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Can Ecolabeling Schemes Preserve The Environment?

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Abstract: A three-stage game of production technology, signal and price competition is developed to study the impact of eco-labeling, in a duopoly model of vertical product differentiation. The production technology and the subsequent pollution level are non observable by consumers. The only way to inform consumers about the environmental quality of the product is to stick an ecolabel on it. However, a polluting firm may also usurp the ecolabel by incurring a certain cost. By assuming that consumers are altruistic and willing to pay for environmental quality, we show that ecolabels can reduce the pollution level. Finally and importantly, under restrictive conditions on labeling cost, ecolabeling can constitute to some extent an environmentally effective and economically efficient policy. However, ecolabeling cannot alone internalize the whole negative externality until the optimum point.

Key words: Altruism, Eco-labels, Duopoly; Environmental Policy.

JEL Classification Numbers: D11, D21, L15.

Can Ecolabeling Schemes Preserve The Environment?

1. Introductory remarks

Some consumers derive utility from buying and using products produced under specific processes, such as environmentally friendly practices (Cason and Gangadharan, 2002). At first glance, environmentally friendly products are similar to the conventional version of the same product, except than they are less harmful for the environment and frequently more expensive. In order to capture the consumers' willingness to pay, some producers market products labeled as 'environmentally friendly'. In the United States, the percentage of new product introductions which were claimed to be environmentally friendly rose from 1.1 percent in 1986 to 9.5 percent in 1999 (Wasik, 1996 quoted in Kirchoff, 2000; Market Intelligence Service, quoted in Kotchen, 2006). A 1998 study of on-pack claims in Belgium, France, Italy, Portugal and Spain found that 78% of 515 detergent products were carrying a green claim (Leubuscher, 1998).

On the consumer side, a 1996 survey in France, found that 54 percent of households indicated that they would be willing to pay up to 10 percent more for environmentally preferable products (EPA, 1998). Teisl et al. (2002) provide market-based evidence that consumers responded to the implementation of dolphin-safe labeling. The dolphin-safe label tuna affected consumer behaviour and increased the market share of canned tuna. Consumers were willing to pay a price premium in order to avoid personally contributing to dolphin mortality as a result of tuna fishing. More recently, using Danish consumer diary data, Bjørner et al. (2003) found statistically significant levels of consumer choice of more expensive, eco-labeled laundry detergents and toilet paper brands.

Nevertheless, markets for environmentally friendly products are dysfunctional because most promised environmental attributes are both *public* (non-rival and non-exclusive) and *unobservable* (credence attributes). For example, claims about the harmlessness of certain products for the ozone layer promise the provision of a public good, which is also unverifiable at the consumer level. Neoclassical theory predicts that consumers will attempt to free ride by enjoying the public good without incurring the provision costs. Despite a willingness to pay for public environmental attributes, problems of adverse selection (Akerlof, 1970) can occur where important product attributes are credence in nature (Darby and Karni, 1973). Price is not a good signal of the product's value because goods of different quality can be purchased at the same price. An adverse selection situation arises when consumers cannot detect a fixed attribute of the product before purchase, while this information is available to sellers. Adverse selection could occur, for example, where some producers provide false or misleading labeling about environmental attributes and underlying production practices causing consumers to choose products that do not in fact have the attributes they want (Grodsky, 1993).

To overcome these market dysfunctions, environmentally friendly firms need altruistic consumers, at least to some extent, and credible signalling. Unlike some preceding contributions that consider ecolabeling schemes as a policy instrument, we study ecolabeling as a firm device. Ecolabeling encompasses several types of labels related to the environment preservation like third party certification schemes or self declaratory statements. Each type of ecolabel implies specific cost issues which can related to design, verification and advertising procedures. Our objective is to determine whether ecolabeling schemes in their diversity may allow the market to mitigate by itself the previously mentioned market failures without policy intervention. To address this question, we consider a duopolistic market. We analyze the ecolabeling decision of each firm by taking into account price competition and the possibility

for the polluting firm to usurp the environmentally friendly firm by ‘purchasing’ the ecolabel. Consumers can only rely on labels to know the environmental quality of firms. We show that pollution can be reduced without public intervention, but only by combining the force of voluntary consumers’ participation and efficient signalling. The outcome depends directly on ecolabeling costs.

The remainder of the paper is organized as follows. The next section discusses the existence of different types of ecolabels and their related cost issues. Section 3 briefly overviews the related literature. Section 4 lays down the main assumptions and presents a duopoly model with vertical differentiation. Section 5 analyzes price, signal and technology decisions. In section 6, we study the impact of consumers’ revision of beliefs on firms’ behavior. We show the conditions related to ecolabeling costs for which pollution emissions can be reduced without governmental intervention. Section 7 concludes and stresses some policy implications.

1. A brief presentation of ecolabels and related cost issues

Broadly speaking, eco-labels are on product claims related to environmental friendliness. Indeed, it is widely admitted that consumers rely heavily on the information provided on labels to make their product selection decisions. Nevertheless, ‘ecolabel’ is a fuzzy and ill-defined term that may encompass different meanings. At one extreme, ecolabels are “labels issued by independent organizations and displayed voluntarily by manufacturer who submit to inspection or in some other way meet the organizations environmental or advertising standards” (Wynne, 1994, p.55). At the other extreme, ecolabels are just on product claims or logos related to some extent to environmental friendliness. Such claims may be vague, undefined, unverified and unverifiable (Wynne, 1994; Leubuscher et al., 1999). The term is frequently used without indicating clearly indicating to the readers the definition used by the

author. Examples of such ecolabels are statements on a box of detergent that the product contains no phosphates or a label on a washing machine claiming that it is energy efficient. In such a confusing context, indicating clearly the underlying definitions is not just unimportant quibbles over words but can change the way we think.

In order to decipher the variety of voluntary eco-labels, we suggest three distinctive criteria.

