UNIVERSITATEA "CONSTANTIN BRÂNCUŞI"
DIN TÂRGU JIU

"CONSTANTIN BRÂNCUŞI" UNIVERSITY
OF TÂRGU JIU

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SIGNALLING GREEN TECHNOLOGY THROUGH PRICE AND ECO-LABEL

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Abstract

We apply signalling games to investigate the effect of environmental friendly technology on the adoption of eco-labels. The framework is information asymmetric because the consumers do not observe a firm type directly, but may infer it indirectly through the market price and eco-label. Also, we assume that eco-labels are unreliable since they imperfectly reveal the actual firm technology.

A monopoly signalling game is studied, where a firm is a sender, and a consumer is a receiver of two signals, price and eco-label. Since the purpose of eco-labels is to distinguish environmentally friendly producer type, we elaborate the factors which affect the existence of the separating equilibria.

We find necessary condition for the existence of the separating equilibrium in which both types extract the whole consumer surplus. Furthermore, if the labelling costs exceed the quality difference between the green and the brown type, then the separating equilibrium does not exist. While the pooling equilibrium without eco-labelling exists for any set of parameters, we identify the parameters' values under which the pooling equilibrium with eco-labelling does not exist.

Key words: *signalling game, green firm, eco-labelling*

1. Introduction

Eco-certification becomes an important part of the business practices. For instance, [19] show that ISO 14000 certification impacts positively firms' profitability. Author in [15] also points out that the number of firms which obtained an eco-label has rapidly increased. In this paper we explore the effect of environmentally friendly technology on eco-labelling practices. We study the information asymmetry problem which is similar to the one formalised in [1]. A framework with credence good is applied, so that the actual product type (green or brown) is not observed by the consumer, even after purchase and consumption, but is known by the firm. The difference between credence, experience and search goods is explained in [12].The concept of credence good is usually applied to study environmental technology choice. For example, [16] differs dirty and clean producer technology which "is known to the firm but not to the consumer". Similarly, [15] points out that "eco-labelled goods are closely related to credence goods". Different mechanisms may be applied to resolve information asymmetry, such as branding, warranties, licensing and certificates [6]. In the context of environmentally friendly technology, the focus is on eco-labelling. One can consult [14] for the basic definitions and aspects of eco-labelling.

There are two important issues about eco-labelling emphasised by many authors (for instance, [15], [13] and [17]): the costs of labelling and the reliability (which may be correlated). The process of obtaining an eco-label may be rather costly (see [13] and [17]) so that many environmentally friendly products are not labelled. An effort to decrease the costs of eco-labelling may result with a decrease in reliability of eco-labels, so that eco-labels may fail to diminish the information asymmetry [18]. Scepticism surrounding organic good labels and distrust of consumers are identified in [10] as important issues. Authors in [4] on page 115 point out that environmental label may sometimes be "unable to discriminate environmentally friendly products from other products even with an eco-label". Sustainability labels should improve consumer awareness. However, a strong increase in labelling claims on food products in recent years increased the risk of consumer confusion and information overloading [2].

Two solutions to the information asymmetry problem related to adoption of environmentally friendly technology are proposed in [15]. One is signalling by price and another is eco-labelling. There is a branch of literature which studies price signalling (e.g. [9], [5], [11]) which proposes various mechanisms which enable signalling buy price, from advertising, word-of-mouth, to the difference in costs of production and oligopolistic setting.

The last mechanism is applied to the context of environmental technology in paper of [16]. However, since eco-labels may be unreliable they may as well serve as signals. This effect is captured in the game proposed by [12] where the consumer observes an eco-label but still does not observe the product type. Thus, we construct a similar signalling game where the firm may signal her choice of technology through an eco-label. Thus, we elaborate the signalling properties of an eco-label.

2. Model

There is a single firm in the market with two traits: friendly behaviour and eco-labelling practices. Environmentally friendly behaviour refers to the firm's polluting practices, and in this respect there are two types of firm: green and brown. Green type undertakes necessary measures to decrease environmental impact of its activities which is costly. Brown firm does not have such costs since it does not care about the environmental impact of its activities and products. In fact, [4] point out that the green products are generally more labour intensive and/or produced at a small scale. On the contrary, the brown (polluting) firms avoid such costs by ignoring environmental impacts of their business practices. However, here we suppose that both firms, green and brown, have the same production costs because we focus on effects of eco-labelling and this simplification does not affects results. Furthermore, we assume that eco-labelling is not reliable and we capture this by allowing to the brown firm to obtain an eco-label, but at a higher cost. Thus, eco-label cost of green and brown firm is c_g and c_b respectively, where $c_g < c_b$.

