm type (a benchmark scenario), net utility of purchasing product i (U_i) depends on ethical level of the purchased product (q_i), and dis-utility from cost of consumed goods (p_i) as Eq. 2:

$$U_i = \begin{cases} \theta q_g - p_g & \text{if he consumes a green product.} \\ q_b - p_b & \text{if he consumes a brown product.} \\ 0 & \text{if he does not consume.} \end{cases} \quad (2)$$

Nevertheless, according to characteristics of credence goods, consumers cannot observe product ethical qualities directly, but they know the distribution of product quality after nature allocating the firm type. Utility of purchasing products in the market (U_{Eq}) is conditional on the expected product ethical quality and becomes as follows:

$$U_{Eq} = \begin{cases} \theta \tilde{q}_{Eq} - p_{Eq} & \text{if he consumes a good.} \\ 0 & \text{if he does not consume.} \end{cases} \quad (3)$$

; where $\tilde{q}_{Eq} = \lambda q_g + (1-\lambda) q_b$ (4)

indicates expected ethical quality of products in pooled market.

Three model scenarios are considered: full information, incomplete information without label, and incomplete information with label scenario. In the full information scenario, consumers completely observe the firm type. Consumers are unable to observe the firm type in the incomplete information scenario. However, eco-label is added in the third scenario.

2.2 Eco-label

In the incomplete information with label scenario, both types of firm can apply for an eco-label in the second stage with an application cost equal to *A*. However, the test is not perfect, green and brown types pass the test with the probability α and β, respectively, where $0 < \beta < \alpha < 1$ and $\alpha > 0.5$. In other word green and brown types fail the test with the probability 1-α and 1-β, respectively. The application cost (*A*) and the probability of obtaining eco-label are known to everyone at the beginning of the game. For the firm who does not apply for a label, the profit function is Eq. 5, but for the firm who applies for an eco-label, *A* is subtracted from the profit as Eq. 6. Then a firm sets price that maximize its profit in the third stage.

$$\pi_{i,nl} = d_{nl}(p_{i,nl} - c_i) \quad (5)$$

$$\pi_{ij} = d_j(p_{ij} - c_i) - A \quad (6)$$

; where $j \in \{nl, l\}$ indicates market of products.

Consumers observe the distribution of products quality but do not observe the firm decision on eco-label application (A or NA). Green firm may apply for label with probability δ_g and δ_b for brown firm, where $0 \le \delta_g \le 1$ and $0 \le \delta_b \le 1$. Thus, consumers update their beliefs of firm type from an observed eco-label and price before they make the purchase decision. Therefore, the utility from consumption (Eq. 7) depends on an expected ethical quality ($\tilde{q}_j$) instead of the unobserved true quality. Besides, the stages of the game and game tree are shown in Fig. 1 and Fig. 2, respectively.

$$U_j = \begin{cases} \theta\tilde{q}_l - p_l & \text{if he consumes a good with label and } q_b < \tilde{q}_l \le q_g. \\ \theta\tilde{q}_{nl} - p_{nl} & \text{if he consumes a good without label and } q_b < \tilde{q}_l \le q_g. \\ \tilde{q}_j - p_j & \text{if he consumes a good in either market and } \tilde{q}_j = q_b. \\ 0 & \text{if he does not consume.} \end{cases} \quad (7)$$

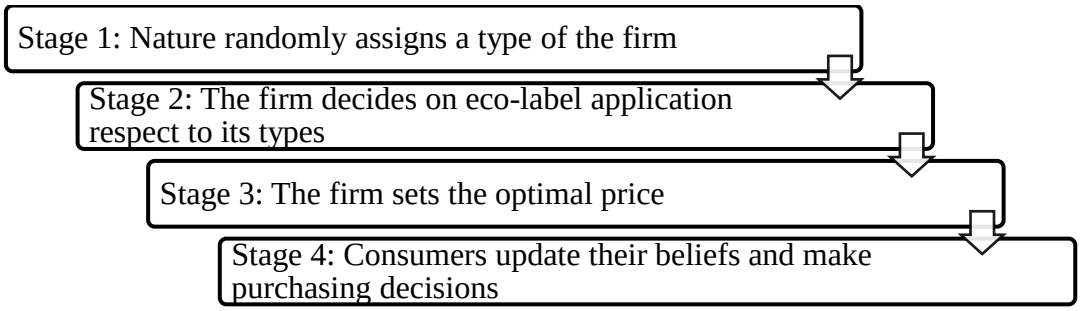
The expected quality in *j* market are as the following equations:

