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Why is price useless to signal environmental quality?

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Abstract

In a context where the credibility of green certification is questioned the present paper investigates the role of price as a possible substitute channel of communication as it has been largely developed since Milgrom and Roberts (1986). In this article, the purpose is to examine the pricing behavior of a green firm competing against a brown firm where the polluting good is sold in a perfectly competitive market. Due to the competitive fringe on the low-quality side, the distortion of the price required to signal a green product is too great to face any demand. As a result pooling price equilibria emerge as the most plausible situations as long as the brown firm can mimic the pricing behavior of the green firm. A green producer is thus constrained to practice uninformative prices which can lead to the lemon outcome (Akerlof, 1970).

Keywords— Credence Attributes, Asymmetric Information, Price Signaling
JEL *classification*— D43, D82, Q5

1 Introduction

Can the price transmit information on the environmental quality of a credence good?

The idea that the price can ensure the correct transmission of information has been largely developed since Milgrom and Roberts (1986). In this literature (Bagwell &

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Riordan, 1991; Mahenc, 2007; Daughety & Reinganum, 2008; Mirman & Santugini, 2014) it is shown that the price ensures the revelation of information. However, authors have to do important specifications to ensure the existence of the market and to raise the possibility for firms to reveal their type.

In this article, we examine the consequence of incomplete information on the price signal in the context of a Duopoly. Whereby it produces vertically differentiated substitute goods according to an environmental attribute. Firms quality is exogenously determined; it can be green (high) or brown (low), and they operate in a one-shot (three periods) model. The main specification is that the brown market is perfectly competitive.

We find that firms do not achieve use separating priceand it implies that price cannot transmit any information about the type of the firm when one of the two segments is perfectly competitive. This result is strengthened by using the Intuitive Criterion which is the most common equilibrium refinement in price signaling literature to show that it selects the lonely separating implausible price.

While it appears impossible for the green firm to reveal its type, it is still possible that the market exists by forcing the green firm to pool with the brown type. Pooling equilibria, in the case of green markets, may be assimilated to Greenwashing as long as these equilibria correspond to a situation where the brown firm makes a misleading claim about the environmental benefits of a product. The recent Volkswagen scandal is a prime example of this where, as stated in Forbes[1]: company leaders had the option to attempt to reap the benefits of being green by merely giving the appearance of an environmentally friendly company on the outside, without making the necessary investments on the inside. Moreover as mentioned in the Guardian[2] the means used for Greenwashing can take different form, such as a combination of advertising and

[1]Forbes 15/09/2016: How To Succeed At Sustainability (And Why Greenwashing Doesn't Work)
[2]The Guardian 20/08/2016: The troubling evolution of corporate greenwashing

higher priced products[3], as long as it provides information that misleads consumers into thinking they are helping the environment.

Fortunately, the transmission of the correct information on environmental quality can notably rely on certification (Bonroy & Constantatos, 2008) to solve the problem of asymmetric information and to ensure the existence of green markets. There exist natural links between the price and the certification. One of the main argument of the certifiers for label adoption is that consumers are ready to pay a price premium for a green product. Thereby when a green product is credibly identified green producers can extract this surplus by charging a higher price. Nevertheless recently there has been an increasing phenomenon of lack of trust towards eco-labels[4] (Jacquet et al., 2010) and green certification (Hamilton & Zilberman, 2006; Mason, 2011). Washington and Ababouch (2011) at the same time made a report wherein they questioned the reality of price premium associated with eco-labels in the fish industry. While there are evidence of this premium for fish retailers, this relation is not established for fish producers (Blomquist, Bartolino, & Waldo, 2015). The report mentioned that there has been no price premium gained from certification for the case of Alaska pollock and pointed to the fact that uncertified Russian pollock was fetching similar prices on the European market. Albeit it is important to mention that in this market the over-riding factor that sets price is still quality, it remains that environmental groups raised objections about the sustainability of the fisheries concerning the Alaska pollock certification. An explanation provided by this analysis is that when the environmental differentiation is not credibly displayed by the certification, an immediate consequence is that green producers are constrained to practice pooling prices to stay in the market. They cannot signal their environmental quality through prices because (1) it corresponds to credence attributes and (2) some of the standard firms would have incentives to mimic any green

[3]The Guardian 25/05/2014: Five sustainable boondoggles: greenwashing all the way to the bank
[4]Le Monde Diplomatique 01/06/2017: Un label agricole toujours moins exigeant

prices.