The consumers are homogenous and there is a vertical product differentiation so that the consumers prefer the green product to brown one. Furthermore, unit money metric consumer utility function is assumed, like in [3], so that the consumer surplus is equal to $\theta - p$ or $\theta - q$ where $\theta \epsilon \{g,b\}$ and $g>b$. Since we imply a vertical product differentiation, all the consumers prefer the less polluting technology. However, environmental friendliness may be viewed as well as horizontal or public characteristics which are discussed in [4] while [8] differentiate polluting and non-polluting technology both vertically and horizontally.

The producer observes his technology (brown or green) and chooses price and eco-label. The consumer does not observe the technology, but his buying decision is based on Bayesian beliefs which consumer constructs after observing the price and the eco-label implementation. The consumer knows the probability that the green technology occurs. Therefore, the consumer makes buying decision based on the expectation about technology. The price of a product with an eco-label cannot exceed the expected consumer utility after the consumer observes signals based on the Bayesian updating:

$$p \leq \mu g + (1 - \mu)b = E[\theta|p]$$

where $b \leq p \leq g$. μ is an updated probability that the firm is green if it holds an eco-label. Non-labelled product can be green or brown as well, so its price cannot surpass the consumer expected utility:

$$q \leq vg + (1 - v)b = E[\theta|q]$$

where $b \leq q \leq g$. v is an updated probability that the firm is green if it does not hold an eco-label. It is evident that prices p and q may both vary from 0 to g. Since we consider a monopoly framework it is reasonable to consider prices from b to g.

The firm profit is a difference between the price and accompanying costs. Depending on the firm technology and eco-labelling choice the profit is defined as follows, where π_{GL}, π_{GN}, π_{BL} and π_{BN} refer to green labelled, green non-labelled, brown labelled and brown non-labelled firm respectively:

$$\pi_{GL} = p - c_G$$
$$\pi_{GN} = q$$
$$\pi_{BL} = p - c_B$$
$$\pi_{BN} = q$$

If the consumer refuses to buy the product, the firm profit is zero.

The game

We define a two-stage game with three players: *nature, firm and consumer*. The players make choices in the following order: (1) nature chooses the producer type (technology) $\theta \in \Theta$; (2) based on the private information about his technology, the producer chooses if to eco-label his product; (3) the producer chooses price; (4) the consumer observes labelling decision and accompanying price *p* or *q* and makes buying decision $x \in \{0,1\}$.

It is evident from the structure that this is a signalling game with two signals, label and accompanying price. The consumer does not observe the actual technology but observes the signals.

We apply the definition of *the signalling equilibrium* provided in [7] on our model. Pair of price and labelling decision, and consumer buying decision which are the best responses to each other constitute the signalling equilibrium if the supporting consumer posterior beliefs about the producer type after observing price and label are based on the Bayesian updating.

The signalling equilibrium may be separating, such that different types choose different eco-labelling practices, or it can be pooling such that both types choose the same eco-labelling practice (both types apply the label or both types do not apply the label).

An important condition for the existence of the separating equilibrium is the *single-crossing property*. Applied to our model, the types will separate (the green type labels the product while the brown type does not label the product) if:

$\pi_{GL} > \pi_{GN}$ and $\pi_{BL} < \pi_{BN}$

$p - c_G > q$ and $p - c_B < q$

$c_B > p - q > c_G$

(Please, note that the opposite case, $\pi_{GL} > \pi_{GN}$ and $\pi_{BL} < \pi_{BN}$ is not possible, because that would require that $c_B < c_G$ which is opposite to the relevant assumption in this model.)

Implications of the monopoly assumption: The producer sets the maximum price at which the consumer buys the product. If the consumer belief $\nu(q) = 0$ for all *q*, then the maximum price of non-labelled product at which the consumer buys is *b*. Since the producer chooses the maximum equilibrium price, in the subsequent analysis of the signalling equilibria we focus on the maximum equilibrium price which we denote by *p'* and *q'*.

