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Laboratoire d'Économie Appliquée de Grenoble

**ON TAXES AND SUBSIDIES WITH PRIVATE ECO-LABELING**

**BARRY Ibrahima ; BONROY Olivier ; GARELLA Paolo G.**

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# On taxes and subsidies with private eco-labeling\*

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## Abstract

Taxes and subsidies on products embodying environmental qualities often coexist with certified private labels—like Ecocert, Scientific Certification System, or OEKO-TEX. Their interaction is yet quite unexplored. We analyze a duopoly where consumers value an environmental quality, with an externality. A certifier sets the quality standard for a label. The fee for granting the label is either set by the certifier (certifier power), or in a noncooperative bidding game (firm power). Taxes and subsidies then affect the fee, depending upon how this is set, and the standard. This channel can produce distorted or even reversed effects. If firm power exists, for instance, a subsidy to the labeled good ends up decreasing the environmental quality and welfare. Conversely, absence of firm power nullifies the effects of ad valorem taxing the unlabeled (“dirty”) product. Only a per unit tax has similar, but always worsening, effects.

**Keywords:** Ecolabels, private certification, environmental quality, tax, subsidy.

**JEL classification:** L13, L15, L5, Q5.

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# 1 Introduction

It is characteristic of markets for environment-friendly goods and services to have conventional environmental policies – green product subsidies and brown product taxes – as well as eco-labeling. Green product subsidies, polluting product taxes and charges, and eco-labeling are all widely used to encourage firms to reduce environmental harm. Thus, in an effort to abate pollution in agriculture, the certified organic farmers in several OECD countries receive subsidies allocated on a per-hectare basis (OECD, 2003), some countries in Europe, such as Belgium, Denmark, Finland and Sweden, have implemented fertilizer and/or pesticide taxes (EEA, 2005). Water effluent charges exist in several countries, for instance in France where polluters are taxed when their activity is harmful to the environment and receive subsidies when their actions are beneficial to the environment (Glachant, 2002). Due to consumers’ keen interest in environment-friendly goods, such regulation tools coexist with the significant and constantly increasing presence of eco-labeling.<sup>1</sup>

An environmental label must usually follow a set standard with which the labeled producer must comply. Certification to obtain a label is delegated to certifying bodies, that in this paper we term “certifiers”. These certifiers grant permission to use a label only to firms that agree to the certifier analyzing and monitoring their production processes and their final products. Certification, therefore, is a costly activity. It has a market value, and there are now several for-profit private certification agencies that develop their own standards, monitoring requirements, and technologies, and deliver the corresponding labels. Certifiers of this type are particularly well represented in eco-certification (see e.g. Ecocert, Scientific Certification System, Asbl Biogarantie, or OEKO-TEX).<sup>2</sup>

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<sup>1</sup>Environmental characteristics are defined by the literature as credence attributes (Darby and Karni, 1973). Revelation mechanisms hinging on bootstrap reputation and bayesian belief update become almost powerless with credence attributes, leaving certification by a reputable agent as the only possible mechanism for signaling quality (see Caswell and Mojduszka, 1996). Even if price signaling cannot be totally excluded, it is contingent on very restrictive assumptions (see for instance Bonroy and Constantatos, 2008, and Garella and Petrakis, 2008). Hence, for credence goods, labels represent the main, if not the only source of reliable information, to the point that in many cases they are a strict requirement for such markets to even exist (see Bonroy and Constantatos, 2015 and Roe *et al.*, 2014 for surveys on the economics of labeling).

<sup>2</sup>Ecocert delivers labels to producers whose products meet standards developed by Ecocert and related to human and environmental protection. Organic cosmetics, environment-friendly detergents, fair trade,

The literature on green taxes, however, is mainly concerned with producers choosing their environmental qualities so as to maximize their own profits (see e.g. [Cremer and Thisse, 1999](#), [Constantatos and Sartzetakis, 1999](#), [Moraga-González and Padrón-Fumero, 2002](#), [Bansal and Gangopadhyay, 2003](#), and [Brécard, 2011](#)). Yet in the presence of a certifier, when a firm adopts a private eco-label it must follow a prescribed standard for environmental quality, otherwise the label is refused or withdrawn. The environmental quality is thus determined by the private certifier—and owner of the label—and not by the firm. As a result, the quality chosen does not necessarily maximize the firm’s profits, contrary to what is often assumed in the literature. This affects consumers as well, and the overall welfare in the industry. Clearly, then, the presence of a certifier is likely to modify the effects of taxes and subsidies as policy tools.

In this paper we therefore focus on the interaction between some conventional environmental policies and private eco-labeling, as do [Hamilton and Zilberman \(2006\)](#), who look in particular at the effects of conventional environmental policies in a setup with third party eco-certification. Similarly to our results, they show that the interaction between a conventional environmental policy and private eco-certification may jeopardize the achievement of the social optimum. The main issue in their model is that environmental fraud changes as a response to policies, while our results hinge upon the way in which the certification fee and the standard are determined.

Unlike Government-owned certification agencies, a for-profit certifier will use the certification fee to extract part of the firms’ profits, which in turn depend upon the level of the standard. Therefore, we expect that the firms’ ability to bargain on the fee (“firm power”) modifies the standard as compared to when the certifier has full bargaining power (“certifier power”). This is, so to speak, the first result and level of analysis in the present paper. Second, we explore whether it is socially desirable and possible to ameliorate the

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and ecological green spaces are some examples. The Scientific Certification Systems develops internationally recognized standards in pursuit of high levels of environmental performance and social accountability. In Belgium, *asbl Biogarantie* delivers a label certifying organic products. OEKO-TEX delivers international labels certifying that a textile has been successfully tested in accordance with OEKO-TEX Standards, guaranteeing a textile to be harmless for human health, environment friendly, and socially responsible.

standard selected by the private certifier, and how firm power may affect the performance of environmental taxes or subsidies.

We consider two firms engaged in price competition in a vertical differentiation model (as in [Gabszewicz and Thisse, 1979](#), and [Shaked and Sutton, 1982](#)). If there is no label their products are homogeneous since both must produce the base quality, or Minimum Quality Standard set for the industry. Due to moral hazard a higher standard than the base quality cannot be communicated directly by a firm to its customers. The firm is therefore left with the options to produce the minimum standard or to adopt a private label, certified by a for-profit certifier. In this way a firm eventually differentiates its product from a non certifying rival. We show that firm power, within the relationships between firms and private certifier, leads to a lower certification standard as compared with the one chosen under certifier power. In the latter case the standard would in fact coincide with the one which maximizes the labeled firm's profit gross of the certification fee. The difference in the standard chosen stems from the following. In the equilibrium under firm power firm A, say, does not need to pay more for acquiring the label than the amount that firm B would be willing to bid. Hence, the certifier's profit as a function of the standard no longer coincides with the (gross of the fee) profit of the labeled firm.

Assuming firm power gains significance when we consider a private certifier and policies like tax or subsidies. Since a market failure occurs in any case, increasing the standard above the level chosen by the private certifier is always socially desirable, whether firm power prevails or not. However, we show that the effects of a green tax or subsidy on the certification level are not as obvious as one may expect. Furthermore, the effects of the policies depend upon whether there is firm power or not. This is because these policies affect the market outcome and the externality not just through the pricing mechanism but also and maybe primarily through the standard chosen for the label. The environmental standard actually depends upon the fee extraction incentives for the certifier, which in turn are affected by anything, like taxes or subsidies, altering the firms equilibrium profits in the price game. Through this channel, for instance, a subsidy for the labeled (environment

friendly or “clean”) product worsens the environmental performance of the market outcome while under certifier power it improves it. In particular, compared to the equilibrium where the certifier sets the certification fee, in the presence of firm power (i) an ad valorem tax on the unlabeled good increases the eco-label standard instead of being neutral, and welfare is improved instead of unaffected; (ii) a per-unit subsidy on the labeled good decreases the private certification standard, instead of increasing it, and social welfare is reduced instead of increased—with a complete reversal of the effects. As a per unit tax on the unlabeled product decreases the private certification standard in any case, it should not be recommended based upon the results of our analysis.

The present paper is related to the literature on labeling (see e.g. [Fulton and Giannakas, 2004](#), [Roe and Sheldon, 2007](#), [Bonroy and Lemarié, 2012](#), and [Manasakis \*et al.\*, 2013](#)), more specifically on eco-labeling (see e.g. [Amacher \*et al.\*, 2004](#), and [Fischer and Lyon, 2014](#)), and on the analysis of the interaction between private labeling and public regulation (see e.g. [Heyes and Maxwell, 2004](#), [Marette, 2008](#), and [Bottega and DeFreitas, 2009](#)). Unlike our paper, this literature largely focuses on the case where the private certifier maximizes the producer’s profit and considers a minimum quality standard or a public label as the only regulation tools.

The paper is organized as follows. Section 2 presents the model’s assumptions. Sections 3 and 4 analyze the certification standard when the certification fees are respectively set by the certifier and by the firms. Section 5 considers the interactions between private certifier and environmental taxes or subsidies. Finally, Section 6 concludes.