$$\tilde{q}_l = E(q \mid l) = \mu q_g + (1-\mu) q_b \quad (8)$$

$$\tilde{q}_{nl} = E(q \mid nl) = v q_g + (1-v) q_b \quad (9)$$

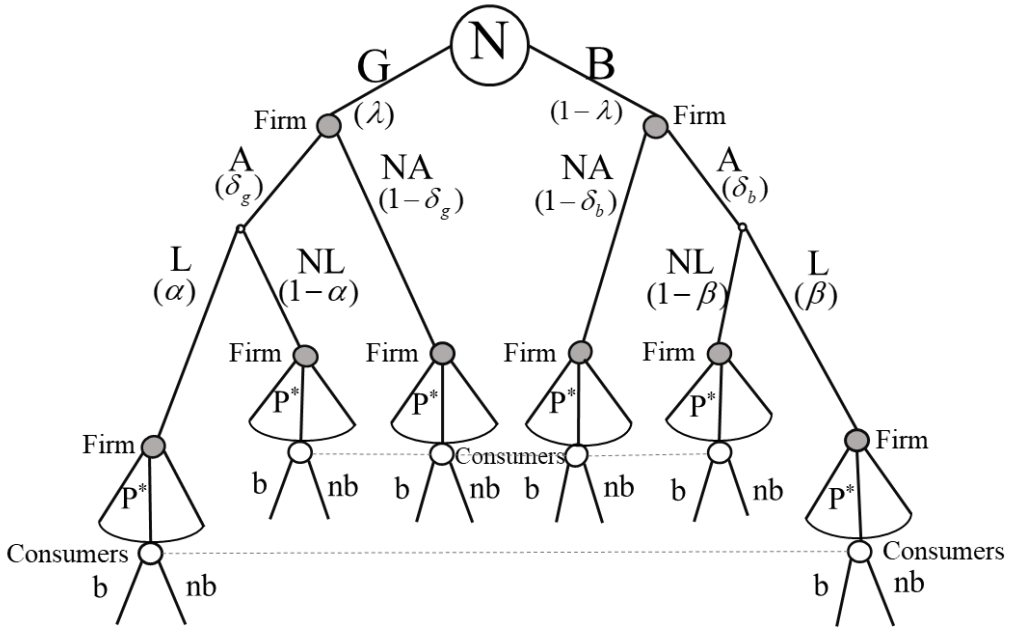
; where μ and v represented the probability of buying green product when observed label and when not observed label, respectively.

Figure 1**:** Game Stage



Source: Authors' explanation.

Figure 2**:** Game tree



Source: Authors' explanation.

There are numerous equilibria happened in this model. In this paper, the Perfect Bayesian Equilibrium is considered. The price equilibria are explained first and then followed by the labeling equilibria.

3. Price Equilibria

In a benchmark scenario, consumers are able to observe product type. If the products are brown, each consumer consumes a product. However, brown type is forced to set the price at q_b and gains zero profit. If the products are green, only consumers who has the willingness to pay greater than the critical one (Eq. 10) buy a product. With the demand for green products (Eq. 11), green firm sets the monopoly price (Eq. 12) and receives positive profit (Eq. 13).

$$\tilde{\theta}_g = \frac{p_g}{q_g} \tag{10}$$

$$d_g = \frac{\bar{\theta} q_g - p_g}{q_g(\bar{\theta} - 1)} \tag{11}$$

$$P_g = \frac{\bar{\theta} q_g + c_g}{2} \tag{12}$$

$$\pi_g = \frac{(\bar{\theta} q_g - c_g)^2}{4 q_g(\bar{\theta} - 1)} \tag{13}$$

Nonetheless, if the information is incomplete, these prices are no longer maximize the profits in every condition. Demands for good in the pooled market (Eq. 14) that used for price setting are constructed from Eq. 3 and 4.

$$d_{Eq} = \frac{\bar{\theta} \tilde{q}_{Eq} - p_{Eq}}{\tilde{q}_{Eq}(\bar{\theta} - 1)} \tag{14}$$

There are two equilibria in this case, separating and pooling equilibria. Firstly, separating equilibrium implies that different types of firm will set different prices. Therefore, the price can reveal the type of products to consumers. In contrary, pooling equilibrium exists when both types set the same price. Unfortunately, type is not implied from the price.

Proposition 1. The separating equilibrium where green firm sets $P_{g,Eq}$ and brown firm sets $P_{b,Eq}$, where $P_{g,Eq} \neq P_{b,Eq}$, never exists.

Proof: If each type of firm maximizes profit with respect to the price by using the first order condition and $q_b < \tilde{q}_{Eq} \leq q_g$, the prices for each firm type are Eq. 15 and 16.