- the way the standard underlying the eco-label is defined
- the way the claim is verified
- the way it is signaled to consumers.

Each criterion or stage can be refined according to the pursued objective. For example, the standard setting process may include a broad array of stakeholders and cover several environmental fields (*e.g.*, Nordic Swan) rather than an manufacturer self-definition of the standard covering only one environmental field (*e.g.*, CFC free). On the basis of the identity of participants in the different stages, we may suggest the following table (Table 1).

Table 1: Characterizing ecolabels according to the participating agents (Examples : ABC : Manufacturer’s self declaration ; DEF : Label Eco-OK)

	Agent in charge of achieving the stage		
	Manufacturer	Independent party	All stakeholders
Definition	A	D	G
Verification	B	E	H
Signaling	C	F	I

We consider that sticking an ecolabel on products is a costly process. This contention is intuitively evident when we refer to a process where each stage is achieved by an independent and competent party (DEF). For example, it is well-known that the certification stage, carried out by a third party, aimed at evaluating the environmental impact along the entire life-cycle

can be time consuming and very expensive (Piotrowski and Kratz, 1999). At the end of the assessment, the label is granted if the product satisfies the pre-requirements set by the auditor, or if the applicant submits a product which the auditor evaluates as the best available product in terms of environmental performance. The relevant producer costs notably include ecolabeling fees, meeting scheme requirements and certification costs. Additional producer costs may include transaction costs involved with the standard setting process, changing suppliers and so forth.

According to an OECD report (Vitalis, 2002), “fees for eco-label certification are also reasonably significant (...). Colombia estimated, for instance, that compliance with the Flower Labelling Programme scheme in Germany would cost the producer at least US\$2,500 annually, on top of a US\$1 charge per label per box of cut flowers. Given the tight margins operating in the market for cut flowers these figures represented a very significant investment. Certification costs for timber eco-labels are similarly substantial, at between 5-10% of existing logging costs, though some estimates are higher.” According to Piotrowski and Kratz (1999), “the costs of testing and verification for foreign producers are significantly higher, especially if they entail plant visits. It was reported in a study carried out in India that for some firms the costs of testing for compliance with the Netherlands ecolabel requirements for footwear could lead to a cost increase of up to 50 per cent.” Environmental report cards (notably delivered by Scientific Certification Systems, Inc., Wynne 1994) are not eco-seal of approvals because they do not offer a judgement value on products but provide a synthetic ‘identity card’ of a product’s environmental burdens in terms of energy consumption, and pollution of the soil, air, and water during its production¹. The costs for completing the report cards was estimated to cost between \$25,000 to \$35,000 per firm (Halverson, 1992).

¹ This ecolabel is similar to the well-known nutrition fact label.

Even candidates using misleading claims can incur non trivial costs, like expenses related to possible prosecution and reputation loss. Indeed, most developed countries have "truth-in-advertising" laws that make it illegal and somewhat risky to misrepresent products to consumers (Grotsky, 1993; Leibuscher et al., 1999). Firms may attempt to avoid prosecution by using vague, generic, non-specific claims, *e.g.*, "environmentally friendly". Even in these cases such, if polluting firms made generic claims of this sort, the abating firms could respond by making their claims specific - for example, this product is "phosphate free" or was "not tested on animals" - and polluting firms would not be able to follow suit without incurring regulatory penalties or reputational losses (Grotsky, 1993). Indeed, competition between firms may reinforce the consumer's ability to deduce relatively complete information about the hidden quality dimensions of products (Ippolito and Mathios, 1990). For instance, a producer might use a generic claim. A competitor with a similar product having specific and well defined and desirable properties (pesticide free) would have an incentive to advertise precisely these desirable attributes. This competitive disclosure results in explicit claims for all positive aspects of products and allows consumers to make appropriate inferences about products making only partial or generic claims or no claims at all. In some cases, the polluting firm can acquire the same label granted to a green firm by affording extra certification costs or exploiting asymmetric information between the principal (the auditor) and the agents (applicant firms) or bribing the auditor.

3. Related literature

There is a fairly sizeable literature that has analyzed (eco)labeling in different perspectives². On the one hand, several contributions question the market share green products can obtain, if

² There is a growing and recent literature devoted to the analysis of ecolabeling policies. An exhaustive review is beyond the scope of this paper. In addition to contributions devoted to the willingness to pay of consumers or to the determinants of green purchases (*e.g.*, Moon et al., 2002; Bjørner, et al. 2003), let us just indicate several other fronts. Kotchen (2005, 2006) analyzes the public dimension of green products. Hamilton and Zilberman (2006) investigate linkages between ecocertification policies and equilibrium fraud. On another front, Matoo and Singh (1994), Dosi and Moretto (1998) and Bougherara et al. (2005) examine under what circumstances eco-

we assume perfectly informed consumers. Auriol and Schilizzi (2003) argue that the market size is determined by certification cost. They show that the higher the certification cost, the fewer will be the number of firms that are able to afford a certification process. Using a duopoly model with vertical product differentiation, Amacher et al. (2004) show that incentives for firms to invest in green technologies (eco-labeling) also depend on the relative cost structure.