The remainder of the paper is organized as follows. Section 2 below relates the article to the existing literature. Section 3 provides the model, extensions, and results. Section 4 discusses the implication of results.

2 Relation to the Existing Literature

The transmission of information regarding environmental quality can be characterized as vertical or horizontal, according to whether it triggers or not, unanimous consumer reactions (Bonroy & Constantatos, 2008). Nevertheless, the literature treats environmental quality as an excludable characteristic of the good and mainly assume that adopting a green production is more costly than a standard process (Amacher, Koskela, & Ollikainen, 2004; Hamilton & Zilberman, 2006; Mahenc, 2007). Therefore there is an indisputable necessity to signal the quality or else fall into the lemon outcome (Akerlof, 1970). On this article, We focus on the price only to provide information. Price signaling literature revealed some important insights on the link between incomplete information market and price strategies.

Milgrom and Roberts (1986) mostly identify various conditions to ensure the existence of separating equilibria between low and high-quality type. However, they find the existence of pooling equilibria if consumers beliefs are high enough. This result comes from that the distortion of the price required to reveal the information may be less attractive when consumers are very optimistic about the quality. Repeat purchases play a major role in the trade-off between the choice to signal by price and/or advertising.

Bagwell and Riordan (1991) show that in a two-types of a quality model that in equilibrium firms choose separating prices. It remains a price distortion for the high-quality firm but for the low quality it has no incentive to deviate because of the informed consumers it would lose significant sales volume.

Daughety and Reinganum (2008) provide a complete model in which the low quality is associated with a disutility parameter. They examine the interplays of imperfect competition and incomplete information. There are two sources of incomplete information (adverse selection and firms anticipations) nevertheless in equilibrium firms charge the separating prices. Even when the disutility is strong and thus inciting low quality to mimic the high segment, the high-quality firm raises its price even further to signal its quality.

Mirman and Santugini (2014) point out the role of the competitive fringe to guarantee the existence of an equilibrium in which the separation takes place to inform uninformed buyers. This is because the incentives for a low-quality firm to mimic the high-quality price is reduced since a higher price triggers more sales on the part of the competitive fringe. They also confirm the well-known result that a large fraction of informed buyers is sufficient for the price to convey information about the quality of the good.

Mahenc (2007) examines a model which involve a monopolist using price to signal quality and shows that a firm has the incentive to disclose its quality as long as consumers do not have too optimistic beliefs. He underlines that the distortion caused by the signaling occurs when the firm chooses the fully informative price and concludes that the monopolist charges a higher price in the case of incomplete information.

It is noteworthy to mention that in all of these studies, firms it exists at least a plausible separating equilibrium which ensures the correct transmission of the information.

3 Model

3.1 Perfect Information

One starts by defining the model of perfect information to use it as a benchmark. The quality of the product (the vertical attribute) can be green or brown. In period one, Nature independently draws a type for each firm from a common distribution and each firm observes its type. The types of firms are denoted $\theta_i \in \Theta$, $i = g$ (green quality) and $i = b$ (brown quality). Environmental quality refers here to the cleanness of production.

We normalize the number of consumers to 1 and we assume that the utility of consumers of a brown good is homogeneous and denoted as follows:

$$v - p_b$$

Where v denotes the reservation price of brown consumers for the good and p_b its price. $v > p_b$ otherwise it would not be socially profitable to produce the good. The utility of consumers of a green good is heterogeneous and defined as follow:

$$v + s_j - p_g$$

Where s_j can be interpreted as each consumer's reservation price for the environmental service provided by the firm. Moreover, s_j is uniformly distributed among $[0, \alpha e]$ where e is the effort provided by the green firm and it is combined with the intrinsic valuation for the environmental service α_j of each green consumers. The upper bound αe represents the reservation price of the household which values the most the environmental service. To ensure that the production of the green good is socially desirable one has to assume that $\alpha > 1$. When the effort is high, or the valuation is large, green consumers are ready to spend more. This framework is similar as Mussa and Rosen (1978). We denote $\tilde{s}$ the customer which is indifferent between consuming the green good and the

brown good. In this case the market is assumed to be fully-covered.