## 2 The model

We consider a market with two producers selling vertically differentiable products to a population of consumers. Each product is characterized by an environmentally relevant and measurable attribute,  $s$ , also called its “environmental quality”. The higher its level, the better the environmental performance of the good. Consumers care for this attribute.

Firm  $i$  produces a good with environmental quality at level  $s_i$ , a real number, and sells it at price  $p_i$ , with  $i = 1, 2$ .

To simplify we assume that there are no variable costs in production but that, in order to achieve the desired environmental quality, firms must incur development costs that are increasing in quality.

We assume, in particular, that a “base” quality product defined by a minimum quality standard  $\underline{s}$  can be developed by firms at no cost. However, the quality of the product can be increased by firms only if they pay a development cost,  $C(s)$ , incurred prior to physical production, and defined as follows:<sup>3</sup>

$$C(s) = \begin{cases} \frac{1}{2} [s^2 - \underline{s}^2] & \text{if } s > \underline{s} \\ 0 & \text{otherwise.} \end{cases} \quad (1)$$

We consider consumers’ preferences as described in [Mussa and Rosen \(1978\)](#). Each consumer has a type  $\theta$  which is uniformly distributed over the interval  $[0, 1]$  (the density is equal to 1 and hence the population mass is also equal to 1). Each consumer buys at most one unit of the indivisible good; similarly to [Cremer and Thisse \(1999\)](#) the utility function of a consumer of type  $\theta$  is defined as:

$$U_\theta(s, p) = \theta s + \gamma \theta s_a - p \quad (2)$$

when she consumes a unit of product of quality  $s$  sold at price  $p$ . The term  $\gamma \theta s_a$  is a positive externality associated with the average environmental quality consumed,  $s_a$ , where the intensity of the externality effect is measured by the positive parameter  $\gamma$ , which is constant over the population of consumers<sup>4</sup>. This positive externality is the way in which

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<sup>3</sup>We consider that providing the base quality does not require any developing costs either because the corresponding investment ( $C(\underline{s}) = \frac{1}{2}\underline{s}^2$ ) has been sunk, or because the production of the base quality is trivial (due for instance to spillovers). In this way, providing a quality  $s$  superior to the base quality requires a quality development cost  $C(s) = \frac{1}{2}(s^2 - \underline{s}^2)$ . Note that the model would be unaffected had we introduced a first stage where firms decide whether or not to enter the market, entry being contingent upon an investment in the base quality  $C(\underline{s}) = \frac{1}{2}\underline{s}^2$ .

<sup>4</sup>Without loss of generality, instead of a positive one, we may consider a negative externality given by  $\gamma(\bar{s} - s_a)$ , with  $\bar{s}$  the unabated emission intensity of the product and  $s_a$  the average abatement effort of firms



the consumer is affected by the environmental market outcome. If  $\gamma$  is zero, which is also possible, then the utility of the consumer is only affected by the environmental quality that she consumes individually (for instance a consumer only cares about her contribution to the environment). On the other hand a positive  $\gamma$  implies that the choice of the rest of the population determines the well-being of a consumer, even for consumers who do not consume any unit of the good. Because an individual cannot affect the average quality, the externality term will be a constant in the optimization problem of each consumer. The externality term therefore has no relevance in the decision about buying from firm 1 or 2, or whether to buy or not, and ultimately it has no effect on the duopoly equilibrium (see [Cremer and Thisse, 1999](#)). Finally, it is worth reminding that the term relating to the externality, since it enters the individual utilities, cannot be considered constant in the evaluation of the welfare in the industry; and in particular, in the evaluation of public policies (Proposition 1 and Section 5).

Furthermore, we assume that when a product is certified by a label, consumers know for sure that the quality meets that standard. In other words, labeling by firm  $i$  can only mean here that the consumer obtains full information about  $s_i$ . Without any label, consumers cannot ascertain the quality of a good neither before nor after purchase (quality is here a credence attribute), so that they expect to buy the *base quality*. This base quality can also be seen as being determined by an exogenous minimum quality standard (MQS), denoted as  $\underline{s}$ . The presence of a label or its absence thus defines a consumer perception of the environmental quality of a product.

Given that firms can improve their product's quality only by increasing their costs, it is natural to assume here that a consumer expects the base quality for an unlabeled product. On the other hand, the condition that firms cannot cheat when labeling can only be guaranteed by the existence of an external private or public supervisory body, entrusted with the task of controlling the firms' behavior with regard to labeling. A signaling equilibrium where a false label is not convenient because it is more costly to label a lemon than a good

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(see [Lombardini-Riipinen, 2005](#))

product is assumed not to exist, e.g. because uncertified labeling is equally costly for any type of product, e.g. truly OGM-free or falsely so.

We assume, furthermore, that self-certification is not technically feasible (or it could be manipulated) and that a certifier is needed. A “monitoring” cost, borne by the certifier, is then incurred in order to ascertain that the good’s quality respects the standard defined by the label. This cost, denoted by  $M(s)$ , and its respective marginal cost,  $MM(s)$ , are assumed to be increasing functions of  $s$ , that is:  $MM(s) > 0$  and  $\partial MM(s)/\partial s \geq 0$ . The certifier sets a fixed fee  $F$  that firms must pay in order to obtain the labeling. Here this fee represents the payments that a producer must pay to certify its production with a label delivered by for-profit private certifiers such as Asbl Biogarantie or OEKO-TEX. We proceed in line with the existing literature and assume that the certifier is independent and honest.

In general, the incentives of the certifier and firms are not aligned. The question of which side has the initiative when the certification fee is set, is therefore important as it bears consequences not only on the profits of both the certifier and the firms, but also on the certification level of the label. As we show below, the effects of public policies also crucially depend upon how the fee is negotiated.

To capture the possible differences in the incentives of certifier and firms, we shall compare two polar cases: (i) certifier power: the certifier makes take-it-or-leave-it offers to the firms, and (ii) firm power: the two firms make offers to the manufacturer in a non-cooperative fashion. In both cases, frequently used policies (tax, subsidy) are considered.

### 3 Certifier power

When the certifier offers contracts to firms we consider the following three-stage game:

1. At the first stage the certifier sets the certification standard  $s_2$  and the respective fee  $F$ .
2. At the second stage each firm decides whether to adopt the label or not. A firm that

does not adopt any label supplies the base quality  $\underline{s}$ ; a firm that adopts the label pays the fee to the certifier, and incurs the supplementary development cost  $C(s_2)$  that enables it to provide quality which conforms to the certification standard.

3. At the third stage firms simultaneously choose prices and competition is resolved.

### 3.1 Price Competition

At the last stage, price competition, the environmental quality levels are given and we assume without loss of generality that  $s_2 \geq s_1$ , so that firm 1 shall always be the low quality firm. We shall denote a good by its  $s_i$  level. The preference index of the consumer who is indifferent about the purchase of  $s_1$  and  $s_2$  is  $\tilde{\theta}(p_1, p_2) = \frac{p_2 - p_1}{s_2 - s_1}$ . This satisfies

$$\tilde{\theta}s_1 - p_1 = \tilde{\theta}s_2 - p_2. \quad (3)$$

All consumers with  $\theta > \tilde{\theta}(p_1, p_2)$  strictly prefer product  $s_2$  to  $s_1$ . Some consumers may refrain from purchasing at all. In particular, all consumers with  $\theta < \theta_1(p_1) = p_1/s_1$  do not buy product 1 at price  $p_1$ . Since  $\underline{\theta} = 0$ , at equilibrium there will always be consumers who do not buy at all (uncovered market configuration). This results in equilibrium demands such that  $D_1(p_1, p_2) + D_2(p_1, p_2) < 1$ , with  $D_i(p_i, p_j) > 0$ . For the purpose of the analysis, the following description of demand functions is sufficient, without detailing on the zero-demand cases that may arise out of equilibrium<sup>5</sup>:

$$\begin{cases} D_1(p_1, p_2) = \tilde{\theta}(p_1, p_2) - \theta_1(p_1) \\ D_2(p_1, p_2) = 1 - \tilde{\theta}(p_1, p_2). \end{cases} \quad (4)$$

Firms choose prices to maximize their profits  $\pi_i(p_i, p_j) = p_i D_i(p_i, p_j) - C(\cdot)$ , with  $i = 1, 2$ ,  $i \neq j$ . Note that as the certification fee is independent of the level of production, we consider here firm 2's profit gross of the fee, to simplify the exposition.

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<sup>5</sup>It is important to remind here that the high quality producer cannot adopt profitable limit pricing strategies, that lead to zero demand for good 1, since  $\underline{\theta}$  and variable costs are both zero.

The resulting best reply function of each firm is upward sloping and linear in the rival's price: the best reply for firm 1 is  $p_1 = \frac{p_2 s_1}{2s_2}$ , that for firm 2 is  $p_2 = \frac{p_1 + s_2 - s_1}{2}$  (see [Choi and Shin, 1992](#)).