For green firm, $$P_{g,Eq} = \frac{\bar{\theta} \tilde{q}_{Eq} + c_g}{2} \tag{15}$$

For brown firm, $$P_{b,Eq} = \frac{\bar{\theta}\tilde{q}_{Eq} + c_b}{2} \quad (16)$$

With regard to these or any different prices, consumers update their beliefs. Therefore, consumers know exactly the firm type from the price. Since they believe that green firm faces with the higher production cost than brown firm does, products with $P_{g,Eq,}$ should be green and products with $P_{b,Eq}$ are brown. Due to the fact that consumers do not purchase any brown products with the price $P_{b,Eq}$ which is greater than q_b, brown firm wants to deviate from this equilibrium and not willing to set this price.

Proposition 2. The pooling equilibrium where both green and brown types set $P_{g,Eq}$ always exists.

Proof: If both types of firms set the same price, consumers are unable to distinguish between green and brown products. Brown firm definitely plays as green and enjoy positive profit. As green firm cannot depart from this condition, many of pooling equilibria exist. However, the price $P_{g,Eq}$ (Eq. 15) Pareto dominates other prices, since green firm reaches the maximum profit (Eq. 17) with this price. Brown type gains positive profit as stated in Eq. 18.

$$\pi_{g,Eq} = \frac{(\bar{\theta}\tilde{q}_{Eq} - c_g)^2}{4\tilde{q}_{Eq}(\bar{\theta} - 1)} \quad (17)$$

$$\pi_{b,Eq} = \frac{(\bar{\theta}\tilde{q}_{Eq} - c_g)(\bar{\theta}\tilde{q}_{Eq} - (2c_b - c_g))}{4\tilde{q}_{Eq}(\bar{\theta} - 1)} \quad (18)$$

Due to Proposition 1 and 2, price is not an effective quality signal in an incomplete information market. Without an eco-label, brown firm sets the same price as green firm does (Eq. 15) to copy the green. Even though either type of firm gathers positive profits in this scenario, green firm receives less profit than that its receives in the first case.

4. Labeling Equilibria

This part explains conditions that make an eco-label becomes the effective quality signal for environmentally friendly products. In the sense that the existence of a label can shape the behaviors of the firm and reveal its type to consumers. When including an eco-label, consumers update their beliefs on product type from their initial beliefs and their available information by using the Bayes rules. Then the probabilities that products with and without a label are green (μ and ν, respectively) become like the following equations:

$$\mu = \Pr(g \mid l) = \frac{\lambda\alpha\delta_g}{\lambda\alpha\delta_g + (1-\lambda)\beta\delta_b} \quad (19)$$

$$\nu = \Pr(g \mid nl) = \frac{\lambda(1-\alpha\delta_g)}{\lambda(1-\alpha\delta_g) + (1-\lambda)(1-\beta\delta_b)} \quad (20)$$

In each market, only consumers who have a level of willingness to pay higher than the critical level (Eq. 21) buy a product. Therefore, the demand for goods is derived from Eq. 7-9 and 19-20 then become as Eq. 22.

$$\tilde{\theta}_j = \frac{p_j}{\tilde{q}_j} \tag{21}$$

$$d_j = \begin{cases} \dfrac{\bar{\theta}\tilde{q}_j - p_j}{\tilde{q}_j(\bar{\theta}-1)} & \text{if} \quad q_b < \tilde{q}_j \le q_g \\ 1 & \text{if} \quad \tilde{q}_j = q_b \end{cases} \tag{22}$$

Given the demand for the firm's product (Eq. 22) and its type, itsets the price that maximize its profit (Eq. 5 and 6) in each market. The optimal price in this scenario (Eq. 23) is consistent with one in the second case in the sense that both types set the same price regardless of its true quality.

$$P_j = \frac{\bar{\theta}\tilde{q}_j + c_g}{2} \tag{23}$$

In this setting, the greatest willingness to pay ($\bar{\theta}$) is large enough to cover c_g over c_b so as to make sure that demand for all markets are positive. Moreover, according to the optimal price, the maximum profit for both types of firm become as the following equations:

For green firm who applies for a label:

$$\pi_{gA,j} = \frac{(\bar{\theta}\tilde{q}_j - c_g)^2}{4\tilde{q}_j(\bar{\theta}-1)} - A \tag{24}$$

For brown firm who applies for a label:

$$\pi_{bA,j} = \frac{(\bar{\theta}\tilde{q}_j - c_g)(\bar{\theta}\tilde{q}_j - (2c_b - c_g))}{4\tilde{q}_j(\bar{\theta}-1)} - A \tag{25}$$

For green firm who does not apply for a label:

$$\pi_{g,nl} = \frac{(\bar{\theta}\tilde{q}_{nl} - c_g)^2}{4\tilde{q}_{nl}(\bar{\theta}-1)} \tag{26}$$