$$v - p_b = v + \tilde{s} - p_g$$

$$\tilde{s} = p_g - p_b$$

Both demands $Q_b(p_b, p_g)$ and $Q_g(p_b, p_g)$ are defined by $\tilde{s}$ such that:

$$Q_g(p_g, p_b) = \begin{cases} 1 - \frac{p_g - p_b}{\alpha e} & \text{if } \alpha > \frac{p_g - p_b}{e} \\ 0 & \text{otherwise} \end{cases} \tag{1.1}$$

$$Q_b(p_g, p_b) = \begin{cases} \frac{p_g - p_b}{\alpha e} & \text{if } p_g > p_b \\ 0 & \text{otherwise} \end{cases} \tag{1.2}$$

Concerning the supply side we assume that firms compete in a simplified Bertrand Duopoly framework. We assume that the price of the brown market corresponds to the perfectly competitive price $p_b = c$. We assume that they have both a linear marginal cost to produce the good such that $c(\theta_i, q_i) = cq_i$ and that the green firm in order to produce a cleaner good has a variable abatement cost such that $c(\theta_g, q_g) = (c + e)q_g$. Where $e \in]0, 1]$ is the effort of the firm and it is assumed exogenously determined. The effort cannot be null because the preferences of Mussa and Rosen (1978) need that green firm which benefits from green demand is at least endowed with the minimum effort possible to be differentiated from the brown firm. Firm producing green quantity solves the following program:

$$\max_{p_g} \pi(\theta_g, p_g) = (p_g - c - e)\left(1 - \frac{p_g - c}{\alpha e}\right) \tag{1.3}$$

$$p_g^* = \frac{\alpha e}{2} + \frac{e}{2} + c \tag{1.4}$$

Even if the brown firm uses a price equalizing its marginal cost, the structure of the analysis corresponds to a price competition through product differentiation which is closely related to Shaked and Sutton (1982). The level of the effort of abatement of the firm here appears as the level of differentiation in a standard model. One can check the

classic result that when $\lim_{e\to 0} p_g(e) \to p_b = c$. For $e = 1$ products are very differentiated and the price competition between firms is softened as a result the price of the green firm increases. The profit equilibrium of the green firm is given by:

$$\pi(\theta_g, p_g^*) = \frac{e(\alpha - 1)^2}{4\alpha} \tag{1.5}$$

3.2 Imperfect Information: Adverse Selection

In this subsection, the problem of asymmetric information occurs in the green market. An environmental attribute associated with the cleanness of production is defined as a *credence attribute*. Although consumers do not directly observe the environmental performance of the product, the price of the green good can be taken as a signal of the environmental quality. Let $\mu(p) = \mu \to [0, 1]$ denotes consumers' posterior belief that the product is truly green when the price is p. Nevertheless, firms are correctly informed on the type of their rival. When information is not complete, the game among the firms and consumers occurs in (one-shot) three stages.

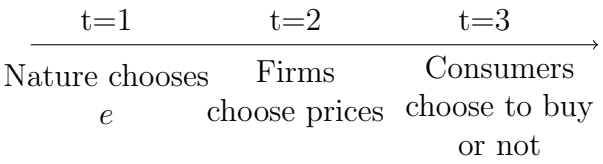


Figure 1: Timing

The utility of green customers is now:

$$v + \mu(p)s_j - p_g$$

$$\tilde{s} = \frac{p_g - c}{\mu(p)}$$

The program of the green firm is now given by:

$$\max_{p_g} \pi(\theta_g, p_g) = (p_g - c - e)\left(1 - \frac{p_g - c}{\alpha e \mu}\right) \tag{2}$$