2.1. Existence of signalling equilibria

c_G, c_B, *g* and *b* can be in various ratios, which predetermines the existence of the separating (signalling) equilibria.

There are three possible cases:

Case 1: $c_B > g - b > c_G$

Case 2: $c_B > c_G > g - b$

Case 3: $g - b > c_B > c_G$

Since *q*=*b* is fixed, we can only consider different values of *p'*, but which cannot exceed *g*. We define $\underline{p} = c_G + b$ and $\bar{p} = c_B + b$ as lower and upper bound of *p'* in the separating equilibrium. In other words, if *p'* is within these bounds the separating equilibrium exists.

Case 1: The signalling equilibrium exists if $p' > \underline{p}$.

Case 2: The signalling equilibrium does not exist. (There are no beliefs which support the signalling equilibrium). The pooling equilibria with labelling do not exist.

Case 3: The signalling equilibrium exists *if* $\underline{p} < p' < \overline{p}$.

We provide the proofs which are related to the listed cases.

Proposition 1: *If and only if* $c_B > g - b > c_G$ *, there exists a separating equilibrium such that the green type sets price p=g, and the brown types sets price q=b.*

Proof of Proposition 1:

Suppose that *v(b)=0* at any *q*. Furthermore, suppose that consumer buys at any $p \in (0, g]$. The best response of the green type is to set *p=b* because in such a case he obtains profit $g\text{-}c_G$ which is larger than *b-e* and it is larger or equal to any $b\text{-}c_G$.

The best response of the brown producer is to set *q=b* because in such a case he obtains profit *b* and $b > g\text{-}c_B \geq p\text{-}c_B$.

The beliefs based on the Bayesian updating at a given price include only a type who chooses such a price in the equilibrium. Thus, this equilibrium is supported by beliefs *μ(g)=1* and *v(b)=0*. At out-of-equilibrium prices, the beliefs can be set arbitrarily. ■

Proposition 2 shows the existence of the separating equilibria in Case 1 and Case 3.

Proposition 2: *If* $c_B > p' - b > c_G$ *there exists a separating equilibrium such that the brown types sets price q=b, green type sets p' and Bayesian belief are* $\mu(p) = 1 \forall p \in [0, p']$ *and* $\mu(p) = 0 \forall p > p'$.

Proof of Proposition 2:

Suppose that *v(b)=0* at any *q*. The best response of the green type is to set *p'* because in such a case he obtains profit $p'\text{-}c_G$ which is larger than *b*. The best response of the brown producer is to set *q=b* because in such a case he obtains profit *b* and $b > g\text{-}c_B \geq p\text{-}c_B$.

The beliefs are based on the Bayesian updating at a given price include only the type who chooses such a price in the equilibrium. Thus, this equilibrium is supported by beliefs *μ(p')=1* and *v(b)=0*. At out-of-equilibrium prices $p \in [0, p')$, the beliefs can be set arbitrarily because neither green nor brown type deviates to such prices. Green type does not deviate because $0 \leq p - c_B < p' - c_B$. Brown type does not deviate as well because $p' - c_B > p - c_B$.

At out-of-equilibrium prices *p>p'*, *μ(p)* must be such that $E[\theta|p] < p$. That is, $\mu(p)g + (1 - \mu(p))b < p$; $\mu(p)(g\text{-}b) < p\text{-}b$. ■

Corollary 1: *Since condition* $\mu(p)(g\text{-}b) < p\text{-}b$ *for prices p>p' must be satisfied in order to sustain the signalling equilibrium, it follows that as out-of-equilibrium prices increases, a larger value of out-of-equilibrium belief μ(p)can support the signalling equilibrium.*

By this we exhaust all the separating equilibria. One can note that we consider *q=b* only. The reason for this is the following. Since the producer is a monopolist, than he will set the maximum price at which the consumer buys the product. We consider only pure strategies and beliefs *v(q=b)=0*. From this follows that the maximum price of non-labelled product at which the consumer buys is *q=b*. There are no beliefs which can force the producer to decrease price *q* bellow *b*. In an oligopoly price *q* could be set bellow *b* due to the competition.

2.2. Existence of pooling equilibria

If the single crossing property is not satisfied, then the pooling equilibrium emerges. There are two types of pooling equilibria, one where green and brown producers label the product, and another where both abandon the labelling practice.