For brown firm who does not apply for a label:

$$\pi_{b,nl} = \frac{(\bar{\theta}\tilde{q}_{nl} - c_g)(\bar{\theta}\tilde{q}_{nl} - (2c_b - c_g))}{4\tilde{q}_{nl}(\bar{\theta}-1)} \tag{27}$$

Firm profits in each market are determined by expected ethical quality of products in consumers' points of view. Green type can receive higher profit than brown type if it provides goods with a trustworthy label, but brown type does not. Separating equilibrium where only green or brown type applies to obtain a label is preferred to a pooling equilibrium. This is because it indicates the trustworthy of the certification. Both equilibria would be considered and explained in the following of this part. In equilibrium, consumers

have potential to infer which equilibrium they are in, and their expectations also meet with the actual decisions of the firm.

4.1.Separating Equilibria

4.1.1 Separating equilibrium with only green type applies for label but brown type does not

Consumers believe that green firm applies for an eco-label, but brown firm decides to provide unlabeled goods or $\{\delta_b, \delta_g\} = \{0,1\}$. Thus, labeled products are provided by green firm for sure ($\mu = 1$). Unlabeled products can be either green or brown products. Consumers evaluate that they can be green with probability v (; where $v = \frac{\lambda(1-\alpha)}{\lambda(1-\alpha)+(1-\lambda)}$). It is because there is a chance for green firm to fail the certification test. The expected product qualities in labeled and unlabeled goods market become $\tilde{q}_l = q_g$ and $\tilde{q}_{nl} = \frac{\lambda(1-\alpha)q_g + (1-\lambda)q_b}{\lambda(1-\alpha)+(1-\lambda)}$, respectively. If this equilibrium exists, it implies that an imperfect green certificate is effective due to the fact that consumers know that all labeled goods are green.

Proposition 3. The separating equilibrium where only green type applies for a label exists if $\underline{A}_{01} < A < \overline{A}_{01}$ and $\beta < k_{01}$;where

$$\overline{A}_{01} = \frac{\alpha(1-\lambda)(q_g - q_b)[\bar{\theta}^2 q_g e_{01} - f_{01} c_g{}^2]}{4q_g e_{01} f_{01}(\bar{\theta} - 1)} \tag{28}$$

$$\underline{A}_{01} = \frac{\beta(1-\lambda)(q_g - q_b)[\bar{\theta}^2 q_g e_{01} - f_{01}(2c_b - c_g)c_g]}{4q_g e_{01} f_{01}(\bar{\theta} - 1)} \tag{29}$$

$$k_{01} = \frac{\alpha(\bar{\theta}^2 q_g e_{01} - f_{01} c_g{}^2)}{\bar{\theta}^2 q_g e_{01} - f_{01}(2c_b - c_g)c_g} > 0 \tag{30}$$

$$e_{01} = \lambda(1-\alpha)q_g + (1-\lambda)q_b \tag{31}$$

$$f_{01} = \lambda(1-\alpha) + (1-\lambda) \tag{32}$$

Proof: According to the separating equilibrium conditions $E(\pi_g \mid a) > \pi_{g,nl}$ and $E(\pi_b \mid a) < \pi_{b,nl}$, the critical application costs are $\overline{A}_{01} = \alpha(\pi_{g,l} - \pi_{g,nl})$ and $\underline{A}_{01} = \beta(\pi_{b,l} - \pi_{b,nl})$.

Since $\pi_{g,l} - \pi_{g,nl} = \frac{(1-\lambda)(q_g - q_b)[\bar{\theta}^2 q_g e_{01} - f_{01} c_g{}^2]}{4q_g e_{01} f_{01}(\bar{\theta} - 1)}$ and

$$\pi_{b,l} - \pi_{b,nl} = \frac{(1-\lambda)(q_g - q_b)[\bar{\theta}^2 q_g e_{01} - f_{01}(2c_b - c_g)c_g]}{4q_g e_{01} f_{01}(\bar{\theta} - 1)}$$

where $e_{01} = \lambda(1-\alpha)q_g + (1-\lambda)q_b$ and $f_{01} = \lambda(1-\alpha) + (1-\lambda)$,

Eq. 28 and 29 are derived. However, this equilibrium may not occur for all label accuracy level, since $\overline{A}_{01} > \underline{A}_{01}$ if $\beta < k_{01}$; given Eq. 30.

This equilibrium which only green type applies for a label is the perfect Bayesian equilibrium, since no one wants to deviate. The key factors for achieving this equilibrium is the level of application fee and the amount of type II errors. The application fee should be in the appropriate level, namely higher than $\underline{A}_{01}$ but not greater than $\overline{A}_{01}$. Furthermore, the type II error should be as low as possible. The probability that brown type will be awarded a label needs to be sufficiently lower than that of the green type, in order to compensate the differences between cost of green and conventional productions. In other words, if green production is very expensive compared to the conventional one, the chance that green type can obtain an eco-label should be high enough to make certification profitable.