The equilibrium prices, quantities and profits are now:

$$Q_g^*(p_g) = \begin{cases} \frac{(\alpha\mu-1)}{2\mu} & \text{if } \mu > \frac{1}{\alpha} \\ 0 & \text{otherwise} \end{cases} \tag{2.1}$$

$$Q_b^*(p_g) = \frac{e(\alpha\mu+1)}{2\mu} \tag{2.2}$$

$$p_g^* = \frac{1}{2}\alpha e\mu + \frac{1}{2}e + c \tag{2.3}$$

$$\pi_g^* = \frac{1}{4}\frac{e(\alpha\mu-1)^2}{\mu} \tag{2.4}$$

Intuitively the total amount of green quantity (2.1) is an increasing function of the perception of green customers. The condition on μ guarantees that the market exists if consumers are not too pessimistic about the environmental attribute of the good. The green firm prefers consumers beliefs about environmental performance to be optimistic. Conversely the total amount of brown quantity (2.2) is a decreasing function of μ because of the effect of substitution between the two kind of goods. Equations (2.3) and (2.4) show that the posterior belief of green customers is a parameter which acts in favour of softening competition for the green firm by increasing differentiation. Concerning (2.4) it reaches its maximum when the differentiation is at its highest state and the information is perfect.

For the green firm the problem is to choose the price to maximize its profit taking into account consumers updated beliefs. The particularity here is that even if the brown firm experiences a competitive market, one assumes that it has the possibility to choose between the informative price, which is equal to the marginal cost, or to mimic the green price. Without loss of generality one supposes that the brown market still exists even if the brown firm decides to mimic the green price because of remaining standard firms which have not the possibility to try to cheat green consumers. The set of strategies and beliefs which characterize the Perfect Bayesian Equilibrium (P.B.E) is $(\phi(\theta_g), \phi(\theta_b), \mu(p))$ where $\phi(\theta_g)$ and $\phi(\theta_b)$ are the strategy of the green and the brown

firm and one assumes that the three conditions are met to ensure the existence of a P.B.E. (Mas-Colell, Whinston, Green, et al., 1995).

3.3 Separating Equilibrium

In any separating P.B.E, $\phi(\overline{\theta_g}) \neq \phi(\overline{\theta_b})$; that is, information is revealed so that $\mu(p) = 1$ and each type of firm receives a profit equal to its environmental level.

Any separating equilibrium must satisfy a credibility constraint saying that the brown type must resist the temptation to cheat consumers by mimicking the price $\phi(\overline{\theta_g})$. For this, the brown type should prefer $\phi(\overline{\theta_b})$ over $\phi(\overline{\theta_g})$ that would falsely signal that its product is green. Formally, this requirement is:

$$\pi(\theta_g, \phi(\overline{\theta_g}), 1) \geq 0 \tag{3.1}$$

$$\pi(\theta_b, \phi(\overline{\theta_b}), 0) \geq \pi(\theta_b, \phi(\overline{\theta_g}), 1) \tag{3.2}$$

(3.1) and (3.2) ensure that profits of each type benefit from the best beliefs of consumers and guarantee that informative prices are attractive.

Proposition 1: *it exists only one separating equilibrium price such that* $\phi(\theta_g) \neq \phi(\theta_b)$ *where* $\phi(\overline{\theta_g}) = \alpha e + c$ *and* $\phi(\overline{\theta_b}) = c$ *yielding profits of* $\pi(\theta_b, \phi(\overline{\theta_b}), 0) = \pi(\theta_g, \phi(\overline{\theta_g}), 1) = 0$.

Proof. Straightforward calculation on (2) shows that there is a continuum of possible price which would satisfy constraint (3.1) with $\phi(\theta_g) \in [c + e; \alpha e + c]$. Condition (3.2) gives the incentive constraint of the brown firm. By assumptions, one knows that if the information is revealed then the brown firm is price taker and thus make a profit equal to zero. The only price which satisfies condition (3.1) and condition (3.2) is $\phi(\theta_g) = \alpha e + c$. At this point for the brown firm it is indifferent between $\pi(\theta_b, \phi(\overline{\theta_b}), 0) = 0$ and $\pi(\theta_b, \phi(\overline{\theta_g}), 1) = 0$.

This proposition follows the intuition of Janssen and Roy (2010) where they justify their assumption of a positive profit for all firms and goes to the opposite to the result of Mirman and Santugini (2014). Note that when the green firm sets this price the demand $Q_g(p, 1) = 0$. To explain this result, recall that the brown market is perfectly competitive so that profits are zero for the brown firm. Therefore (3.2) can only hold if the right-hand side is nonpositive. Since production costs are strictly lower for the brown firm, this can only happen when the demand for the green firm is zero.