On the other hand, other contributions study whether the low quality firm decides to imitate the high-quality producer. De and Nabar (1991) consider efficient but imperfect third-party certification in a competitive market. High quality sellers, with a higher likelihood to obtain a high ranking, expect revenues to be higher if products are certified. Since the certification process is imperfect, some low quality sellers also opt for certification if relative certification costs are sufficiently low. This outcome results from the price setting assumption: prices are equal to the willingness to pay for expected quality. Crampes and Ibanez (1996), Linnemer and Perrot (2000), consider a monopolistic market. Market prices of labeled and unlabeled products depend on consumer beliefs, in other words to what extent they believe the green claim is true. Crampes and Ibanez (1996) show that according to labeling costs and consumer beliefs on the green label, the monopolistic polluter might have an incentive to claim it is an environmentally friendly producer. And in some cases, the environmentally friendly producer is not willing to signal its low pollution level. Linnemer and Perrot (2000) analyze quality signalling strategies of a monopoly considering whether the firm uses a label, certificate or even both. They suppose that certification reveals perfectly the product quality whereas the use of a label only indicates a minimum quality level. They show that numerous configurations are possible which may explain consumer confusion. Bourgeon and Coestier (1998) consider perfectly competitive markets but study in what manner monitoring policies

labeling may generate an adverse result, *i.e.*, an environmental degradation rather than an improvement. Lastly, Bruce and Laroia (2007) examine how the achievement promises of ecolabeling schemes are threatened on the

influence the quality level of labeled products by assuming that too much adoption of the label by low quality producers will undermine the label credibility. Mason (2006) analyses a market characterized by asymmetric information in which firms decide whether to seek an ecolabel. Market equilibrium is discussed in three settings: where both technologies and outputs are fixed (so the only choice is whether to seek certification), where technologies are fixed but outputs are not, and where firms can choose both technology and output.

4. The model

Consider a duopoly model of vertical product differentiation with endogenous technology and signal choices. We assume that firms have only two ways to produce a homogeneous product³: a ‘good’ technology that preserves the environment (denoted by g) and a ‘bad’ technology that harms the environment (denoted by b). Technologies are differentiated by the associated production costs and pollution levels. The unit cost for the environmentally friendly production technology, $c_g=c$, is higher than the unit cost for the polluting technology, $c_b=0$. The use of a polluting technology implies a pollution emission $B>0$. Given the structural disadvantage for environmentally friendly producers and the inability of consumers to distinguish between green and polluting products, firms can stick a green label on their products⁴. Using a green label is costly and even polluting firms might be willing to imitate high environmental quality producers. We suppose that the ecolabel is unique. The adoption of the green label entails a fixed sunk cost $F(t_i)$ for a producer that uses technology t_i . The producer bears no extra cost if he decides to market an unlabelled product.

production side, e.g., by increasing returns to scale and complexities in production.

³ In other words, consumers have identical value in use whatever the technology used.

⁴ If the green producer cannot signal its high environmental quality to consumers, it is impossible to raise its price above the price of the polluting version. At the equilibrium, products will be sold at one unique price (Akerlof, 1970) and no green products will be marketed despite a potential demand (Crampes and Ibanez, 1996).

We consider a three-stage game. In the first stage, firms choose simultaneously their production technology (t) which is either a polluting one (b) or one that respects the environment (g); $t_i \in \{b, g\}$. After the first stage, choices become common knowledge for both firms. On the other hand, consumers are not able to observe the technology choices. They observe signal choices made in the second stage where firms decide simultaneously whether they stick a label on their products (s). Either the firm sticks a label on its products ($s=1$) or do not ($s=0$). In the last stage, firms fix simultaneously product prices, $p_i \in \mathcal{R}^+$.

Consumers purchase only one unit of product⁵. To determine demand functions, let us assume that consumers have the following utility function:

$$U(\eta) = \begin{cases} \theta - p_i(s_i, s_j) - \eta EB(\rho_i(s_i, s_j)) - P & \text{if he buys a product with signal } s_i \text{ from firm } i \\ \theta - p_j(s_j, s_i) - \eta EB(\rho_j(s_j, s_i)) - P & \text{if he buys a product with signal } s_j \text{ from firm } j \\ -P & \text{if he doesn't buy at all} \end{cases}$$

where P is the overall pollution level⁶, and $p_i(s_i, s_j)$ the price paid for the product with signal s_i to the firm i , knowing that another product with signal s_j is sold by firm j . Consumers obtain a direct utility from consumption. θ represents the value in use of products, either the polluting version or the environmentally friendly one. η represents consumer's altruistic parameter, which can be interpreted as consumer's willingness to pay for environmental quality⁷. We

⁵ A necessary condition to ensure a full consumption imposes the value in use parameter to be sufficiently high ($\theta > B+c$).

⁶ P corresponds to the pollution level generated by the aggregation of all other consumers' decisions. This pollution is exogenous for consumer i whatever his consumption decision. We suppose that the pollution created by his consumption decision does not affect his own utility. Consumer i 's utility is however affected by the expected pollution level of his consumption depending on whether he is concerned not polluting other individuals in society.

⁷ Environmental quality is a public good and neoclassical predicts that consumers will free ride. Nevertheless, real world examples and experimental economics attest that people do not free ride as much as predicted by the neoclassical theory and contribute to some extent to public goods. This behavior may be notably explained by introducing altruistic preferences that encompass pure and impure altruism. Eisenberg and Miller (1987) define

define altruism as the internalization of negative effects one creates on the utility of others. In other words, altruistic consumers are sensitive to the fact that other consumers are harmed by a higher pollution level if they buy the polluting product instead of the environmentally friendly version. The degree of altruistic preferences (η) measures to what extent the consumer is concerned with the environmental harm he causes to the whole society. We suppose that consumers are uniformly distributed according to their altruistic behavior, η , on the interval $[0,1]$; $f(\eta)=1$ and $F(\eta)=\eta$.

Potential buyers are conscious that two production technologies can be used but cannot distinguish from product inspection or use which technology has been adopted. $EB(\rho)$ is the expected pollution level of the product which depends on consumer beliefs⁸. Consumers form beliefs by observing signals on products. $\rho_i(s_i, s_j)$ is the probability that the firm i is a green producer when the consumer observes products from firm i with signal s_i and products from firm j with signal s_j . Let us make two assumptions on beliefs:

Assumption 1: Beliefs are symmetric, $\rho_i(s_i, s) = \rho_j(s_j, s)$ where $s_i = s_j, \forall s \in \{0,1\}$

Assumption 1 reflects the idea that consumers cannot distinguish between identically labeled products since the physical aspect is completely the same. It might also mean that even if trademarks are mentioned on products, consumers are totally indifferent.