In this case, the existence of an eco-label with a proper amount of application fee allows the labeled good price to reach the benchmark green goods price (Eq. 12). However, due to the chance that green firm may fail to be labeled (type I error), unlabeled goods price is higher than benchmark brown product price (q_b).

The separating equilibrium with only brown type applies for a label does not exist. The reason is quite clear, so the mathematical proof is not shown here. If this equilibrium exists, all labeled goods are certainly In this case, consumers believe that eco-label represents low ethical quality. Consumers prefer to consume an unlabeled goods. Either green or brown type is better off by not requesting for the label and selling unlabeled products at the average price.

4.2.Pooling Equilibria

4.2.1. Pooling equilibrium that both types do not apply for a label

This part considers the equilibrium that both types of firm choose the same application decision. Note that no one applies for an eco-label implies $\{\delta_b, \delta_g\} = \{0,0\}$. With regard to this belief, the market for labeled goods does not exist. Whether green or brown products are provided unlabeled products. The expected ethical quality in this market is Eq. 4. Consumer utility becomes the same with the absence of a label scenario. Besides, the optimal price and the maximum profits are the same as those in the second scenario (Eq. 15, 17 and 18). Let μ^* represents the probability that labeled goods are green in consumer viewpoints, where $0 \le \mu^* \le 1$. Therefore, the expected quality in a labeled goods market is $\tilde{q}_l = R = \mu^* q_g + (1-\mu^*)q_b$.

Proposition 4 If $0 \le \mu^* \le \lambda$, the pooling equilibrium where no one applies for a label exists for any positive application fees. In the case that $\lambda < \mu^* \le 1$, this equilibrium occurs if $A > \max\{\underline{A}_{00}, \underline{A}_{33}\}$; where

$$\underline{A}_{00} = \alpha \frac{(\mu^* - \lambda)(q_g - q_b)[\bar{\theta}^2 R\tilde{q}_{Eq} - c_g^2]}{4R\tilde{q}_{Eq}(\bar{\theta} - 1)} \tag{33}$$

$$\underline{A}_{33} = \beta \frac{(\mu^* - \lambda)(q_g - q_b)[\bar{\theta}^2 R\tilde{q}_{Eq} - (2c_b - c_g)c_g]}{4R\tilde{q}_{Eq}(\bar{\theta} - 1)} \tag{34}$$

$$R = \mu^* q_g + (1 - \mu^*) q_b \tag{35}$$

$$\tilde{q}_{Eq} = \lambda q_g + (1 - \lambda) q_b \tag{36}$$

Proof: The followings, $E(\pi_g \mid a) < \pi_{g,nl}$ and $E(\pi_b \mid a) < \pi_{b,nl}$ are the pooling equilibrium conditions. Therefore, the critical application costs are $\underline{A}_{00} = \alpha(\pi_{g,l} - \pi_{g,nl})$ and $\underline{A}_{33} = \beta(\pi_{b,l} - \pi_{b,nl})$.

When $0 < \mu^* \leq 1$,

$$\pi_{g,l} - \pi_{g,nl} = \frac{(\mu^* - \lambda)(q_g - q_b)[\bar{\theta}^2 R\tilde{q}_{Eq} - c_g^2]}{4R\tilde{q}_{Eq}(\bar{\theta} - 1)}$$

and

$$\pi_{b,l} - \pi_{b,nl} = \frac{(\mu^* - \lambda)(q_g - q_b)[\bar{\theta}^2 R\tilde{q}_{Eq} - (2c_b - c_g)c_g]}{4R\tilde{q}_{Eq}(\bar{\theta} - 1)}$$

Eq. 33 and 34 are derived. Note that if $\mu^* \leq \lambda$, the profit differences become zero or negative. Thus, this pooling equilibrium exits for any positive application fees.

4.2.2. Pooling equilibrium that both types apply for a label

In the pooling equilibrium that both types of firm apply for a label, an eco-label is not effective as the one in the separating equilibrium conditions owing to the fact that both labeled and unlabeled products can be either green or brown products. However, the existence of an eco-label is better than its absence. Consumers are able to notice that labeled goods are more likely to be green than brown, thanks to the certification process.