3.4 Pooling Equilibria

Because the profit is null in the case of separating equilibrium, pooling equilibria appear more plausible in the model. Since it is the same (uninformative) price charged by the firms, regardless of environmental performance, the consumers' posterior beliefs after observing the price are the same as their prior beliefs denoted μ_0. Recall from Section 1 that the nature of these equilibria in this model represents Greenwashing because it corresponds to a case where the brown firm by equalizing its price to the green firm claims to be environmentally friendly. If such a phenomenon is revealed one cannot be very optimistic about the beliefs of consumers and the sustainability of such a market because of the condition (2.1). Note that in that case, both firms share the demand on the green market equally.

In any pooling P.B.E., $\phi(\underline{\theta_g}) = \phi(\underline{\theta_b})$; that is, where the green and the brown firm have incentive to conceal the information.

The incentives constraints of both types are:

$$\pi(\theta_g, \phi(\underline{\theta}_g), \mu_0) > \pi(\theta_g, \phi(\theta_g), 0) \tag{4.1}$$

$$\pi(\theta_b, \phi(\underline{\theta}_b), \mu_0) > \pi(\theta_b, \phi(\theta_b), 0) \tag{4.2}$$

The incentive constraints express the profits of firms at the pooling price given the prior beliefs of consumers supported that treat any out-of-equilibrium price as indicating that the firm is a brown type for sure.

Proposition 2: *there exists a continuum of pooling equilibria such that* $\phi(\theta_g) = \phi(\theta_b) \in]c + e; \alpha e\mu + c[$.

Proof. There is a continuum of possible prices for the green firm which satisfy (4.1). The brown firm has a larger set of possible price (4.2) due to the fact that it does not pay abatement cost. Anyway the set of possible price is reduced to the set of the green firm because of the definition of PBE.

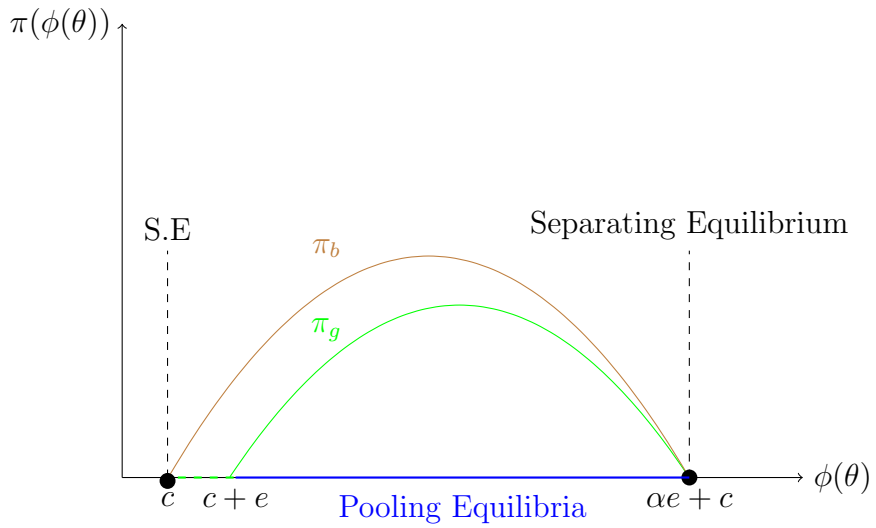


Figure 2: Summary of the Signaling Game

Figure 2 describes a situation between the green and the brown firm. These curves are drawn according to specific posterior beliefs μ of green customers. Brown curve is the profit of the brown type and green curve is the profit of the green type given the chosen price. Dashed green lines on the horizontal axis represent the space where the green firm would not operate given these prices.