The Nash equilibrium prices are given by

$$p_1(s_1, s_2) = \frac{s_1(s_2 - s_1)}{4s_2 - s_1}, \quad p_2(s_1, s_2) = \frac{2s_2(s_2 - s_1)}{4s_2 - s_1}. \quad (5)$$

The equilibrium firms' profits (as it is assumed  $0 < s_1 < s_2$ ) are given by:

$$\begin{cases} \pi_1(s_1, s_2) = \frac{s_1 s_2 (s_2 - s_1)}{(4s_2 - s_1)^2} - C(s_1), \\ \pi_2(s_1, s_2) = \frac{4s_2^2 (s_2 - s_1)}{(4s_2 - s_1)^2} - C(s_2). \end{cases} \quad (6)$$

It can easily be verified that, for a given level of  $s_1$ , the profit  $\pi_1(s_1, s_2)$  of firm 1 increases as the rival's quality  $s_2$  increases; by contrast, for a given level of  $s_2$ , the profit  $\pi_2(s_1, s_2)$  decreases as the rival's quality  $s_1$  increases. Finally, if  $s_1 = s_2$  profits gross of development costs are zero.

### 3.2 Choice of certification level and associated fee

At the third stage, if both products are perceived to be of identical environmental quality, the ensuing Bertrand equilibrium entails prices equal to marginal costs (here zero for simplicity). If development costs are positive, firms make then negative profits, or zero profits if both firms produce the MQS. Both firms therefore have an incentive to differentiate their products. Accordingly, if firm  $i$  adopts the label, the best reply by firm  $j$  is not to adopt it. As a result only one firm adopts the label in equilibrium; technically, there are two possible asymmetric equilibriums, one with firm 1 and one with firm 2 being the labeled firm. In line with our notation in what follows we assume that firm 1 is the one not choosing the label. This firm supplies the minimum quality standard,  $s_1 = \underline{s}$ . In any case, any different choice by the unlabeled firm could not be communicated to consumers, who would anyway perceive the unlabeled quality as  $\underline{s}$ . To shorten the notation, we define  $\pi_1(s_2) = \pi_1(\underline{s}, s_2)$  as firm 1's

profit when it produces the MQS level against  $s_2$ ; similarly, we let  $\pi_2(s_2) = \pi_2(\underline{s}, s_2)$ .

A private certifier sets the certification standard  $s_2$ , and firms decide whether to adopt it or not. If a firm adopts the standard it has to pay a fee  $F(s_2)$  to the certifier. Both firms gain from escaping the Bertrand-like trap due to imperfect information on qualities. The profit of the environmental labeled firm then becomes  $\pi_2(s_2)$  and that of the other  $\pi_1(s_2)$ . The labeled firm should then pay a certification fee  $F(s_2)$  which must at least cover the costs  $M(s_2)$ , with  $M(s_2) \leq F(s_2)$ . Obviously, the maximum fee that a firm can agree to is defined by the equivalence  $\pi_2(s_2) - F_2(s_2) = 0$ .

The profit for the certifier is then  $F(s_2) - M(s_2)$  and the maximization problem is:

$$\max_{s_2} \{\pi_2(s_2) - M(s_2)\}. \quad (7)$$

To avoid trivial cases we assume that the set of environmental quality levels  $s_2$  such that  $\pi_2(s_2) - M(s_2) > 0$  is not empty. The first order condition (FOC) of (7) under certifier power can be written as:

$$MR_{cp}(s_2) = MM(s_2), \quad (8)$$

where  $MR_{cp}(s_2)$ , the marginal revenue function, is given by

$$\frac{\partial \pi_2}{\partial s_2} = \frac{1}{4} - s_2 + \frac{s^2(20s_2 + \underline{s})}{4(4s_2 - \underline{s})^3}, \quad (9)$$

and with  $MM(s_2) \equiv \frac{\partial M(s_2)}{\partial s_2}$ , the marginal monitoring cost. Since  $MR_{cp}(s_2)$  is continuous and decreasing and  $MM(s_2)$  continuous and increasing in  $s_2$ , the certifier's profit function given by  $\pi_2(s_2) - M(s_2)$  is concave, and the FOC has a unique solution denoted  $s_{cp}^*$ .<sup>6</sup>

## 4 Firm power

In this section we consider a game where firms make bids to the certifier. The certifier sets a certification level and firms can “buy” the certification by offering a fee. Given the

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<sup>6</sup> $\forall s_2, \underline{s} > 0 : \frac{\partial MR_{pc}}{\partial s_2} = -1 - \frac{8s^2(5s_2 + \underline{s})}{(4s_2 - \underline{s})^4} < 0$ .

zero profit Bertrand equilibrium that would follow if both obtained the certification, firms would not bid at all if the certifier could accept both bids, as they would end up making a loss. Therefore firms participate only if an exclusivity clause is attached to the bid. For the purpose of this specification of the game a bid  $b_i$  is intended as a payment proposal for an exclusive certification. The game then unfolds as follows:

1. At the first stage the certifier sets the certification level  $s_2$
2. At the second stage each firm  $i$  makes a bid  $b_i$ .
3. At the third stage the certifier accepts one bid or refuses both bids. The firm whose bid is accepted pays the fee to the certifier, and incurs the supplementary development cost required to produce quality that conforms to the certification standard. The other firm supplies the minimum quality standard  $\underline{s}$ .
4. At the final stage both firms simultaneously choose prices and competition is resolved.

#### 4.1 The negotiation game

To find the solution to the game we proceed by imposing sequential rationality and by using backward induction.

The solution to stage 4, which is the last, is given in subsection 3.1.

To analyze stage 3 we must describe the certifier's best reply function to the received bids. Given a bid pair  $(b_1, b_2)$ , if the certifier accepts  $b_i$  he obtains  $b_i - M(s)$ ; if he refuses both bids his payoff is zero. Let  $b' \equiv \max\{b_1, b_2\}$ , then the best reply for the certifier is:

$$\left\{ \begin{array}{l} (i) \text{ if } b' < M(s_2) \text{ reject both bids} \\ (ii) \text{ if } b' > M(s_2) \text{ and } b_i \neq b_j, \text{ accept } b' \\ (iii) \text{ if } b' > M(s_2) \text{ and } b_1 = b_2, \text{ randomize with probability } \frac{1}{2} \text{ to each.} \end{array} \right. \quad (10)$$

If  $b' < M(s_2)$  the certifier would make a loss by accepting any bid. Case (ii) is self-evident. Case (iii) is the way to solve a tie.

We now proceed with stage 2. As previously, to shorten the notation, we define here  $\pi_1(s_2) = \pi_1(\underline{s}, s_2)$  as the profit to firm 1 when it produces the MQS level against  $s_2$ . Similarly, we let  $\pi_2(s_2) = \pi_2(\underline{s}, s_2)$ . Thus, if a bid is accepted, the firm with the accepted bid (if any) gets  $\pi_2(s_2) - b_i$  in the ensuing price game of stage 4; the firm with rejected bid gets  $\pi_1(s_2)$ . If no bid is accepted the firms produce  $\underline{s}$  and obtain a null profit at stage 4.

Given  $s_2$ , assume first that  $\pi_2(s_2) - M(s_2) > 0$  (A.A.) and analyze all possible pairs of bids and possible *unilateral* deviations in order to check for all possible pair of mutual best replies in the subgame starting after  $s_2$ :

- (a)  $(b_i, b_j)$  with  $b' = \max\{b_1, b_2\} \leq M(s_2)$  cannot be a pair of mutual best replies because the certifier would reject both bids and  $\pi_i = \pi_j = 0$ , while given Assumption (A.A.) there exists  $\varepsilon$  (small enough) such that for  $b_i = \varepsilon + M(s_2)$  the certifier accepts  $b_i$  at stage 3 and firm  $i$  obtains  $\pi_2(s_2) - M(s_2) - \varepsilon > 0$ .
- (b)  $(b_i, b_j)$  with  $b_i > b_j$  and  $b_i = b' > M(s_p)$  cannot be mutual best replies because the winning firm  $i$  can choose  $\varepsilon$  small enough and bid  $b_i = b' - \varepsilon > b_j$  and still win.
- (c) If  $b_i = b_j = b$  then the certifier will randomize its choice. At any  $(b_i, b_j) = (b, b)$  the expected payoff to either firm is  $(1/2) [\pi_2(s_2) - b] + (1/2) [\pi_1(s_2)] = E$ . If  $b$  is such that  $\pi_2(s_2) - b < \pi_1(s_2)$  one of the two firms can deviate to  $b - \varepsilon$ , lose the bid and make payoff  $\pi_1(s_2)$  for sure instead of  $E$ ; such a deviation is profitable for some  $\varepsilon$ . Suppose instead  $b$  such that  $\pi_2(s_2) - b > \pi_1(s_2)$  then either firm can deviate to  $b + \varepsilon$  and win the bid for sure gaining  $\pi_2(s_2) - b - \varepsilon$  instead of  $E$ ; such a deviation is profitable for any  $\varepsilon$  such that  $E < \pi_2(s_2) - b - \varepsilon$  holds. Hence in equilibrium it must be that  $\pi_2(s_2) - b = \pi_1(s_2)$ .