Consumer beliefs are updated with $\{\delta_b, \delta_g\} = \{1,1\}$. They think that labeled or unlabeled products can be either green or brown products, namely $\mu = \frac{\lambda\alpha}{\lambda\alpha + (1-\lambda)\beta}$ and $\nu = \frac{\lambda(1-\alpha)}{\lambda(1-\alpha) + (1-\lambda)(1-\beta)}$ Hence, the expected qualities in labeled and unlabeled product markets are as follows:

For a labeled product market: $$\tilde{q}_l = \frac{\lambda\alpha q_g + (1-\lambda)\beta q_b}{\lambda\alpha + (1-\lambda)\beta}$$

For an unlabeled product market: $$\tilde{q}_{nl} = \frac{\lambda(1-\alpha) q_g + (1-\lambda)(1-\beta) q_b}{\lambda(1-\alpha) + (1-\lambda)(1-\beta)}$$

Proposition 5. The pooling equilibrium where either green or brown type applies for a label exists if $A < \min\{\bar{A}_{11}, \bar{A}_{22}\}$; where

$$\bar{A}_{11} = \alpha \frac{\lambda(1-\lambda)(q_g - q_b)(\alpha - \beta)[\bar{\theta}^2 e_{11}e_{22} - f_{11}f_{22}c_g^2]}{4e_{11}e_{22}f_{11}f_{22}(\bar{\theta}-1)} \quad (37)$$

$$\bar{A}_{22} = \beta \frac{\lambda(1-\lambda)(q_g - q_b)(\alpha - \beta)[\bar{\theta}^2 e_{11}e_{22} - f_{11}f_{22}(2c_b - c_g)c_g]}{4e_{11}e_{22}f_{11}f_{22}(\bar{\theta}-1)} \quad (38)$$

$$e_{11} = \lambda\alpha q_g + (1-\lambda)\beta q_b \quad (39)$$

$$e_{22} = \lambda(1-\alpha)q_g + (1-\lambda)(1-\beta)q_b \quad (40)$$

$$f_{11} = \lambda\alpha + (1-\lambda)\beta \quad (41)$$

$$f_{22} = \lambda(1-\alpha) + (1-\lambda)(1-\beta) \quad (42)$$

Proof: Since the critical application fees, $\bar{A}_{11} = \alpha(\pi_{g,l} - \pi_{g,nl})$ and $\bar{A}_{22} = \beta(\pi_{b,l} - \pi_{b,nl})$, are obtained from the pooling equilibrium conditions, $E(\pi_g \mid a) > \pi_{g,nl}$ and $E(\pi_b \mid a) > \pi_{b,nl}$.

Note that $\pi_{g,l} - \pi_{g,nl} = \dfrac{\lambda(1-\lambda)(q_g - q_b)(\alpha - \beta)[\bar{\theta}^2 e_{11}e_{22} - f_{11}f_{22}c_g^2]}{4e_{11}e_{22}f_{11}f_{22}(\bar{\theta}-1)}$ and

$$\pi_{b,l} - \pi_{b,nl} = \frac{\lambda(1-\lambda)(q_g - q_b)(\alpha - \beta)[\bar{\theta}^2 e_{11}e_{22} - f_{11}f_{22}(2c_b - c_g)c_g]}{4e_{11}e_{22}f_{11}f_{22}(\bar{\theta}-1)}$$

; where given Eq. 39-42, the critical application cost becomes as Eq. 37 and 38.

Nonetheless, neither $\bar{A}_{11}$ nor $\bar{A}_{22}$ completely binds for all level of parameters, so the upper bound application cost for pooling equilibrium would be $\min\{\bar{A}_{11}, \bar{A}_{22}\}$.

Similar to achieving separating equilibria, the amount of application fee plays the significant role in the pooling equilibria. However, the level of type I error may not be as much as important. As stated in Proposition 4, no firm applies for a label if the application cost is too high. Furthermore, the firm has more incentive to be labeled when the consumer beliefs toward the accuracy of the eco-label are strong, namely μ^* is close to 1. While, there are some implications from Proposition 5. Both types are willing to compete for being labeled if the application cost is sufficiently low regardless of type I error level. Although brown firm is not likely to be awarded label in the case with highly accurate certification, it still has an incentive to ask for it. It is because the credibility of a label allows it to receive much higher profit if it can pass the test.

Nonetheless, it is difficult to conclude which equilibria are expected to be seen if the parameters are not quantified. Furthermore, either type of equilibria can happen at some levels of fee and accuracy. The numerical examples and explanation are provided in the next section.

In any equilibrium, it is clear that green type gets lower profit than brown type if they sell products in the same market (Eq. 24-27). This is contrast to the results in full

information case which green firm gets positive profit and brown firm gains zero profit. If the monopoly firm can choose, conventional technology which provides higher profit may be selected. Consequently, green market collapses even consumers are willing to pay for green products.