3.5 Intuitive Criterion vs Undefeated Equilibrium

Facing the multiplicity of equilibrium there is a necessity to use a refinement concept. The idea behind the mobilization of two different refinement criterion is to open the possibility for green consumers to behave in various ways. Price signals literature usually use the *intuitive criterion* (Cho & Kreps, 1987) to select a unique separating equilibrium (Milgrom & Roberts, 1986; Bagwell & Riordan, 1991; Daughety & Reinganum, 2008). Another well known concept is the *undefeated equilbrium* (Mailath, Okuno-Fujiwara, & Postlewaite, 1993) used by Mahenc (2007) in the case of signaling through prices.

Proposition 3: *Intuitive Criterion rules-out every pooling equilibria*

Proof. *Appendix.*

The most common refinement used in price literature crowds-out every equilibrium associated with possible positive profits for firms and selects the single separating price yielding a null demand. It bolsters the idea that the green firm cannot use the price as a signal. In this case, it is not possible to rely on price to be a substitute to certification for the green credibility as in (Mahenc, 2007).

Proposition 4: *The set of undefeated equilibria restricts the set of pooling equilibria to* $\left[\frac{1}{2}\alpha e\mu_0 + c; \frac{1}{2}\alpha e\mu_0 + c + \frac{1}{2}e\right]$

Proof. *Appendix.*

Here it is an analysis of a pure pooling strategy sequential equilibria where the brown firm mimics the green firm's price. In other words, these equilibria are characterized by the fact that the brown firm is sending misleading signals to green consumers. This is a situation where the green firm strictly prefers the pooling equilibria in which $\phi(\theta_g) = \phi(\underline{\theta_g})$ to the separating equilibrium where $\phi(\theta_g) = \phi(\overline{\theta_g})$.

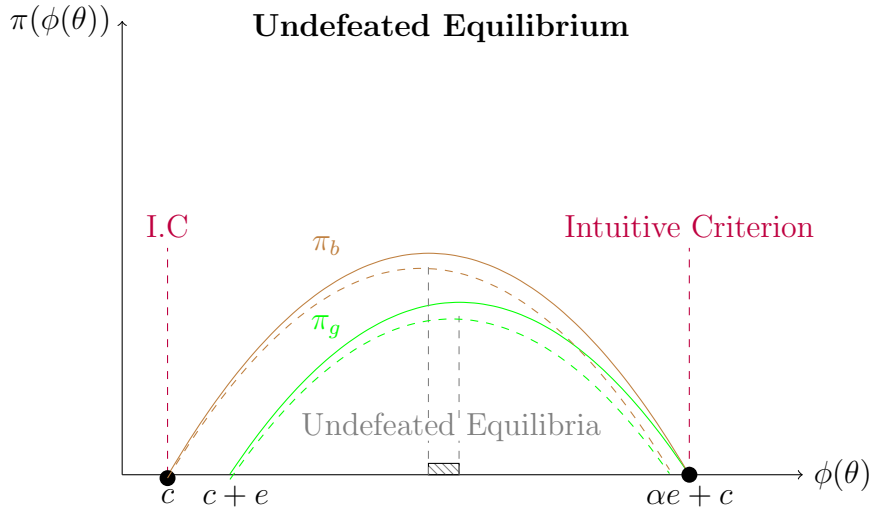
These boundaries characterize Pareto efficient prices for the brown type and the green type respectively. These optimal prices are changing given the posterior beliefs of customers μ_0. As a result when consumers have sufficient prior beliefs to do not fall into the lemon outcome the market exists. However, the market experiences Greenwashing.

Figure III

Intuitive Criterion

vs

Undefeated Equilibrium



The graph displays the profit associated to both type of firms in the case where prices are informative (thick curves) compared to pooling situations where the equilibrium beliefs correspond to prior beliefs (dashed curves). The results in this section are quite extremes. If agents on the green markets follow the intuitive criterion, the output is that there is no green market at all. Otherwise using the undefeated equilibrium concept the market would at least exist.