The only possible pair of bids that can be part of a subgame perfect Nash equilibrium therefore is  $(b_i, b_j) = (b_s, b_s)$  where  $b_s$  is such that

$$\pi_2(s_2) - b_s = \pi_1(s_2). \quad (11)$$

The equilibrium fee offered by the winning firm is such that firms make the same equilibrium

profit,  $\pi_1(s_2)$ . If a firm unilaterally deviates to bid less than  $b_s$  it will obtain  $\pi_1(s_2)$ , with no gain. A bid above  $b_s$  will lead the firm to obtain  $\pi_2(s_2) - b_s - \varepsilon = E - \varepsilon$  instead of  $E$ , leading to a lower profit than by sticking at  $b_s$ . Hence, the pair of bids  $(b_i, b_j) = (b_s, b_s)$  is part of a subgame perfect Nash equilibrium of the game. Furthermore, given the above reasoning this it is the unique Nash equilibrium pair of bids.

To complete the reasoning, assume now that (A.A.) is violated and  $\pi_2(s_2) - M(s_2) < 0$ . Any acceptable bid would then lead to negative profits for the firm. In this case any pair of bids lower than or equal to  $\pi_2(s_2)$  is an equilibrium pair, but the certifier refuses the bids and firms produce the base quality. All agents, including the certifier, make zero profits.

**Lemma 1.** *Under firm power, if  $s_2$  is set such that  $\pi_2(s_2) - M(s_2)$  is nonnegative, then the certification fee is given by  $F = \pi_2(s_2) - \pi_1(s_2)$ . Furthermore, after paying the fee, the labeled firm has the same equilibrium profit as the unlabeled one.*

The choice of the standard  $s_2$  made at stage 1 by the private certifier is considered in the following subsection.

## 4.2 Choice of certification level

Stage 1. At stage 1 any choice  $s_2$  that violates (A.A.) implies zero profits for the certifier and is strictly dominated by the choice of  $s_2$  such that (A.A.) holds true, since this leads to acceptable bids equal to  $b_s = \pi_2(s_2) - \pi_1(s_2)$ . Hence, the certifier chooses  $s_2$  so as to maximize  $b_s - M(s_2)$ , namely to solve:

$$\max_{s_2} \{\pi_2(s_2) - \pi_1(s_2) - M(s_2)\}. \quad (12)$$

Whence the following FOC obtains:

$$MR_{fp}(s_2) = MM(s_2), \quad (13)$$



with  $MR_{fp}(s_2)$ , the marginal revenue function, given by:

$$\frac{\partial(\pi_2(s_2) - \pi_1(s_2))}{\partial s_2} = \frac{1}{4} \left( 1 - 4s_2 + \frac{3\underline{s}^2}{(4s_2 - \underline{s})^2} \right). \quad (14)$$

Since  $MR_{fp}(s_2)$  is continuous and decreasing in  $s_2$ , the private certifier's profit function, given by  $\pi_2(s_2) - \pi_1(s_2) - M(s_2)$ , is strictly concave, and the condition given by the equation (13) has a unique solution, denoted  $s_{fp}^*$ .<sup>7</sup>

By comparison with the certification level when the certifier offers a take-it-or-leave-it contract to firms, we find that  $s_{cp}^* > s_{fp}^*$ . Furthermore, irrespective of the agent offering the contract (certifier or firms) the certification level is always lower than the socially optimal certification level  $s_g^*$  (see Appendix 1 for the derivation of the socially optimal certification). The following proposition summarizes these results.

**Proposition 1.** *i) The private certification standard is always lower than the socially optimal certification standard; its level is lower under firm power than under certifier power, namely  $s_g^* > s_{cp}^* > s_{fp}^*$ . ii) The distance  $s_g^* - s_{cp}^*$  increases with the externality intensity  $\gamma$ .*

*Proof.* i) For all  $s_2 > \underline{s}$ , the inequalities  $MR_g(s_2) > MR_{cp}(s_2) > MR_{fp}(s_2)$  are verified, with  $MR_g(s_2)$  the marginal revenue function of the government given by the equation (24). Therefore for  $MM(s) > 0$  and  $\partial MM(s)/\partial s \geq 0$  we have  $s_g^* > s_{cp}^* > s_{fp}^*$ . See Figure 1 for a graphical illustration. ii) See Lemma 2 in Appendix 1.  $\square$

Our result, that a for-profit monopoly private certifier may set a certification level inferior to the one maximizing the profit of the high-quality firm contrasts with [Bottega and DeFreitas \(2009\)](#), where the certifier extracts all the rent from the firm and chooses the level of the standard that maximizes the firm's profit. In our approach, crucial to the result is the existence of an (endogenous) reserve profit, given by the "firm power" and equal to the profit of an unlabeled firm, that the private certifier must leave to the labeled firm. In order to avoid increasing this reserve profit, the private certifier must choose a lower level of certification than the self-certification level.

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<sup>7</sup> $\forall s_2, \underline{s} > 0 : \frac{\partial MR_{fp}}{\partial s_2} = -1 - \frac{6s^2}{(4s_2 - \underline{s})^3} < 0.$

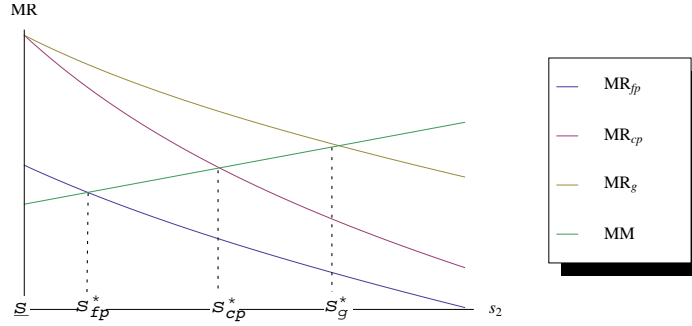


Figure 1: Graphical representation of the FOCs for  $MM(s_2) = s_2$  and for  $\gamma = 0$ .

## 5 Private certification and public intervention

Given the result in Proposition 1 it is natural to ask whether traditional policy tools like taxes or subsidies may increase the private standard towards the socially optimal level, and whether this increases welfare. It is worth stressing that this possible basis for taxes and subsidies differs from the usual arguments resting on discouraging the consumption of goods with poor environmental standards, while encouraging that of “cleaner” or environment friendly ones. In our framework, demand effects of taxes and subsidies are brought forth by changes in the certification standard, which in turn also affects consumer welfare directly (also through the externality term).

Possible policies include encouragement of the production of the labeled product by means of a unit subsidy that eventually determines a lower final price in the market, or a tax on the unlabeled product so as to discourage its consumption and favor that of the labeled good. We distinguish in particular between an *ad valorem* and a *per-unit* tax. In the following we consider the “firm power” case, and we compare the results with those obtained with “certifier power”.

A tax on the unlabeled product may or may not shift the best reply function of firm 1 in the price game, according to whether it is a per-unit or an *ad valorem* tax. It also affects the firms’ profits and the solution in the negotiation game. In fact we shall see that this effect plays an important role in the analysis. We start with the analysis of a unit subsidy

on production and then proceed with the analysis of taxes.

### *Subsidy*

Consider a subsidy for the production of the labeled product consisting in the transfer from the government to the producer of a fixed amount of money for each unit sold. We call this a *subsidy policy*. A subsidy on labeled products can be used or advocated by producers' organizations or by pro-environment agencies. An example is the subsidies allocated on a per-hectare basis to organic farmers in several OECD countries (OECD, 2003).<sup>8</sup> We represent a subsidy here as a per-unit subsidy  $\lambda$ . The profit function in the price game for firm 2 is changed to

$$\pi_2(p_1, p_2, \lambda) = (p_2 + \lambda)D_2(p_1, p_2) - C(s_2). \quad (15)$$

In the price game, it is clear that if one depicts the best reply functions in the space of ordinate pairs  $(p_1, p_2)$ , then the best reply function of firm 2 is shifted downward, and the equilibrium prices *for given*  $s_1$  and  $s_2$  are both lowered by the presence of a subsidy. One does not know however if the change in  $s_2$  caused by the subsidy will increase or lower prices. The Nash equilibrium prices as functions of qualities, denoted by  $p_i(s_1, s_2, \lambda)$ , are indeed equal to:

$$p_1(s_1, s_2, \lambda) = p_1(s_1, s_2) - \frac{s_1\lambda}{4s_2 - s_1}, \quad p_2(s_1, s_2, \lambda) = p_2(s_1, s_2) - \frac{2s_2\lambda}{4s_2 - s_1} \quad (16)$$

where  $s_1 = \underline{s}$  and  $p_1(s_1, s_2)$  and  $p_2(s_1, s_2)$  are the equilibrium prices in (5).