Moreover, if the certifier sets application fee and the test accuracy that not satisfy either separating or pooling equilibria, the consumer expectation about the firm application decision will not meet with the firm action. In other words, an equilibrium does not exist. Therefore, the information about product types cannot infer to consumers.

5. Numerical Examples and Result Discussion

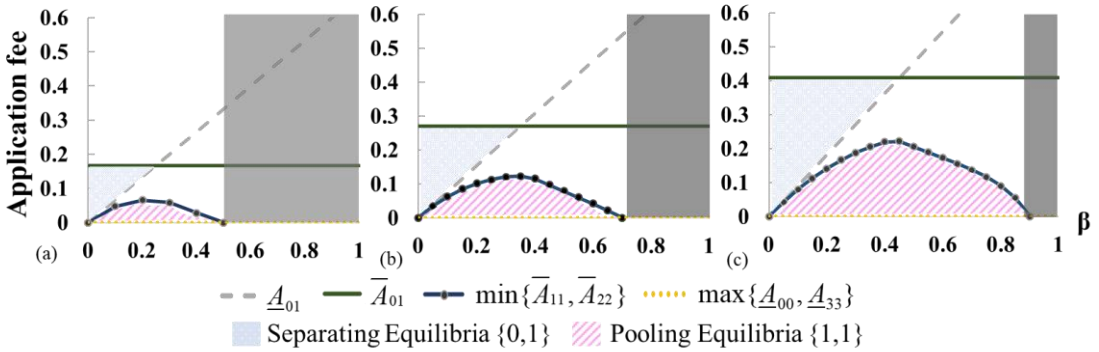
The area of each equilibrium from given parameter values will be shown in this part. This model assumes that a firm would be green with probability 0.5 ($\lambda = 0.5$). The marginal costs of each product type productions are the same as that product value. The unit cost of conventional good and its value are normalized to one ($c_b = q_b = 1$), so the unit cost of green good and its values represent relative cost and benefit compared with the conventional goods. They are assumed to be 2 ($c_g = q_g = 2$). The highest willingness to pay for green products is also set to be 2 ($\bar{\theta} = 2$). The numbers used in these examples are for simplification and represent the extreme case. Given the positive demand assumption on the willingness to pay parameter, the following results hold for the wide range of values.

As the accuracy of the certification plays an important role, we fix type I error (1-α) at 3 different levels and vary type II error (β). There are three simple cases shown in Fig. 3 which are determined by α, when α is very low, namely 0.5, when $\alpha = 0.7$, and when $\alpha = 0.9$. At any level of α, the separating equilibrium is more likely to occur when type II error is less likely, namely β is relatively small. This result supports the importance of the test accuracy.

However, for any positive value of fee and β, it is possible that both types of firm decide not to request for a label. Namely, pooling equilibrium {0,0} exits. The area of this equilibrium overlaps all other equilibria. Thus, it is complicated to expect the firm decision and which equilibrium will occur. This results from the entanglement of consumer's off-equilibrium belief. Additionally, both types are willing to apply for a cheap label (Pooling equilibrium {1,1} exits.). In the case that β is close to α (large type II error), we could predict that pooling equilibrium {0,0} is more likely to exist. The reason is that if the cost of untrustworthycertification is too high, a firm will not want to spend itsmoney on it.

Although type I error presents in this model, the evidences are in line with the previous study results. The higher effectiveness of a label requires sufficiently high application fee and a great chance for green type to obtain a label and in reverse for brown type. This result is similar to the model of Bottega & De Freitas (2013), but the accuracy of certification is also required in our study. Besides, this study found that an eco-label partly reveals information about product type to consumers when application fee is low and pooling equilibrium exists. This is due to the fact that labeled products are more likely to be green than brown. While the conditions for achieving an effective label of Pavlinović (2013) model are different due to the different setting. In that model, the markup price of labeled goods is needed to be high and able to cover the differences of labeling cost. Furthermore, the overlap area of separating and pooling equilibria exists in that model.

Figure 3**:** Area of equilibria on a space of β and the application fee in a monopoly numerical example. (a) $\alpha = 0.5$ (b) $\alpha = 0.7$ (c) $\alpha = 0.9$



6. Conclusion and Implications

6.1 Conclusion

This research shows the behaviors of a monopoly firm on its pricing and eco-labeling strategies when the information about the firm type is not fully revealed to consumers. However, this is not a normal signaling game, the firm may fail to send the signal. It is because the eco-certification which is an ethical quality signal is not perfect in the sense that both type I and type II errors occur.