3.6 Extension: A share of informed consumers

Confronting to the extreme output of the previous section it is important to keep in mind that price signaling literature also showed that above a critical size of informed

consumers, signaling is feasible with full-information prices (Mirman & Santugini, 2014; Belleflamme & Peitz, 2015). It is not a new idea in price competition that a share of informed consumers may be extremely efficient as long as it has sufficient impact on the incentives constraints either of the low-quality firm as in Bagwell and Riordan (1991) or of the high-quality firm. Now assume that some buyers can ascertain the quality of the environmental good. A fraction β of buyers, say the readership of reviews publishing accurate advice on quality, learn the product quality before purchase, while the remaining fraction $1-\beta$ of buyers believe that quality is green with probability μ. Then the total demand for the green producer is:

$$Q_g(p_g, \mu, \beta) = \beta Q_g(p_g, 1) + (1-\beta) Q_g(p_g, \mu)$$

$$Q_g(p_g, \mu, \beta) = \frac{\alpha\, e\mu + ((1-\mu)\,\beta - 1)\,(p_g - c)}{\alpha\, e\mu}$$

When β increases, the problem of asymmetric information is reduced as a consequence the green quantity which is sold increases. In this framework the signal through price has an influence on the remaining share of uninformed customers, this quantity is denoted $Q_g^R(p_g, \mu, \beta)$:

$$Q_g^R(p_g, \mu, \beta) = (1-\beta)\left(\frac{\alpha e\mu - p_g + c}{\alpha e\mu}\right)$$

Immediately one can rewrite the credibility constraints for both firms to signal their quality through prices as follow:

$$\pi(\theta_g, \phi(\overline{\theta_g}), 1) \geq (\phi^*(\theta_g) - c - e)\beta Q_g(\phi^*(\theta_g), 1) \tag{5.1}$$

$$0 \geq (\phi(\overline{\theta_b}) - c) Q_g^R(\phi(\theta_b), \mu, \beta) \tag{5.2}$$

Proposition 5: *For $\beta \leq 1$ the share of informed consumer does not rise plausible separating equilibria.*

While it reduces the incentives for the green firm to apply the informative price due to the possibility to set the optimal price to the share of informed consumers, (5.2) is never satisfied for $\beta < 1$. The intuition behind this result is that if the brown firm displays its true quality to consumers then on a perfect competitive market its profit would be null, therefore the brown firm has always the temptation to mislead the remaining share of uninformed buyers. The main positive effect of the introduction of the share of informed customers is that in pooling equilibrium the profit of the green firm is enhanced which directly support the possibility for the environmental producer to sustain on the market.

4 Discussion

This analysis constitutes a case where assumptions to ensure the existence of separating equilibrium associated with positive payoffs do not hold (Milgrom & Roberts, 1986) or where the disutility associated with the polluting product is very high (Daughety & Reinganum, 2008). Mentioned but less highlighted than separating equilibria, pooling equilibria remain problematic. The case of credence attribute market in environment constitutes an interesting situation as long as the repetitive purchase cannot provide any information. Knowing that some brown firms have incentives to fraud (Hamilton & Zilberman, 2006) one can easily imagine a market where a polluting firm which experiences low-profit may be tempted to use a pooling price as long as punishments and regulations are not efficient enough. This study points out the importance of the credibility of the means to provide information as lobbying (Feddersen & Gilligan, 2001) and certification (Bonroy & Constantatos, 2008; Ibanez & Grolleau, 2008) otherwise green information could not be revealed. The assumption that the brown side of the market is competitive is more related to the producers of raw materials as coffee, forest, fish than retailers which are more likely to have market share. The output

where no separating equilibria exist would be maintained in the case where an industry experiences fixed costs. This particular framework of duopoly where the brown market exists even if the brown firm would mimic the green price may be confusing in a first place, but it is a simplified way to reflect the idea that not every firm operating on the brown market could send misleading signals. The hypothesis on the exogenous choice on quality was to focus on the transmission of information on environmental quality. It would be interesting to investigate the consequence of such implications on the choice of investments in green technologies.

5 Appendix

Proof of Proposition 3

To simplify notations we note that $\pi_{\theta_i} = \pi_i$.

An equilibrium ϕ^* is said to violate the Intuitive Criterion if $\exists\ \phi' > \phi^*$ with $\mu(\phi') = 1$ such that:

$$\pi_b(\phi^*, \mu_0) \geq \pi_b(\phi', 1) \tag{5.1}$$

$$\pi_g(\phi^*, \mu_0) < \pi_g(\phi', 1) \tag{5.2}$$

The left hand sides are equilibrium payoffs whereas the right hand sides are the maximum payoff that each type could get by setting a price ϕ'.