Under firm power, in the certification game the certifier will manipulate  $s_2$  considering the effects of the subsidy on the equilibrium bid,  $b_s = \pi_2(s_2, \lambda) - \pi_1(s_2, \lambda)$ . Therefore, on the one hand the certifier's marginal revenue from an increase in  $s_2$  is enhanced by the positive effect of a subsidy on the marginal effect of  $s_2$  on  $\pi_2(s_2, \lambda)$ , on the other

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<sup>8</sup>Governments may also use a subsidy to encourage consumption of high-quality products such as sustainable products (OECD, 2008). In this case the subsidy is granted directly to consumers. Our results remain valid, irrespective of the agent receiving the subsidy: the high-quality firm or the consumers of the high-quality product. The only difference is the monetary transfer between these agents.

hand the subsidy leads to a change in the function  $\pi_1(s_2, \lambda)$  — implying a higher marginal effect of  $s_2$  on  $\pi_1(s_2, \lambda)$ . The direction of change in the result of the maximization of  $\pi_2(s_2, \lambda) - \pi_1(s_2, \lambda) - M(s_2)$  is therefore not clear a priori. However we show that, compared to  $s_{fp}^*$ , the private certification standard is lowered by a subsidy on the labeled product. This result is driven by the downward shift of the marginal revenue function in equation (13) above as modified after the introduction of a subsidy. By contrast, under certifier power, it is apparent from equation (8) that only the positive effect on  $\pi_2(s_2, \lambda)$  remains, and as a consequence the subsidy increases the certification level and is welfare improving.

**Proposition 2.** *i) Under firm power, a not-too-high subsidy policy decreases the private certification standard, with a negative impact on welfare. The total effect of a subsidy on welfare is then ambiguous. ii) By contrast, under certifier power, the private certification standard is increased and welfare is unambiguously improved.*

*Proof.* See Appendix 2. □

The result is to be interpreted for small subsidies. Under firm power the equilibrium prices after the change in  $s_2$  are both lowered by the introduction of a subsidy, which is quite intuitive considering that: (i) the quality difference is reduced and (ii) the price reaction function of the high quality shifts downward, as discussed above. The effect on the equilibrium demand for the labeled product can also be shown to be positive, as this firm attracts consumers who would buy from the rival if the subsidy was zero. This increase in demand is entirely due to the lower equilibrium price difference since firm 2's labeled quality is lowered by the subsidy. The change in the demand for the unlabeled product cannot be signed (see Appendix 3). This seller, given that  $s_1 = \underline{s}$  and that its equilibrium price is lowered by the standard, also sells to consumers that did not purchase before the introduction of the subsidy, thereby countervailing the loss of consumers that buy from firm 2.

Under firm power, the desirable increase in consumption of the labeled product is obtained at the cost of a lower standard. As a consequence it cannot be said if the average

quality (weighted by the market shares) is increased or decreased. This is a surprising result and most likely an unintended one for a policy maker.

Under certifier power the effect on prices and on the demand for the labeled product is ambiguous. Nonetheless the overall welfare effect is positive, as it is driven by the increase in the standard.

Summarizing, a subsidy has opposite effects on the level of the standard in the two cases: negative under firm power and positive under certifier power. The welfare effect cannot be signed under firm power while it is positive under certifier power; however, we can say that firm power always reduces the welfare improvement induced by a subsidy due to the negative effect on the standard.

*Per unit tax*

Normally a (unit) subsidy generates opposite effects to a unit tax. Therefore one could expect that if a subsidy reduces the private standard, as under firm power, a tax may succeed in increasing it. This intuition is however misleading, because the channel through which the tax or the subsidy affects the standard is the objective function of the certifier. The tax reverses the result only in the case of certifier power, where the subsidy improves the standard while the tax lowers it. Consider a tax targeted *only* on the unlabeled product, and that we call a *per unit tax policy*. Obviously one can only consider tax rates that allow firm 1 to have a positive equilibrium profit. A per unit tax,  $\tau$ , on the unlabeled product changes firm 1's profit in the price stage to

$$\pi_1(p_1, p_2, \tau) = (p_1 - \tau)D_1(p_1, p_2) - C(s_1). \quad (17)$$

In the price game, it is clear that firm 1 responds with a higher price to any price by the rival (its best reply shifts to the left). Since prices are strategic complements, the equilibrium prices for given  $s_1$  and  $s_2$  are both higher than without a tax (firm 2's best reply remains unchanged). The Nash equilibrium in the price game is then given by:

$$p_1(s_1, s_2, \tau) = p_1(s_1, s_2) + \frac{2s_2\tau}{4s_2 - s_1}, \quad p_2(s_1, s_2, \tau) = p_2(s_1, s_2) + \frac{s_2\tau}{4s_2 - s_1}. \quad (18)$$

Under firm power, in the certification game the effect of the tax on the private certification standard  $s_p$  depends upon its effect on both the high-quality firm's profit,  $\pi_2$ , and the reserve profit  $\pi_1$ . For this reason,  $\forall \tau \in ]0, \underline{s}[$ , and compared to  $s_{fp}^*$ , the private certification standard is lowered by the tax. This outcome, again, is driven by the downward shift of the marginal revenue function in equation (13) above, modified by the introduction of a unit tax. The downward shift moves  $s_2$  away from  $s_g^*$ , leading to ambiguous effects of a per unit tax policy on the welfare. It is furthermore easy to show that the signs of the effects are the same in the case with certifier power, where the certifier maximizes  $\pi_2(s_2, \tau) - M(s_2)$ .

**Proposition 3.** *Under both certifier power and firm power, a not-too-high per unit tax policy lowers the private certification standard. This has a negative effect on welfare, so that the tax total effect on welfare is ambiguous.*

*Proof.* See Appendix 4 □

Under firm power, the effect on the level of equilibrium prices is ambiguous. Since qualities are brought closer together by the tax, price competition is exacerbated. However the tax also pushes prices upward via the displacement in firm 1's reaction function. There are, also, two forces, countering each other, that affect the *demand* for the labeled good: the decrease in  $s_2$  and the decrease in the equilibrium price difference  $p_2 - p_1$  (and in the relative price  $p_2/p_1$ ). The final effect on the demand for the labeled good can be shown to be positive, it is entirely due to the lower relative price (see the Appendix 5).

To summarize, under both regimes, a trade-off arises in terms of quality and consumption: a unit tax *increases* consumption of the labeled good (possibly as intended by the policymaker) but *lowers* the certification standard, thus reducing the desired “environmental quality” of the labeled good.

### *Ad valorem tax*

An ad valorem tax modifies the revenue from the sale of one unit of the unlabeled product, decreasing it from  $p_1$  to  $p_1(1 - t)$ , where  $0 < t < 1$  is the tax rate. The profit to firm 1 in the price game is then defined as:

$$\pi_1(p_1, p_2, t) = p_1(1 - t)D_1(p_1, p_2) - C(s_1). \quad (19)$$

In the price game, and compared to the equilibrium without tax, the best replies are not affected by an ad valorem tax (a property that does not hold for the unit tax or for the subsidy) and the equilibrium prices as functions of  $s_2$  are given by equation (5). The demand functions, the profit function to firm 2, and the welfare function are also unchanged. Under firm power, in the certification game, the effect of the tax on the private certification standard,  $s_2$ , only depends on the reservation profit  $\pi_1(s_2, t)$ , which is affected by the tax. It can then be shown that, compared to  $s_{fp}^*$  (given in Section 4.2), the private certification standard is increased. Such a result is driven by the upward shift of the marginal revenue function in equation (13) above, modified after the introduction of an ad valorem tax. It is also easy to show that if we consider “certifier power” an ad valorem tax has no effect whatsoever on the certification level ( $s_{cp}^*$ ).

**Proposition 4.** *i) Under firm power, a not-too-high ad valorem tax policy on the unlabeled product increases the private certification standard; total welfare is improved. ii) By contrast, under certifier power the tax has no effect on the private certification standard or on welfare.*

*Proof.* See Appendix 6 □

It is interesting to consider that under firm power the increase in  $s_2$  leads to a higher degree of differentiation, which relaxes price competition and entails a higher price level for both products (see Appendix 7). It can be shown then that the equilibrium demand for both types of product decreases under an ad valorem tax. As a policy remark, it seems

striking that while the tax aims at encouraging the consumption of the labeled good, it actually obtains the opposite result, even though a welfare improvement is achieved.

It is worth noting that if the same tax is levied on *both* the labeled and the unlabeled good, then the certifier's marginal revenue function can be shown to shift downwards, leading to the opposite result: a *lower* standard and a lower welfare level.<sup>9</sup> This aligns our finding to the result of [Cremer and Thisse \(1994\)](#) for the ad valorem tax when the same rate applies to both goods and where the firms themselves choose their own qualities to maximize their profits (in their model there is no certifier and no MQS).

#### *Certifier's profit and firms' profit*

Consider now how the certifier and the firms are affected by tax and subsidy policies.<sup>10</sup> We show that the certifier always benefits from taxes and subsidies.<sup>11</sup> Under certifier power, by setting the certification fee the certifier may capture the entire benefit provided by the policy to the subsidized producer or (indirectly) to the non-taxed one. Therefore a tax or a subsidy has no effect on the profit of the labeled firm. Under firm power, the competition between firms on the label drives a transfer of the benefit of the subsidy or the tax from the labeled firm to the certifier. Therefore the effect of a per-unit tax or a subsidy on the labeled firm's profit is given by the effect on the non-labeled firm's profit, which is always negative as expected.