Assumption 2: Beliefs fit the monotone likelihood ratio, $\rho_i(1, s_j) \geq \rho_i(0, s_j) \quad \forall s_j \in \{0,1\}$

altruism as an intentional voluntary behavior that benefits another and is not performed with the expectation of receiving external rewards in return. Another definition of altruism given by Rushton (1982) is a social behavior carried out to achieve positive outcomes for another rather than for themselves. Of particular relevance to the analysis of 'green' markets is the concept of "warm-glow," or "joy-of-giving," motivations (Andreoni, 1990). Simply put, the idea is that individuals may derive a distinct private benefit from their own purchase decision rather than from the overall level of pollution.

Assumption 2 means that consumers consider that labeled products are more likely to preserve the environment than unlabeled versions.

If both firms decide to adopt the same signal (green label or nothing), consumers consider products to be identical and will turn to the less costly product. We suppose that each firm is able to serve the entire market. In the case of identical prices, demand is equally divided. If only one producer sells products with the green label, consumers choose between vertically differentiated products according to their taste parameter for altruistic behavior.

5. Environmental quality and labeling behavior

5.1. Price competition

Using backward induction, we first study price decisions. At this stage, firms have already made their signal and technology choices. However, consumers only rely on signals when making their consumption decision. In order to calculate sub-game perfect equilibria, two distinct cases need to be distinguished, either both firms sell identically labeled products or both sell differently labeled (vertically differentiated) products.

Lemma 1: *If firms market identically labeled products, firms face perfect price competition. Then, the sub-game perfect equilibrium follows the Bertrand paradox when firms use the same technology and the “lemon market” outcome of Akerlof when firms adopt distinct technologies.*

Given that identically labeled products are perceived as identical product by consumers and firms are able to serve the whole market, we have only one price at the equilibrium. Price decisions will be as follows:

⁸ We suppose that the prior probability of a product to be environmentally friendly, is equal to ρ for all

$$p_i^*(s_i, s_j) = \begin{cases} c(t_i) & \text{if both firms use the same production technology, } t_i = t_j \\ c & \text{if they use different production technologies, } t_i \neq t_j \end{cases} \quad (1)$$

When firms have adopted the same production technology, sub-game equilibrium will be marginal cost pricing (Bertrand Paradox). In the case where one firm uses a polluting technology and the other one, an environmentally friendly technology that is also more costly, the environmentally friendly producer is disadvantaged because it cannot signal its high environmental quality to consumers. Consequently, the polluter drives out of the market the environmentally friendly producer by selling its products just below the marginal cost of its rival (Akerlof, 1970).

When firms sell differently labeled products, imperfect price competition arises as consumers perceive differentiated products. Without loss of generality, we suppose that firm i (respectively firm j) sells labeled (respectively unlabeled) products. Sub-game perfect equilibrium prices can then be written:

$$p_i(1,0) = \begin{cases} \frac{2}{3}A + c(t_i) & \text{if } t_i = t_j \\ \frac{2}{3}A + \frac{2c(t_i) + c(t_j)}{3} & \text{if } t_i \neq t_j \end{cases} \quad \text{for the labeled product} \quad (2),$$

$$p_j(0,1) = \begin{cases} \frac{1}{3}A + c(t_j) & \text{if } t_i = t_j \\ \frac{1}{3}A + \frac{2c(t_j) + c(t_i)}{3} & \text{if } t_i \neq t_j \end{cases} \quad \text{for the unlabeled product} \quad (3).$$

consumers and all products.

where $\Delta = [\rho_i(1,0) - \rho_j(0,1)]B$ represents the perceived difference in pollution emission between a labeled and a unlabeled product. We obtain the classical vertical differentiation equilibria⁹ (Gabszewicz and Thisse, 1979), *i.e.*, an equilibrium with unique production costs and another one with a structural advantage for the polluting producer. The extensive form of the game in appendix 1 summarizes the pay-off results for both firms according to their price, signal and technology decisions.

52. Labeling behavior

Taking into account the pricing behavior of firms, their signaling strategies can be analyzed by determining sub-game perfect equilibria. Simply put, two questions must be solved. First, what are the necessary conditions for an environmentally friendly firm to signal its high environmental quality? Second, does a polluting firm want to imitate a “green” producer? The answers depend on the technology choices made in the first stage. Indeed, the outcome of the first stage, which is common knowledge for both producers, determines whether firms face balanced competition or not.

When firms use the same production technology, they incur the same production and signaling cost. Firms produce identical products, but consumers cannot assess product quality and only rely on signals. The normal form of the ecolabeling subgame if both firms adopt identical technologies can be resumed in table 2.

Table 2: Normal form of ecolabeling subgame if firms have adopted identical production technologies

i, j	No ecolabel	Ecolabel
No ecolabel	$(0, 0)$	$(\frac{1}{9}\Delta, \frac{4}{9}\Delta - F_j)$
Ecolabel	$(\frac{4}{9}\Delta - F_i, \frac{1}{9}\Delta)$	$(-F_i, -F_j)$

⁹ Market segmentation is explained by willingness to pay for preservation of environment (altruistic preferences)

If the adoption costs of an ecolabel are too high ($F(t_i) > \frac{4}{9}\Delta$), none of the firms adopts an ecolabel. Indeed, the benefit of selling differentiated products does not cover labeling costs. If signaling costs are sufficiently low ($F(t_i) \leq \frac{4}{9}\Delta$), the benefit from selling vertically differentiated products will be higher than the cost to signal the environmental superiority of the firm. As the adoption of an ecolabel by both firms cancels out product differentiation, it is in their mutual interest that only one of them sticks a green label on its products. In this case the subgame has two pure symmetric Nash Equilibria and can be referred to as the “battle of the sex” game. To resolve the best equilibrium outcome, different solutions exist: mixed strategies, correlated equilibria, or sequentiality. As both equilibria are perfectly symmetric, none of the two is more likely to appear. In practice, firms do not take long term decisions such as ecolabeling adoption simultaneously. As firms know they are better off if they differentiate their products, we suppose that one of the two firms is the leader and so only one of the equilibria occurs. This assumption allows us to not to introduce probabilities and complicated consumer revisions into the games. We argue that this assumption is more adapted on a practical and technical level and does not alter the interest and objective of the paper. So, sub-game perfect equilibria of the second stage of the game (ecolabeling decisions) are unique and stable and depend on labeling costs.