In this case, it is clear that price is not an effective ethical signal for a firm, since a conventional firm always pretends to be an environmental-friendly firm by setting the same price as an eco-friendly firm does. Consumers do not reach to any further information about product qualities. Therefore, an adverse selection problem still happens if the label does not exist. If it is possible for a firm to apply for an eco-certificate, there is the case that the firm type may reveal or at least partly reveal to consumers. The eco-certification will be an effective quality signal when consumers can infer the firm types from the label information. This situation happens when the application fee lies in the appropriate range and the chance that brown firm might wrongly get the label is low enough. The appropriate application fee is sufficiently high to eliminate the application of conventional firms. It is because expensive fee lowers the firm expected profits that it can get when it decides to apply. Moreover, higher level of label accuracy makes it believe that it is less likely to obtain the label and it is better to provide unlabeled products. However, the appropriate application fee is still affordable for the ethical firm. Green firms that provided labeled goods are allowed to set the highest price that it can set when consumers are able to observe it type. Besides, with this price, it benefits from greater profit.

Firm types partially signal to consumers when the application fee is low according to the certification process. Both types are willing to afford the application fee and it is worth the risk. Any type accepts higher fee and competes for the label when consumers wholeheartedly trust the label. In contrary, if the application fee is extremely high, it might be the case that any firm type will not want to be labeled. Therefore, an eco-label does not improve the situation. Unfortunately, it is impossible to predict each firm certain labeling decision under specific application fee and accuracy level due to overlapped areas of equilibria.

The use of the eco-label helps green goods price adjust to a suitable level. Labeled goods are always expensive than unlabeled goods in any equilibria thanks to the certification process. Nevertheless, if green and brown types are in the same conditions, namely market. Brown type mostly gets higher profit than that green obtains since it has potential to pretend to be green. As a result, if the model allows the firm to choose their own type like the situation in the real world, it might choose to be a conventional firm instead of an ethical one.

The proper level of application fee is the important element behind the effective certification. Therefore, a certifier like government or environmental organization should research wellabout the cost of ethical technology, product ethical values and consumer willingness to pay as they determine the size of the critical application fee. In addition, the accuracy of certification is another key factor. Increasing the chance that green firm might get the label, while reducing the one of brown firm are needed in order to maintain the effectiveness condition. Nevertheless, to improve the testing preciseness, the higher monitoring costs are required for the certifier. This may significantly push the application fee up except the case of extremely low monitoring costs.

6.2 Eco-label and Further Challenging

The effective eco-label is able to be achieved despite its uncertainty according to the conclusion of this study. Credible labels attract more consumers than uncertain ones, but small green firms might not be able to benefit from them. The certifiers may have to tradeoff between keeping the application cost affordable for green firms and rising the fee to develop the test accuracy. In the case that consumers are willing to pay for expensive green products, the certifier has an opportunity to charge costly fee. Developing consumer attitudes toward green goods is also essential to improve the effectiveness of a label.

However, the implement of eco-labels may not be as successful as we are expected. This is because there are other difficulties. Eco-labels can be considered as the barrier of trade (Nimon & Beghin, 1999). Additionally, in consumer sides, they might have different purchasing behaviors compared to their attitude towards ethical products (Prakash, 2002). Thus, their willingness to pay and preferences are distinguished. While, various eco-labels and their standards may lead to consumer confusion (Nguyen & Du, 2010). The criteria of labels need to be clarified. Moreover, the credible of the label might be affected by consumers' attitude toward a certifier, which is difficult to control.

Eco-label can be successfully implemented. However, if the government and certifiers have no potential to set the proper application fee and prevent brown firm to lie, in the long run, green firm who faces high ethical cost is more likely to become brown and claim to be green instead. To support ethical market, the government needs to lower the ethical technology cost, such as developing alternative production methods, promoting the use of clean fuel and resources, and providing tax allowance. Besides, other ethical production policies like setting minimum environmental quality standard and prohibiting child labors are still essential to control overall externalities.

6.3 Limitation and Further study

This model provides basic insight on the firm and consumer behaviors under an imperfect eco-certification. The model is simplified by using uncomplicated cost and utility structures to make straightforward implications. Moreover, the role of government environmental policy is not included in this setting. Since the application fee does not take the certifier cost into account, the model can be developed by adding another player, a

certifier or the government. Therefore, the application fee can be freely adjusted. The optimal application fee from both firm and the certifier perspectives will be useful for further labeling policy. The model will be more realistic if both vertical and horizontal product differentiation are combined. In other words, consumers that unconcerned in ethical qualities may be included into the model.

Finally, this model does not only apply for the case of ethical products, but it can also be adopted to other cases of credence goods, like an industrial standard of supplement companies and other quality certifications. It is due to the fact that ethical products are one kind of credence products. The effects of an eco-label on social welfare and the effectiveness of the certification are left for further study. Besides, the processes of consumer trust development will be much clearer in the dynamic model. The certifier can require firms to pay both application and annual fees like the situation in the real world.

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