## 6 Conclusions

The present work, using a duopoly, as for example in [Cremer and Thisse \(1999\)](#), [Bansal and Gangopadhyay \(2003\)](#), and [Amacher et al. \(2004\)](#), makes a contribution to the literature on eco-labeling of credence goods with environmental externalities. Consumers are assumed

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<sup>9</sup>By computation when both goods are taxed at the rate  $t$  one gets  $\frac{\partial MR_{fp}(s_2)}{\partial t} = -\frac{1}{4} \left(1 + \frac{3s^2}{(4s_2 - s)^2}\right) < 0$ . This entails a lower total welfare.

<sup>10</sup>The proof is given in Appendix 8

<sup>11</sup>The only case where the certifier does not benefit from the policy instrument is under certifier power when the government implements an ad valorem tax on the unlabelled firm. The tax then has no effect on the certifier's profit.



to care about the environmental consequences of their consumption; as a consequence, the environmental “quality” of a good is positively valued (for instance because consumers are happy to reduce Co2 emissions if they can do so). The population of consumers is however heterogeneous as to the importance given to this dimension of their consumption. Furthermore, each consumer may also be affected by an externality arising from the total consumption of the good in the market. Since consumers are unable to ascertain the environmental quality, a firm willing to increase it for attracting more consumers must resort to a certifier. We show that a for-profit private certifier chooses a certification level that depends upon whether the fee is set by a take-or-leave-it offer by the certifier (certifier power) or by a negotiation where firms bid for the certification (firm power). In the second case the certification level is lower than the one maximizing the profit of the labeled firm. This result, which cannot be found in the literature so far, is due to the certifier not being able to extract the whole surplus from the labeling firm, since the latter can win the bidding game by offering at most as much as is necessary to outbid the non-labeled rival. This implies that once the fee is paid out the labeled and the unlabeled firm end up with an identical equilibrium profit.

Furthermore, the private certification standard remains below the welfare maximizing level that a Government may want to obtain. We therefore analyze the effects of commonly used policy tool options that aim to improve environmental quality and in general to increase welfare.

We show that subsidies for production of the labeled product have different effects in the two possible scenarios: under certifier power a subsidy increases the level of the standard chosen by the certifier and improves total welfare in the industry. Under firm power, however, the environmental standard is lowered by the subsidy, which reduces welfare. This result contradicts the very purpose of a subsidy favoring a specific environmental quality. A per unit tax on the unlabeled product leads the certifier to choose a lower environmental standard in both scenarios, which reduces welfare, showing that quality effects are important in shaping the total impact of a tax.

The ad valorem tax targeted only at the unlabeled product is the only policy option among the three considered here that never leads to a lower standard: it increases both the standard and total welfare under firm power, although its effects are nullified if no firm power exists. Among the two tools that raise revenue for the Government from the industry, therefore, our analysis is in favor of an ad valorem tax and rejects a per unit tax.

As a possible extension to the discussion, one may consider that a duopoly, also taken as a reference model in the literature quoted above, is a limited representation of most industries in which certification is used, and therefore that a more general setting needs to be envisaged. This is a venue for research in the field of oligopoly theory that we do not pursue here as it would imply a considerable shift in focus and a heavy modeling burden. However, it is worth stressing that an environment with horizontal variants of a product that can be made more or less environmentally clean, where each variant is produced by two firms would look like an oligopoly market with replicas of the duopoly analyzed above, and complicated by the further strategic interactions at the price stage among the neighboring firms in the horizontal dimension. Otherwise, under only vertical differentiation, if firms have limited production capacities, there may be equilibriums where some firms take the label and some do not, while still enjoying positive profits, so that equilibrium bids should equalize the profits of labeled and unlabeled firms.

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# Appendix

## 1 Analysis of the socially optimal certification

We consider next that firms cannot certify their products by a private label and that a public certifier implements a voluntary label. Compared to the game developed in section 3 only the first stage is modified such as the certification standard  $s_2$  and the respective fee  $F$  are now set by the public certifier.

The public certifier sets the certification level  $s_2$  so as to maximize total welfare  $W$ :<sup>12</sup>

$$W(s_2) = \pi_1(s_2) + \pi_2(s_2) + SC(s_2) - M(s_2), \quad (20)$$

with the consumer surplus:

$$SC(s_2) \equiv \int_{\tilde{\theta}(p_1, p_2)}^1 (\theta s_2 + \theta \gamma s_a - p_2) d\theta + \int_{\theta_1(p_1)}^{\tilde{\theta}(p_1, p_2)} (\theta \underline{s} + \theta \gamma s_a - p_1) d\theta, \quad (21)$$

and the average weighted environmental quality (see [Cremer and Thisse, 1999](#)) is:

$$s_a \equiv \frac{\int_{\tilde{\theta}(p_1, p_2)}^1 (\theta s_2) d\theta + \int_{\theta_1(p_1)}^{\tilde{\theta}(p_1, p_2)} (\theta \underline{s}) d\theta}{1 - \theta_1(p_1)} = \frac{2s_2 + \underline{s}}{3} \quad (22)$$

$p_1$  and  $p_2$  are given by the equation (5).

We assume that the public certifier is constrained to zero profits and therefore charges the firm a fee equal to the monitoring costs  $M(s_2)$ . The following condition determines the level of the public label:

$$MR_g(s_2) = MM(s_2), \quad (23)$$

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<sup>12</sup>The solution to stage three is given by the subsection 3.1.

where  $MR_g(s_2)$ , the marginal revenue function, is given by

$$\frac{\partial (\pi_1(s_2) + \pi_2(s_2) + SC(s_2))}{\partial s_2} = \frac{1}{8} \left( 3 - 8s_2 + \frac{s_2^2 (4s_2 + 11\underline{s})}{(4s_2 - \underline{s})^3} \right) + \frac{(20s_2^3 - 15s_2^2\underline{s} + 3s_2\underline{s}^2 + \underline{s}^3)\gamma}{(4s_2 - \underline{s})^3}. \quad (24)$$

Since for not too high value of  $\gamma$ ,  $MR_g(s_2)$  is continuous and decreasing in  $s_2$ , the strict concavity of the  $W(s_2)$  is ensured, and the FOC given by the equation (23) has a unique solution denoted  $s_g^*$ . As expected  $s_g^*$  is increasing in  $\gamma$ .

**Lemma 2.** *The socially optimal certification standard  $s_g^*$  is increasing with the intensity  $\gamma$  of the externality positive for the consumers.*

*Proof.* As  $\frac{\partial MR_g(s_2)}{\partial \gamma} = \frac{(20s_2^3 - 15s_2^2\underline{s} + 3s_2\underline{s}^2 + \underline{s}^3)\gamma}{(4s_2 - \underline{s})^3} > 0$  and  $\frac{\partial MM(s_2)}{\partial \gamma} = 0$ , then  $s_g^*$  is also increasing in  $\gamma$ .

## 2 Proof of Proposition 2

In the following we analyze the effect of a subsidy policy on the certification level and on welfare.

i) Using the FOC in the certification game, one can define how a subsidy  $\lambda$  affects the private certification standard. By fully differentiating the FOC with respect to  $\lambda$  one obtains:

$$\frac{\partial s_2}{\partial \lambda} = \frac{\frac{\partial MR_{fp}(s_2, \lambda)}{\partial \lambda}}{\frac{\partial MM(s_2)}{\partial s_2} - \frac{\partial MR_{fp}(s_2, \lambda)}{\partial s_2}},$$

as we have  $\frac{\partial MM(s_2)}{\partial s_2} - \frac{\partial MR_{fp}(s_2, \lambda)}{\partial s_2} > 0$  (due to the second order condition), then  $sign \frac{\partial s_2}{\partial \lambda} = sign \frac{\partial MR_{fp}(s_2, \lambda)}{\partial \lambda}$ .

Under firm power, in the certification game the FOC is given by  $MR_{fp}(s_2, \lambda) = MM(s_2)$  with

$$MR_{fp}(s_2, \lambda) \equiv \frac{\partial (\pi_2(s_2, \lambda) - \pi_1(s_2, \lambda))}{\partial s_2} = A - \frac{2\lambda\underline{s} + 4\lambda^2}{(4s_2 - \underline{s})^2} \quad (25)$$

where  $A$  is a term independent of  $\lambda$  and is given by the right hand side in equation (14). It is obvious that  $\frac{\partial MR_{fp}(s_2, \lambda)}{\partial \lambda} = -\frac{2(\underline{s} + 4\lambda)}{(4s_2 - \underline{s})^2} < 0$ . Therefore the private certification standard is

decreasing in the subsidy level ( $\frac{\partial s_2}{\partial \lambda} < 0$ ).

Now, we evaluate the full derivative of the welfare with respect to  $\lambda$ :  $\frac{dW}{d\lambda} = \frac{\partial W}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial W}{\partial \lambda}$ .