Proposition 1: *Producers, having adopted the same the technology, differentiate their products to relax price competition if $F(t_i) \leq \frac{4}{9}\Delta$*

We should point out that if the two firms adopt the same production technology, ecolabeling by the two firms at the second stage will never be an equilibrium. This result is directly

instead of income dispersion.

derived from Lemma 1. As each firm can serve the entire market, selling identically labeled products implies a perfect price competition. Given that ecolabeling is costly and consumers are unable to distinguish environmental quality if both firms ecolabel their products, a firm is always better off by differentiating its products, *i.e.*, by selling unlabeled products. Then, the firm will earn positive profits and incur no labeling costs.

When firms adopt distinct production technologies, products are vertically differentiated. However without the possibility of ecolabeling, consumers perceive products as identical and firms face perfect price competition. As the polluter has lower production costs, it can drive the environmentally friendly producer out of the market (Akerlof, 1970). The normal form of the ecolabeling subgame is represented in table 3.

Table 3: Normal form of ecolabeling subgame if firms have adopted different production technologies

$i=b, j=g$	No ecolabel	Ecolabel
No ecolabel	$(c, 0)$	$(\frac{\Delta}{9}(1 + \frac{c}{\Delta})^2, \frac{\Delta}{9}(2 - \frac{c}{\Delta})^2 - F_g)$
Ecolabel	$(\frac{\Delta}{9}(2 + \frac{c}{\Delta})^2 - F_b, \frac{\Delta}{9}(1 - \frac{c}{\Delta})^2)$	$(c - F_b, -F_g)$

Lemma 2: *We suppose that producers adopt distinct production technologies. Therefore, the polluter benefiting from a structural production cost advantage achieves a trade-off between product differentiation and competitor exclusion.*

The polluting firm has a structural advantage in terms of production cost and can exclude the environmentally friendly producer from selling its products by adopting an identical signal. As consumers cannot distinguish between identically ecolabeled products, the polluter will prevent the environmentally friendly producer from selling by fixing product price just below the marginal cost for the environmentally friendly technology, c . If the labeling cost for a

polluter is sufficiently low, then the polluter prefers usurping the identity of a high environmental quality producer. If the labeling cost for a polluter is sufficiently high, the polluter does not usurp the identity of the environmentally friendly firm.

Proposition 2: *We suppose producers have adopted distinct production technologies. Then,*

(i) *The two firms market unlabeled products if:*

$$F_b \geq \frac{4\Delta^2 - 5\Delta c + c^2}{9\Delta} \text{ and } F_g \geq \frac{4}{9}\Delta \left[1 - \frac{c}{2\Delta}\right]^2$$

(ii) *The environmentally friendly producer only labels its products if:*

$$F_b \geq \frac{7\Delta c - \Delta^2 - c^2}{9\Delta} \text{ and } F_g \leq \frac{4}{9}\Delta \left[1 - \frac{c}{2\Delta}\right]^2$$

(iii) *The polluting producer only labels its products if:*

$$F_b < \frac{4\Delta^2 - 5\Delta c + c^2}{9\Delta}$$

Proof: We suppose $t_i=g$ and $t_j=b$. We have the following equilibria:

$$- \quad s_i = s_j = 0 \text{ if } 0 \geq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta}\right]^2 - F_g \text{ and } c \geq \frac{4\Delta}{9} \left[1 + \frac{c}{2\Delta}\right]^2 - F_b$$

$$- \quad s_i = 1, s_j = 0 \text{ if } \frac{4}{9}\Delta \left[1 - \frac{c}{2\Delta}\right]^2 - F_g \geq 0 \text{ and } \frac{\Delta}{9} \left[1 + \frac{c}{\Delta}\right]^2 \geq c - F_b$$

$$- \quad s_i = 0, s_j = 1 \text{ if } \frac{\Delta}{9} \left[1 - \frac{c}{\Delta}\right]^2 \geq -F_g \text{ and } \frac{4\Delta}{9} \left[1 + \frac{c}{2\Delta}\right]^2 - F_b \geq c$$

End of proof.

If signaling costs are high for the two producers, none of them wants to market ecolabeled products. Given the structural advantage of the polluter, it will drive out of the market the environmentally friendly producer (Akerlof, 1970). Restrictive conditions on labeling costs are needed to allow the environmentally friendly producer to differentiate itself from the polluter by adopting an ecolabel. Ecolabeling costs must be high (respectively low) for the producer using a polluting (respectively environmentally friendly) technology. If ecolabeling means sufficiently low costs for the polluter, we obtain a sub-game perfect equilibrium where the polluter uses an ecolabel to sell its products and the environmentally friendly producer adopts no signal. The polluter earns higher profits by imitating a green producer rather than by driving out of the market its competitor. The environmentally friendly producer prefers selling 'no green' products rather than not being able to sell at all. And for this reason it will accept that the polluter earns the 'high quality' profit. Noteworthy, if it is neither too costly nor too cheap for a polluter to use a green label¹⁰, there are no sub-game perfect equilibria in pure strategy. The environmentally friendly and polluting producers have opposite interests. The polluter would like to adopt the same signal as its competitor whereas the environmentally friendly producer prefers distinguishing its products from the polluter in order to sell them at a price above marginal cost of production.