• Consider a ϕ' s.t $\pi_b(\phi^*, \mu_0) = \pi_b(\phi', 1)$ which can be rewritten

$$(\phi^* - c)Q_g(\phi^*, \mu_0) = (\phi' - c)Q_g(\phi', 1) \tag{5.3}$$

One verifies (5.2):

$$\begin{aligned} \pi_g(\phi^*, \mu_0) = &\quad \pi_b(\phi^*, \mu_0) - eQ_g(\phi^*, \mu_0) \\ = &\quad \pi_b(\phi', 1) - eQ_g(\phi^*, \mu_0) \\ \pi_g(\phi', 1) = &\quad \pi_b(\phi', 1) - eQ_g(\phi', 1) \end{aligned}$$

With (5.3) $Q_g(\phi^*, \mu_0) = \left(\frac{\phi' - c}{\phi * - c}\right) Q_g(\phi', 1)$

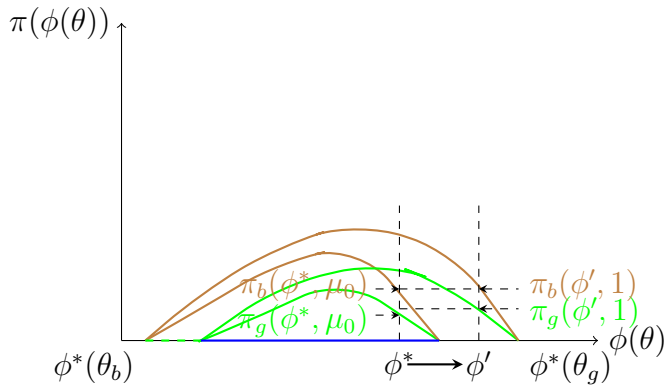
$$\begin{aligned} Q_g(\phi', 1) &< Q_g(\phi^*, \mu_0) \\ Q_g(\phi', 1) &< \left(\frac{\phi' - c}{\phi * - c}\right) Q_g(\phi', 1) \end{aligned}$$

It implies that $\phi' > \phi^*$ and verifies the definition.

QED.

Figure III

Graphic associated to the proof



Proof of Proposition 4

To ensure the existence of an undefeated equilibrium there are three necessary conditions:

$$\frac{\partial \pi(\theta_g, \phi(\theta_g), \mu)}{\partial \mu} > 0 \tag{6.1}$$

$$\frac{\partial \pi(\theta_g, \phi(\theta_g), \mu)}{\partial \phi(\theta_g)} < \frac{\partial \pi(\theta_b, \phi(\theta_b), \mu)}{\partial \phi(\theta_b)} \tag{6.2}$$

$$\frac{\partial^2 \pi(\theta_g, \phi(\theta_g), \mu)}{\partial^2 \phi(\theta_g)} < 0 \tag{6.3}$$

(6.1) States that the profit increases if consumers believes the firm more likely to be of environmental type. (6.2) is the single-crossing property. It says that the slope of the pay-off function of the brown firm with respect to the price is higher than the one of the green firm. This captures the idea that higher messages are more profitable for the brown firm. This is counter-intuitive because, usually, condition (6.2) imposes that it's easier for higher type to send a higher message. Finally condition (6.3) says that increasing the price may result into a loss even if the result was the most favorable possible beliefs on green consumers.

Undefeated equilibrium is closely related to the Pareto efficiency. Thus prices survive the undefeated equilibrium if there exist an equilibrium $\rho(\phi(\theta_g), \phi(\theta_b), \mu_0)$ where:

$$\exists \theta \in [b, g], \phi(\theta) \text{ and } \exists \theta [b, g], \phi'(\theta)$$

$$\text{with } \pi(\rho, \theta) \geq \pi(\rho', \theta)$$

The price which satisfies the equation above is not the same for both type. Anyway it always crowd-out the separating equilibrium and restrict the set of pooling equilibria to $\forall i \in b, g \ \phi(\theta_i) \in [\frac{1}{2}\alpha e \mu_0 + c; \frac{1}{2}\alpha e \mu_0 + c + \frac{1}{2}e]$.

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