The welfare is given by:

$$W = \int_{\tilde{\theta}(p_1, p_2)}^1 (\theta s_2 + \gamma \theta s_a) d\theta + \int_{\theta_1(p_1, p_2)}^{\tilde{\theta}(p_1, p_2)} (\theta \underline{s} + \gamma \theta s_a) d\theta - C(s_2) - M(s_2) \quad (26)$$

with  $p_1$  and  $p_2$  given by equation (16) and  $s_a = \frac{(2s_2 + s + 2\lambda)s_2}{3s_2 + \lambda}$ . As a)  $\frac{\partial W}{\partial \lambda} = \frac{(4s_2 - 3\underline{s})s_2(s_2 - \underline{s} - \lambda)}{(4s_2 - \underline{s})^2(s_2 - \underline{s})} + \frac{(8s_2^2 - 5s_2\underline{s} - 4s_2\lambda)\gamma}{2(4s_2 - \underline{s})^2} > 0 \forall \lambda < (s_2 - \underline{s})$ , b),  $\frac{\partial W}{\partial s_2} > 0 \forall s_2 \in ]\underline{s}, s_g^*(\lambda)[$  with  $s_g^*(\lambda)$  the socially optimal certification standard for a per subsidy  $\lambda$  given, and c)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then the sign of  $\frac{dW}{d\lambda}$  is ambiguous.

ii) Under certifier power, in the certification game the FOC is given by  $MR_{cp}(s_2, \lambda) = MM(s_2)$  with

$$MR_{cp}(s_2, \lambda) \equiv \frac{\partial \pi_2(s_2, \lambda)}{\partial s_2} = B + \frac{(4\underline{s}^2(s_2 - \underline{s})^2 - \lambda(2s_2 - \underline{s})(8s_2^2 - 10\underline{s}s_2 + 5\underline{s}^2))\lambda}{(4s_2 - \underline{s})^3(s_2 - \underline{s})^2} \quad (27)$$

where  $B$  is a term independent of  $\lambda$  and is given by the right hand side in equation (9).

We find that for sufficiently low values of the subsidy,  $MR_{cp}(s_2, \lambda)$  is increasing with  $\lambda$  ( $\frac{\partial MR_{cp}(s_2, \lambda)}{\partial \lambda} = \frac{4\underline{s}^2(s_2 - \underline{s})^2 - 2\lambda(2s_2 - \underline{s})(8s_2^2 - 10\underline{s}s_2 + 5\underline{s}^2)}{(4s_2 - \underline{s})^3(s_2 - \underline{s})^2}$ ), therefore both the private certification standard and the welfare are increasing in the subsidy ( $\frac{\partial s_2}{\partial \lambda} > 0$ , and  $\frac{dW}{d\lambda} > 0$ ).

### 3 The Effects of a subsidy policy on prices and quantities

First we consider the effect of a subsidy policy prices and quantities under firm power. The following results are to be interpreted for small values of  $\lambda$ .

The effect of the subsidy on the equilibrium price  $p_1$  is given by  $\frac{dp_1}{d\lambda} = \frac{\partial p_1}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial p_1}{\partial \lambda}$ . As i)  $\frac{\partial p_1}{\partial \lambda} = -\frac{s}{4s_2 - \underline{s}} < 0$ , ii)  $\frac{\partial p_1}{\partial s_2} = \frac{s(3s + 4\lambda)}{(4s_2 - \underline{s})^2} > 0$  and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then  $\frac{dp_1}{d\lambda} < 0$ . The effect of the subsidy on price  $p_1$  is negative.

The subsidy effect on the equilibrium price  $p_2$  is given by  $\frac{dp_2}{d\lambda} = \frac{\partial p_2}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial p_2}{\partial \lambda}$ . As i)



$\frac{\partial p_2}{\partial \lambda} = -\frac{2s_2-s}{4s_2-s} < 0$  , ii)  $\frac{\partial p_2}{\partial s_2} = \frac{2(\underline{s}^2+4s_2^2+s(-2s_2+\lambda))}{(4s_2-s)^2} > 0$  and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then  $\frac{dp_2}{d\lambda} < 0$ . The effect of the subsidy on price  $p_2$  is negative.

The subsidy effect on the price difference  $(p_2 - p_1)$  is given by  $\frac{d(p_2-p_1)}{d\lambda} = \frac{\partial(p_2-p_1)}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial(p_2-p_1)}{\partial \lambda}$ . As i)  $\frac{\partial(p_2-p_1)}{\partial \lambda} = -\frac{2s_2-s}{4s_2-s} < 0$  , ii)  $\frac{\partial(p_2-p_1)}{\partial s_2} = \frac{8s_2^2-s^2-2s(2s_2+\lambda)}{(4s_2-s)^2} > 0$  for low value of  $\lambda$  and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then  $\frac{dp_2}{d\lambda} < 0$ . The effect of the subsidy on price difference  $(p_2 - p_1)$  is negative.

The subsidy effect on equilibrium demand  $D_1$  is given by  $\frac{dD_1}{d\lambda} = \frac{\partial D_1}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial D_1}{\partial \lambda}$ . As i)  $\frac{\partial D_1}{\partial \lambda} = -\frac{s_2}{4s_2^2-5ss_2+s^2} < 0$ , ii)  $\frac{\partial D_1}{\partial s_2} = -\frac{s(s_2-s)^2-(4s_2^2-s^2)\lambda}{(4s_2^2-5ss_2+s^2)^2} < 0$ , and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then the sign of  $\frac{dD_1}{d\lambda}$  is undefined. The subsidy effect on unlabeled product quantity is ambiguous.

The subsidy effect on equilibrium demand  $D_2$  is given by  $\frac{dD_2}{d\lambda} = \frac{\partial D_2}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial D_2}{\partial \lambda}$ . As i)  $\frac{\partial D_2}{\partial \lambda} = \frac{2s_2-s}{4s_2^2-5ss_2+s^2} > 0$ , ii)  $\frac{\partial D_2}{\partial s_2} = -\frac{2s(s_2-s)^2+(8s_2^2-8s_2s+3s^2)\lambda}{(4s_2^2-5ss_2+s^2)^2} < 0$ , and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then  $\frac{dD_2}{d\lambda} > 0$ , the subsidy final effect on labeled product quantity is positive.

The subsidy effect on total demand  $(D_1 + D_2)$  is given by  $\frac{d(D_1+D_2)}{d\lambda} = \frac{\partial(D_1+D_2)}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial(D_1+D_2)}{\partial \lambda}$ . As i)  $\frac{\partial(D_1+D_2)}{\partial \lambda} = \frac{1}{4s_2-s} > 0$ , ii)  $\frac{\partial(D_1+D_2)}{\partial s_2} = \frac{-3s-4\lambda}{(4s_2-s)^2} < 0$ , and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then  $\frac{dD_2}{d\lambda} > 0$ , the subsidy effect on total demand is positive.

Now we consider the subsidy effects under certifier power. Comparing to the environment under firm power, the only difference is on the sign of  $\frac{\partial s_2}{\partial \lambda}$  that is now positive. Therefore i) the effect on both equilibrium prices  $p_1$  and  $p_2$  is ambiguous, ii) the effect on equilibrium demand is negative for the unlabeled product and ambiguous for the labeled product, and iii) the effect on total demand is ambiguous.

The following table summarizes the effects of a small subsidy on prices and demand:

	Firm power	Certifier power
$s_2$	–	+
$p_1$	–	undefined
$p_2$	–	undefined
$p_2 - p_1$	–	undefined
$D_1$	undefined	–
$D_2$	+	undefined
$D_1 + D_2$	+	undefined

Table 1. Effects of a subsidy

## 4 Proof of Proposition 3

In the following we analyze the effect of a per unit tax policy on the certification level and on the welfare.

i) Under firm power, in the certification game the FOC is given by  $MR_{fp}(s_2, \tau) = MM(s_2)$  with

$$MR_{fp}(s_2, \tau) \equiv \frac{\partial(\pi_2(s_2, \tau) - \pi_1(s_2, \tau))}{\partial s_2} = A - \frac{2\tau \underline{s} - \tau^2}{(4s_2 - \underline{s})^2} \quad (28)$$

where  $A$  is a term independent of  $\tau$  and is given by the right hand side in equation (14). It is obvious that  $\forall \tau \in [0, \underline{s}[$  then  $\frac{\partial MR_{fp}(s_2, \tau)}{\partial \tau} = -\frac{2(\underline{s} - \tau)}{(4s_2 - \underline{s})^2} < 0$ , therefore the private certification standard is decreasing in the tax rate for small values of  $\tau$  ( $\frac{\partial s_2}{\partial \tau} < 0$ ).