53. *Technology choice: polluting technology versus environmentally friendly technology*

Now we turn to the first stage, where firms choose simultaneously their production technologies. The main question is: under which conditions a firm wants to adopt voluntarily a more costly but environmentally friendly production technology? The firm decision to adopt an environmentally friendly technology or a polluting one depends on the signaling

¹⁰ The exact conditions are: $F_b \in \left[\frac{4\Delta^2 - 5\Delta c + c^2}{9\Delta}, \frac{7\Delta c - \Delta^2 - c^2}{9\Delta} \right]$ and $F_g \leq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2$.

possibilities in the second stage and therefore on the signaling costs for the polluting and the environmentally friendly production technology. There are three possible outcomes: either the two firms adopt the technology that preserves the environment or the polluting technology, or they choose different production technologies.

Proposition 3: *It is never optimal for the two firms to adopt the environmentally friendly technology.*

Proof: We can easily show that $\pi_i(b, g) \geq \pi_i(g, g)$ for $\forall s_i, s_j, \forall i = 1, 2$.

End of proof.

The adoption of environmentally friendly technology by both producers cannot be a sub-game perfect equilibrium. Indeed, each producer would prefer deviating. Technology choices are not observable by consumers. Only the signaling level determines whether firms set prices above marginal cost. By adopting a polluting technology (knowing its rival uses an environmentally friendly production technology), the firm acquires a structural advantage. This means that pollution cannot be totally reduced through the market mechanism even if consumers internalize pollution in their consumption decision (proposition 3). However, proposition 4 shows that the negative externality can be partially reduced without governmental intervention. Indeed, we can determine sub-game perfect equilibria in pure strategies, where firms differentiate their products by the pollution level they emit during production despite a higher marginal cost for the environmentally friendly production technology. Of course, such equilibria only hold under specific conditions on ecolabeling costs: the polluter needs to be discouraged (high ecolabeling costs and/or high penalties) whereas the environmentally friendly producer needs to be encouraged (low ecolabeling costs and/or credibility).

Proposition 4: *Firms will adopt different production modes if*

$$\text{either } F_g \in \left[\frac{3\Delta^2 - 2\Delta c - c^2}{9\Delta}, \frac{3\Delta^2 - 4\Delta c + c^2}{9\Delta} \right] \text{ and } F_b \geq \frac{4}{9}\Delta,$$

$$\text{or } F_g \in \left[\frac{3\Delta^2 - 2\Delta c - c^2}{9\Delta}, \frac{3\Delta^2 - 4\Delta c + c^2}{9\Delta} \right], F_b \in \left[\frac{7\Delta c - \Delta^2 - c^2}{9\Delta}, \frac{4\Delta}{9} \right] \text{ and } F_b - F_g \geq \frac{c}{9} \left(4 - \frac{c}{\Delta} \right)$$

Proof: From proposition 2, we know that the environmentally friendly producer labels if

$$F_g \leq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2 \text{ and } F_b \geq \frac{7\Delta c - \Delta^2 - c^2}{9\Delta}. \text{ If } F_b > \frac{4}{9}\Delta, \text{ the polluter will never adopt an}$$

ecolabel and thus the environmentally friendly producer never has an incentive to become a

polluter. If $F_b \in \left[\frac{7\Delta c - \Delta^2 - c^2}{9\Delta}, \frac{4\Delta}{9} \right]$, the environmentally friendly producer has no incentive

to change its production technology if $\frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2 - F_g \geq \frac{4\Delta}{9} - F_b$ and

$$\frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2 - F_g \geq \frac{\Delta}{9}.$$

The polluting producer will not deviate if $\frac{\Delta}{9} \leq \frac{\Delta}{9} \left[1 + \frac{c}{\Delta} \right]^2$ which is always true, and if

$$\frac{4\Delta}{9} - F_g \leq \frac{\Delta}{9} \left[1 + \frac{c}{\Delta} \right]^2 \text{ which implies, } F_g \geq \frac{3\Delta^2 - 2\Delta c - c^2}{9\Delta}.$$

End of proof.

If the conditions of proposition 4 are not satisfied, we turn to the ‘lemons’ outcome (Akerlof, 1970): none of the two firms wants to make an effort to reduce the pollution level by adopting an environmentally friendly production technology.

Proposition 5: *Both firms will adopt a polluting production mode if*

$$\text{either } F_g \geq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta}\right]^2, F_b \geq \frac{4\Delta^2 - 5\Delta c + c^2}{9\Delta},$$

$$\text{or } F_b \leq \frac{3\Delta^2 + 2\Delta c - c^2}{9\Delta}, \forall F_g,$$

$$\text{or } F_g \in \left[\frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta}\right]^2 - \frac{\Delta}{9}; \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta}\right]^2 \right], \quad F_b \in \left[\frac{7\Delta c - \Delta^2 - c^2}{9\Delta}, \frac{4\Delta}{9} \right] \quad \text{and}$$

$$F_b - F_g \leq \frac{c}{9} \left(4 - \frac{c}{\Delta}\right)$$

Proof: If $F_g \geq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta}\right]^2$ and $F_b \geq \frac{4\Delta^2 - 5\Delta c + c^2}{9\Delta}$, then the alternative strategy for the

firm to choose an environmentally friendly technology will imply that in the second stage, it will be driven out of the market. So (b, b) will always be an equilibrium under these

conditions. If $F_b \leq \frac{4\Delta^2 - 5\Delta c + c^2}{9\Delta}, \forall F_g$, then the alternative strategy for the firm to choose

an environmentally friendly technology will imply that, in the second stage, the polluter will

ecolabel its products. So, (b, b) will be an equilibrium if $\frac{\Delta}{9} \left[1 - \frac{c}{\Delta}\right]^2 \leq \frac{\Delta}{9}$, which is always

true, and $\frac{\Delta}{9} \left[1 - \frac{c}{\Delta}\right]^2 \leq \frac{4\Delta}{9} - F_b$, which implies that $F_b \leq \frac{3\Delta^2 + 2\Delta c - c^2}{9\Delta}$.