The pooling equilibria may emerge due to the technical reasons (levels of labelling costs, *g* and *b*), or due to the consumer beliefs.

Firstly we elaborate the technical reasons. Proposition 3 refers to pooling equlibria without labelling and to separating equilibria in Case 2. In this case the pooling equilibria with labelling do not exist.

Proposition 3*: If $c_B>c_G>g-b$, then, there exists a multiplicity of pooling equilibria with $q'\leq \alpha g+(1-\alpha)b$ whereas the separating equilibria do not exist.*

Proof of Proposition 3:

If $c_B>c_G>g-b$, there is no price *p'* between *b* and *g* which can cover the costs of labelling. Therefore, neither green no brown firm label their products.

We demonstrate by contradiction that $q'> \alpha g+(1-\alpha)b$ can not constitute the pooling equilibrium.

Suppose that the consumer beliefs are such that $q'> \alpha g+(1-\alpha)b$. Then, the best response of the both firm types is to set *q'*, but then the expected utility (based on the Bayesian belief) is negative since $q'>\alpha g+(1-\alpha)b$. Thus, the best consumer response is not to buy. Thus, $q'> \alpha g+(1-\alpha)b$ cannot constitute an equilibrium, and this is a contradiction.

Suppose that the consumer beliefs are such that $q'< \alpha g+(1-\alpha)b$. The best response of both producer types is to set *q'* and the best response of the consumer is to buy. Since some *q* such that $q'<q<\alpha g+(1-\alpha)b$ is an out-of-equilibrium price, the beliefs at *q* can be set arbitrarily, so that consumer expectation is lower than price and the best response of the consumer is not to buy at such a price. ■

Next, we elaborate the existence of the pooling equilibria due to the beliefs. We demonstrate in Proposition 4 that the pooling equilibrium without labelling exists in all three cases.

Proposition 4: *For any values of parameters there exist equilibrium beliefs which sustain pooling equilibria where both firm types do not label.*

Proof of Proposition 4: Consider an out-of-equilibrium price *p'* such that $b<p'<c_G+b$. Then the best response of the green type is not-label and set $q=b$ since $p'-c_G<b$. If the consumer beliefs above p' are such that the consumer does not buy, then the separating equilibrium does not exist and both producer types do not label and set the same price. ■

In proposition 5 we demonstrate under which particular condition the pooling equlibria with labelling exist. Corollary 2 emphasises that there is a set of parameters under which the pooling equilibrium with labelling does not exist even in Case 3.

Proposition 5: *If $g-b>c_B>c_G$ and if $\alpha g+(1-\alpha)b>c_B+b$ there exists a pooling equilibrium such that all types set price p'.*

Proof of Proposition 5: *If $p'>c_B+b$,* i.e. $p'-c_B>b$, then the best response of the brown firm is to label and set *p'*. Since $\alpha g+(1-\alpha)b>p'$, the best response of the consumer is to buy at *p'*. Thus *p'* constitutes the pooling equilibrium. ■

Corollary 2: *If $g-b>c_B>c_G$ and if $c_B+b>c_B>\alpha g+(1-\alpha)b$ there does not exist a pooling equilibrium in which both types label.*

Proof of Corollary 2: *If $p'>c_B+b$,* i.e. $p'-c_B>b$, then the best response of the brown firm is to label and set *p'*. Since $p'>\alpha g+(1-\alpha)b$ the best response of the consumer is not buy. Thus, the pooling equilibrium with labelling does not exist. ■

2.3. The discussion

In order that the separating equilibrium exists, relevant conditions applying to green and brown producer type need to be satisfied. Before we proceed with the elaboration, we comment the relation between the consumer beliefs and prices.

Please, not that as the price increases, the higher believes that the product is green need to hold in order that the consumer is ready to buy the product. I.e. as Corollary 1 point out, the larger set of out-of-equilibrium beliefs for the prices about the equilibrium price of the labelled product sustain the separating equilibrium.

The difference in prices of labelled and non-labelled product must be sufficiently large relative to the cost of labelling of the green producer. In other words, if the price of non-labelled product is sufficiently large, then non-labelling practice may become attractive even for the green producer. Thus, the key is in keeping the cost of labelling for the green consumer sufficiently small. In other words, in order to create efficiently eco-labelling program, Case 2 needs to be avoided.