Now, we evaluate the full derivative of the welfare with respect to  $\tau$ :  $\frac{dW}{d\tau} = \frac{\partial W}{\partial s_2} \frac{\partial s_2}{\partial \tau} + \frac{\partial W}{\partial \tau}$ . The welfare is given by the equation (26) with  $p_1$  and  $p_2$  given by equation (18) and  $s_a = \frac{(2s_2 + \underline{s} - \tau)\underline{s}}{3\underline{s} - 2\tau}$ . As a)  $\frac{\partial W}{\partial \tau} > 0 \forall \tau < \frac{s^2 s_2 - s^3}{4s_2^2 - 3\underline{s}s_2}$ , b),  $\frac{\partial W}{\partial s_2} > 0 \forall s_2 \in ]\underline{s}, s_g^*(\tau)[$ , with  $s_g^*(\tau)$  the socially optimal certification standard for a per unit tax  $\tau$  given, and c)  $\frac{\partial s_2}{\partial \tau} < 0$ , then the sign of  $\frac{dW}{d\tau}$  is ambiguous.

ii) Under certifier power, in the certification game the FOC is given by  $MR_{cp}(s_2, \tau) =$

$MM(s_2)$ , with

$$MR_{cp}(s_2, \tau) \equiv \frac{\partial \pi_2(s_2, \tau)}{\partial s_2} = B - \frac{s_2 \tau (8\underline{s}(s_2 - \underline{s})^2 + \tau(4s_2^2 + \underline{s}s_2 - 2\underline{s}^2))}{(4s_2 - \underline{s})^3 (s_2 - \underline{s})^2} \quad (29)$$

where  $B$  is a term independent of  $\tau$  and is given by the right hand side in equation (9).

We find that  $MR_{cp}(s_2, \tau)$  is decreasing in  $\tau$  ( $\frac{\partial MR_{cp}(s_2, \tau)}{\partial \tau} = -\frac{s_2(8\underline{s}(s_2 - \underline{s})^2 + 2\tau(4s_2^2 + \underline{s}s_2 - 2\underline{s}^2))}{(4s_2 - \underline{s})^3 (s_2 - \underline{s})^2} < 0$ ), therefore, as under firm power, the private certification standard is decreasing in the tax rate ( $\frac{\partial s_2}{\partial \tau} < 0$ ), and the sign of  $\frac{dW}{d\tau}$  is ambiguous.

## 5 The Effects of a per unit tax policy on prices and quantities

In the same way as in Appendix 3 we determine the effect of a per unit tax policy on prices and quantities under both firm power and certifier power. Note that as the sign of  $\frac{\partial s_2}{\partial \tau}$  is the same under firm power and under certifier power, the sign of the effects of the tax is also the same under these environments. The results are summarized in the following table. They are to be interpreted for small values of  $\tau$ .

	Firm power	Certifier power
$s_2$	–	–
$p_1$	undefined	undefined
$p_2$	undefined	undefined
$p_2 - p_1$	–	–
$D_1$	undefined	undefined
$D_2$	+	+
$D_1 + D_2$	+	+

Table 2. Effects of a per unit tax

## 6 Proof of Proposition 4

In the following we analyze the effect of an ad valorem tax policy on the certification level and on the welfare.

i) Under firm power, in the certification game the FOC is given by  $MR_{fp}(s_2, t) = MM(s_2)$  with

$$MR_{fp}(s_p, t) \equiv \frac{\partial(\pi_2(s_2) - \pi_1(s_2, t))}{\partial s_2} = A + \frac{\underline{s}^2(2s_2 + \underline{s})t}{(4s_2 - \underline{s})^3}, \quad (30)$$

where  $A$  is a term independent of  $t$  and is given by the right hand side in equation (14). Then it is clear that  $\frac{\partial MR_{fp}(s_2, t)}{\partial t} > 0$ . Therefore the private certification standard is increasing in the tax level ( $\frac{\partial s_2}{\partial t} > 0$ ).

The welfare is given by the equation (26) with  $p_1$  and  $p_2$  given by equation (5) and  $s_a$  given by equation (22). As for welfare, the first derivative  $\frac{dW}{dt} = \frac{\partial W}{\partial s_2} \frac{\partial s_2}{\partial t} + \frac{\partial W}{\partial t}$  where a)  $\frac{\partial W}{\partial t} = 0$ , b)  $\frac{\partial W}{\partial s_2} > 0$  in the relevant range, and c)  $\frac{\partial s_2}{\partial t} > 0$ . Therefore,  $\frac{dW}{dt}$  is positive as far as  $s_2$  is lower than  $s_g^*$ .

ii) Under certifier power, in the certification game the FOC is  $MR_{cp}(s_2) = MM(s_2)$ , with  $MR_{cp}(s_2) \equiv \frac{\partial \pi_2(s_2)}{\partial s_2}$  given by the right hand side in equation (9) and independent of  $t$ . Then it is clear that an ad valorem tax policy has no effect on the certification level and the welfare ( $\frac{\partial s_2}{\partial t} = 0$ , and  $\frac{dW}{dt} = 0$ ).

## 7 The Effects of an ad valorem tax policy on prices and quantities

In the same way as in Appendix 3 we determine the effect of an ad valorem tax policy on prices and quantities under both firm power and certifier power. Note that under certifier power the tax has no effect on prices and quantities. The results are summarized in the following table. They are to be interpreted for small values of  $t$ .

	Firm power	Certifier power
$s_2$	+	no effect
$p_1$	+	no effect
$p_2$	+	no effect
$p_2 - p_1$	+	no effect
$D_1$	-	no effect
$D_2$	-	no effect
$D_1 + D_2$	-	no effect

Table 3. Effects of an ad valorem tax

## 8 The Effects of taxes and subsidy on the certifier's profit and the firms' profit

First we analyze the effect of a subsidy policy. They are to be interpreted for small values of  $\lambda$ .

Under firm power the certifier's profit is given by:  $\pi_2(s_2, \lambda) - \pi_1(s_2, \lambda) - M(s_2)$ . Due to the envelope theorem we have  $\frac{d(\pi_2(s_2, \lambda) - \pi_1(s_2, \lambda) - M(s_2))}{d\lambda} = \frac{\partial(\pi_2(s_2, \lambda) - \pi_1(s_2, \lambda) - M(s_2))}{\partial\lambda} = \frac{2(s_2 + \lambda)}{4s_2 - \underline{s}} > 0$ ; the subsidy increases the certifier's profit. Under certifier power the certifier's profit is given by:  $\pi_2(s_2, \lambda) - M(s_2)$  and is increasing in the subsidy ( $\frac{\partial(\pi_2(s_2, \lambda) - M(s_2))}{\partial\lambda} = \frac{2(2s_2 - \underline{s})(2s_2(s_2 + \lambda) - \underline{s}(2s_2 + \lambda))}{(4s_2 - \underline{s})^2(s_2 - \underline{s})} > 0$ ).

Under firm power the two firms get identical profits given by:  $\pi_1(s_2, \lambda)$ . The effect of the subsidy on  $\pi_1(s_2, \lambda)$  is given by  $\frac{d\pi_1(s_2, \lambda)}{d\lambda} = \frac{\partial\pi_1(s_2, \lambda)}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial\pi_1(s_2, \lambda)}{\partial \lambda}$ . As i)  $\frac{\partial\pi_1(s_2, \lambda)}{\partial \lambda} = -\frac{2s_2\underline{s}(s_2 - \underline{s} - \lambda)}{(4s_2 - \underline{s})^2(s_2 - \underline{s})} < 0$ , ii)  $\frac{\partial\pi_1(s_2, \lambda)}{\partial s_2} = \frac{\underline{s}(s_2 - \underline{s} - \lambda)(8s_2^2t + 2s_2\underline{s}(s_2 - 2t) - \underline{s}^3 - \underline{s}^2(s_2 + \lambda))}{(4s_2 - \underline{s})^3(s_2 - \underline{s})^2} > 0$  and iii)  $\frac{\partial s_2}{\partial \lambda} < 0$ , then  $\frac{d\pi_1(s_2, \lambda)}{d\lambda} < 0$ . The effect of the subsidy on firms' profit is negative. Under certifier power, the firm 2's profit is null; the subsidy has no effect over it. The effect of the subsidy on the firm 1's profit ( $\pi_1(s_2, \lambda)$ ) is given by  $\frac{d\pi_1(s_2, \lambda)}{d\lambda} = \frac{\partial\pi_1(s_2, \lambda)}{\partial s_2} \frac{\partial s_2}{\partial \lambda} + \frac{\partial\pi_1(s_2, \lambda)}{\partial \lambda}$ . Comparing to the environment under firm power, the only difference is on the sign of  $\frac{\partial s_2}{\partial \lambda}$  that is now positive. Therefore the subsidy effect on firm 1's profit cannot be signed.

In the same way, we determine the effects of ad valorem and per unit taxes on the certifier's profit and the firms' profit. All results are summarized in the following table.

	Subsidy		Per unit tax		Ad valorem tax	
	<i>FP</i>	<i>CP</i>	<i>FP</i>	<i>CP</i>	<i>FP</i>	<i>CP</i>
Certifier's profit	+	+	+	+	+	no effect
Firm 2's profit	-	no effect	-	no effect	undefined	no effect
Firm 1's profit	-	undefined	-	-	undefined	-

Table 4. Effects of policy instruments on certifier and firms payoffs