If $F_b \geq \frac{7\Delta c - \Delta^2 - c^2}{9\Delta}$ and $F_g \leq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta}\right]^2$, then the alternative strategy for the firm to

choose an environmentally friendly technology will imply that, in the second stage, the

environmentally friendly firm will label its products. So, (b, b) will be an equilibrium if

$$0 \geq \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2 - F_g \quad \text{for} \quad F_b \geq \frac{4}{9}\Delta, \quad \text{which is never true, and for} \quad F_b \leq \frac{4}{9}\Delta,$$

$$\frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2 - F_g \leq \frac{\Delta}{9} \quad \text{and} \quad \frac{4\Delta}{9} \left[1 - \frac{c}{2\Delta} \right]^2 - F_g \leq \frac{4\Delta}{9} - F_b .$$

End of proof.

Proposition 5 shows that if labeling costs are high whatever the production technology adopted, environmentally friendly products will never be produced. We have an equilibrium where only polluting products will be marketed. Firms do not want to invest in an expensive technology preserving the environment because the negative effect of adopting such a technology (higher production cost) is not compensated by the positive effect (lower signaling cost). If labeling costs for a polluter are very low, we also return to an economy with only polluting products, *i.e.*, the lemon market of Akerlof (1970), as the environmentally friendly producer will never be able to distinguish its product from the polluting one and will be driven out of the market by the polluter.

The most interesting situation is depicted in proposition 4 and shows that pollution can be reduced partially without governmental intervention but requires a willingness to pay for environmental quality by consumers, and specific conditions on labeling costs. If labeling is much more costly for a polluter than for an environmentally friendly producer, firms will choose voluntarily distinct production technologies and the environmentally friendly producer will label its products. We then have an economy with ecolabeled products as well as polluting and unlabeled products. Pollution is partially reduced through the market mechanism. Sufficiently low labeling cost for environmentally friendly technology is a necessary condition but not a sufficient one for the firm to become environmentally friendly. Indeed, it also depends on labeling cost for the polluting technology. Indeed, if the labeling

cost for a polluter is sufficiently low, it becomes much harder for the environmentally friendly producer to distinguish its products from polluting ones. Consequently, the environmentally friendly producer is unlikely to adopt an expensive (though less polluting) production technology. A sub-game perfect equilibrium where the polluter markets ecolabeled products and the environmentally friendly producer unlabeled ones never exists because the environmentally friendly producer prefers to become a polluter, facing lower production costs. In the next section, we analyze what happens if consumers can revise their beliefs on the ecofriendliness of green labeled products.

6. Voluntary pollution reduction under rational consumer behavior

In section 5, we presented sub-game perfect equilibria, where consumers have fixed beliefs on ecolabels. In other words, consumers attribute more environmental value to labeled products than to unlabeled ones. If we assume rational consumer behavior and common knowledge of the structure of the game, consumers revise their beliefs on technology choices made by firms for different labeling costs by observing their labeling strategies. Of course, firms anticipate that consumers will revise their beliefs in their decision making, this anticipation being also anticipated by consumers, and so forth. In this way, *a posteriori* beliefs can be deduced. The assumption of consumer revision of their beliefs implies that consumers can deduce from the labeling costs structure as well as the observation of the adopted signal (label choice), the optimal behavior (technology choice) of firms.

Consequently the question can be formulated as follows: under which conditions of labeling costs can we obtain a market differentiation based on environmental quality where an ecolabel truly signals environmental friendliness? Let us consider the most relevant case where $c < B$: *i.e.*, where the pollution emission per unit is higher than the marginal abatement cost to prevent this pollution emission. Indeed, an intervention promoting environmentally friendly

technology would improve social welfare if the marginal external benefit of pollution abatement (B) is higher than the marginal pollution abatement cost (c) (Coase, 1960).

Proposition 6: For all values (F_b, F_g) such that $F_b \geq \frac{4B}{9}$, $F_b \geq \frac{7Bc - B^2 - c^2}{9B}$ and

$F_g \in \left[\frac{3B^2 - 2Bc - c^2}{9B}, \frac{4B^2 - 4Bc + c^2}{9B} \right]$, there is a separating PBE (Perfect Bayesian

Equilibrium) where firms adopt distinct production technologies and where only the environmentally friendly firm ecolabels its products.

Proof: Consumers interpret perfectly production technologies through label behavior; Thus,

$\Delta = B$. Equilibria profits are then $\pi_g = \frac{4B}{9} \left[1 - \frac{c}{2B} \right]^2 - F_g$ and $\pi_b = \frac{B}{9} \left[1 + \frac{c}{B} \right]^2$. The

environmentally friendly producer who ecolabels will never abandon ecolabeling ($\pi_g > 0$, the alternative case implies perfectly substitutable products) and will have no incentive to become

a polluter ($\pi_g > 0$; the polluter will have no incentive to label its products if $F_b \geq \frac{4B}{9}$). The

polluter who does not ecolabel its products will not label them if $\pi_b > c - F_b$ and has no

incentive to become an environmentally friendly producer if $\pi_b > \frac{4B}{9} - F_g$ and $\pi_b > \frac{B}{9}$.

End of proof.