If the difference between the prices is too large relative to the costs of eco-labelling for brown producer, then the brown producer may deviate and eco-label his product. However, under particular set of parameters this cannot be the case, which is elaborated in Proposition 5 and Corollary 2. Namely, if $c_B<g-b<c_B/\alpha$, then the pooling equilibrium with labelling does not exist.

We provide a summary of the mentioned cases in *Table 1*. The second column refers to cases defined in Section 2.1. One can note that separating equilibria exist only if particular conditions are satisfied. The least stringent conditions refer to the case where costs are sufficiently different compared to the difference in environmental impacts between two products. In this in is reasonable to study separating equilibria with labelling only since we neglect eventual differences in production costs between brown and green firm. Furthermore, we identified two sources of pooling equilibria: technical reasons and beliefs. Technical reasons refer to relationsips between actual prices, fraction of green types (prior probability that green type occurs), costs c_G and c_B, and technology g and b. The technical reasons can be responsible for the existence of pooling equilibria in both circumstances, with and without eco-labelling practices. The last column refers the existence of pooling equilibria without labelling due to appropriate consumer beliefs. It is always possible to find such consumer beliefs (which affect expectations about product) that consumer is ready to buy the product where both producer types set the same price.

Table 1: Equilibria existence

	CASE	EXISTENCE OF SEPARATING EQUILIBRIA	EXISTENCE OF POOLING EQUILIBRIA		
			TECHNICAL REASONS		BELIEFS
			with labelling	without labelling	
1	$c_B > g - b > c_G$	exists if $p'>c_G+b$	no	no	exists
2	$c_B > c_G > g - b$	no	no	exists if $q'>\alpha g+(1-\alpha)b$	exists
3	$g - b > c_B > c_G$	exists if $c_G+b<p'<c_B+b$	exists if $\alpha g+(1-\alpha)b>c_B+b$	no	exists

2.4. The policy implications

There are a few measures by which the government can assure the separating equilibrium. Firstly, c_G should be reduced to zero, while c_B should be raised. Focus and magnitude of these measures depends on the utility of the green product. More specifically, if the utility of the green product is relatively low, the cost of eco-labelling for such a product must be reduced. On the other hand, when the utility of the green product is very high, the crucial intervention is in the cost of eco-labelling the brown product. In such a case, the cost of labelling the brown product must be raised, so that the brown producer type does not take an eco-label.

Furthermore, the consumer expectations significantly influence the existence of signalling equilibria. In the case of the separating equilibrium, the beliefs placed on the green product after observing high prices of eco-labelled product should be close to one, and the opposite holds for the price of a non-labelled product. Thus, here

we arrive to the issue of eco-label reputation and reliability. The government may affect the reputation of an eco-label by increasing the transparency of the labelling process.

As the Bayesian updated beliefs constitute the separating equilibrium, an important factor is the level of prior belief α. For example, if α is very larger, then it is very likely that both, brown and green producer type, label their products.

3. Conclusion

Eco-labelling became widely applied tool to foster environmentally friendly business. However, the concerns about eco-labels trustfulness urges for a more comprehensive analysis of firms' motives with respect to eco-friendly business practices and eco-labelling.

We analysed the adoption of the eco-label by a firm with given technology (green or brown). We constructed a signalling game and we focused on the analysis of the separating equilibria. We conclude that the existence of the signalling equlibria depends first of all on the accessibility of eco-labelling to the green firms, and on the impediment for the brown firms to eco-label their products. Furthermore, the beliefs have an important role in eco-labelling. If the prior belief about eco-friendliness of an industry is very high, then the eco-labelling might not be very effective since the producers may have high expectations about the non-labelled product. The trust in eco-label is related to the posterior belief. If the consumer trusts the label, he will place high expectations on the eco-labelled product. We may speculate that if utility of a green product is very high, then one should focus on the impediments to eco-labelling of brown products. On the other hand, if the utility of a green product is rather low, it may crucial to reduce the eco-labelling costs of the green product in order to sustain the separating equilibrium.

There are many directions for improvements of this analysis and future research. One may consider the endogeneous technology and/or oligopoly framework. Furthermore, the equilibria can be refined by Intuitive Criterion and D1 refinements.

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