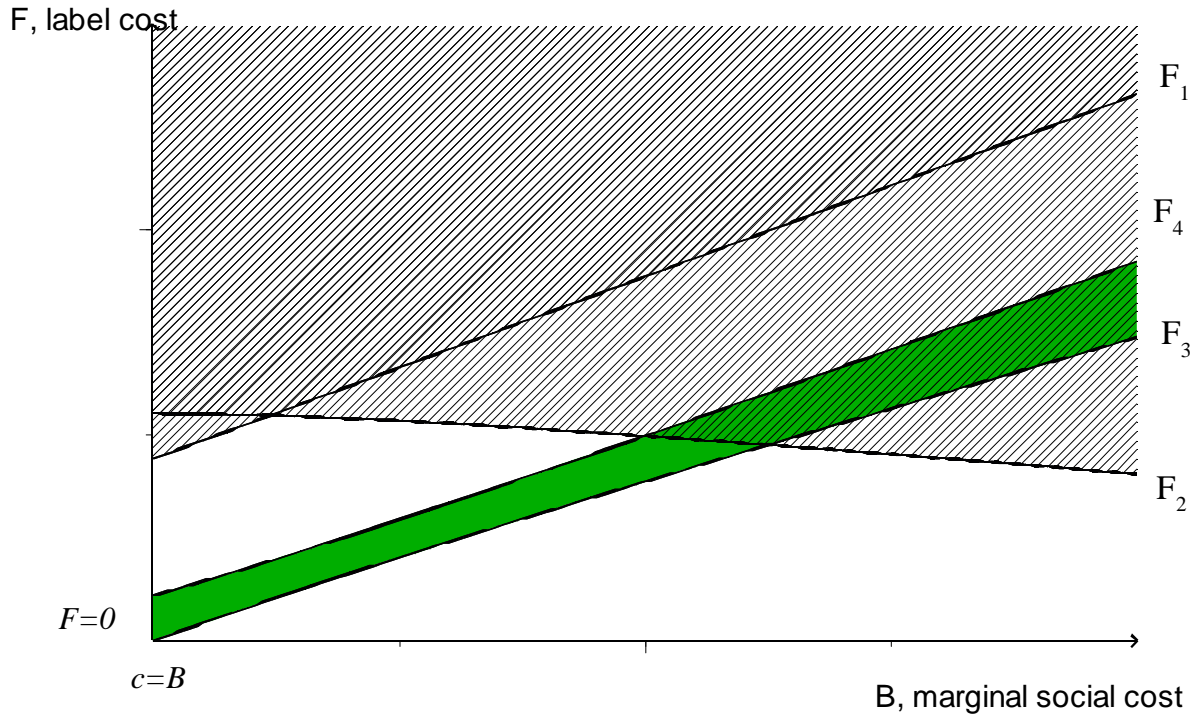


Figure 1: Ecolabeling costs conditions for separating PB equilibrium where two firms distinguish their production mode and ecolabeling strategy¹¹

Proposition 6, depicted in figure 1, shows that some restrictive conditions on labeling costs are necessary to reduce pollution through the market mechanism despite a higher willingness to pay for environmentally friendly products by consumers. First of all, labeling costs should be sufficiently dissuasive for a polluter ($F_1 \cup F_2$). Otherwise, it would want to drive out of the market its environmentally friendly competitor by adopting a green label. The labeling conditions for the polluter become less restrictive as the marginal social cost increases (F_2). On the other hand, the labeling cost for the environmentally friendly producer should neither be too high nor too low, depending on the level of the marginal social cost ($F_3 \cap F_4$). If the social marginal cost is low (high), the labeling cost for the environmentally friendly producer should be low (high). Of course, the labeling cost for the environmentally friendly producer

¹¹ The ecolabeling conditions can be expressed as $F_1 = \frac{4B}{9}$, $F_2 = \frac{7Bc - B^2 - c^2}{9B}$, $F_3 = \frac{4B^2 - 4Bc + c^2}{9B}$ and $F_4 = \frac{3B^2 - 2Bc - c^2}{9B}$.

should not exceed expected profit gains. But even if this cost is too low, the polluter might want to deviate and become a green producer. It might gain higher profits by sharing profits with another green producer. However, this gain is not certain as it can also gain only $\frac{B}{9}$, so an equilibrium where the two firms adopt an environmentally friendly technology will never exist (see proposition 3). Consequently, if the restrictive conditions stipulated in proposition 6 are not satisfied, it is not possible to regulate market imperfections without intervention. Firms will not adopt an environmentally friendly production technology even though consumers are willing to pay more for less polluting products. Indeed the adverse selection outcome occurs because the firm adopting the environmentally friendly technology cannot inform consumers about its greenness.

7. Conclusive remarks

Ecolabeling is not a well-defined category. It includes a broad variety of environmental claims going from third party certification schemes to self declaratory statements. According to the institutional context, this ecolabel variety generates different levels of ecolabeling costs. The main result of our analysis is to show that market can partly mitigate imperfections of "green" markets if certain restrictive conditions on labeling costs are satisfied. If it is sufficiently more costly for a polluter to use a green label than for an environmentally friendly producer, the informational problem is solved. The environmentally friendly producer will stick a green label on his products and inform perfectly consumers about the environmental quality of the product. At the same time, the pollution emitted during production (negative externality) is reduced. However, we show that pollution cannot be totally regulated through market mechanisms. This result is coherent with those of Foulon et al. (2002). The number of egoist consumers in the economy determines to what extent pollution will be reduced. In our model, we suppose that consumers are uniformly distributed on a continuum from pure

egoism to pure altruism. A logical extension of the model will be to consider different consumers' behaviour in relation to the preservation of the environment.

Even though this paper does not give an answer to how a governmental intervention might promote the use of less polluting production technologies, it provides an economic rationale to assess the ability of ecolabeling to be an effective and efficient policy instrument. As the outcome of the game depends on the levels of labeling costs, it will be interesting to know to what extent these costs can be influenced. Grodsky (1993) points out the necessity of an optimal labeling policy not to get the 'lemon' outcome. The author suggests either the "carrot" approach (by rewarding firms that sell environmentally friendly products with an exemplary ecolabel) or the "stick" approach (legally binding standards). In our analysis, these two approaches may respectively correspond to (1) the reduction of labeling costs for firms who preserve the environment *e.g.*, by subsidizing a recognized labeling organization and (2) the increase of labeling costs for polluting firms by enforcing stricter labeling guidelines and severe punishment in case of deceptive use of environmental claims.

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