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The Economics of Certifying the Environmental Friendliness of Products[1]

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Abstract

This paper examines the welfare consequences of offering a voluntary environmental quality certification program in addition to requiring products to meet a minimum quality standard (MQS). We consider a model of duopolistic competition in which prices and qualities are decision variables. Our results show that providing an option of voluntary certification at a higher quality level instead of requiring all firms to meet and obtain certification at a particular designated level (MQS) is welfare increasing under certain circumstances. In this situation, the optimal MQS will be lower than the optimal MQS when there is only one mandated level of certification while the higher quality level will be higher than it. Demand will be lower for both products. Furthermore, we show that a government certification scheme designed to maximize social welfare leads to higher environmental qualities than those chosen by private firms when they are allowed to choose freely quality levels for certification.

(Quality Differentiation; Asymmetric Information; Certification; Bertrand Competition; MQS; Fixed Costs)

1. Introduction

Asymmetries between buyers and sellers about product qualities are important causes of market failures. Such asymmetries can imply that only poor quality products are attracted to the market although consumers are willing to pay for higher quality and suppliers can offer the desired quality (see, e.g., Akerlof [1]). The qualities of a product can be defined in terms of all those attributes that a consumer values and is willing to pay for. Some of these attributes ("type 1") can be observed by consumers at the point of purchase (e.g., colour, stiffness). There are no asymmetries in information between buyers and sellers with respect to such attributes. Information about some other attributes ("type 2") can be obtained by buyers only after consuming the goods (e.g., product durability and reliability). There are, however, attributes that cannot be discerned by consumers even after consumption ("type 3"). For example, consumers may have interest in the environmental impacts caused by the production, packaging and disposal of the products they purchase and may be willing to pay more for those products that are more environmental friendly or "green", i.e., those with a lesser negative impact on the environment. In some cases products produced through processes that have different impacts on the environment are indistinguishable. Thus there is an asymmetry in information between the consumer and the producer.

Correcting for market failure resulting from asymmetries of information about unobservable attributes ("type 3" attributes) must involve either a research effort by the consumer or the use of credible third parties that can provide the information to consumers at or before the point of purchase[2]. Since there are economies of scale in the generation of such information, the

[2] Although market failure also exists with respect to "type 2" quality, suppliers can mitigate this effect by using signals or reputation while consumers can learn information about quality through repeated purchasing (see e.g., Allen [2]; Chan and Leland [7]; Cooper and Ross

establishment of such "third party" organizations is a precondition for the emergence of a market for products with higher unobservable quality (such as the environmental quality). Typically, such organizations generate the information and certify the product. Sellers apply and pay for the certification and use product labels or advertising to inform consumers.

The importance of unobservable attributes for differentiating products has increased significantly with the increases in incomes, the evolution of "post materialistic" value systems and the growth of the environmental movement. Post materialistic values imply internalization of social objectives into individual preferences (Inglehart [11]). Caincross [6] reports that in a survey of U.S. consumers 53% of the respondents reported that in the year previous to the survey they had decided not to buy a product because they were worried about its effects on the environment. Consumers, however, are both confused by and distrust claims by sellers about the environmental quality of the products they sell. The distrust is not entirely without merit as Kangun et al. [13] found that 58% of the advertising of environmental product attributes in their sample contained at least one misleading deceptive claim. The growth of environmental and other third party credible organizations to assess and certify environmental impact claims of products is facilitating the emergence of separate markets for "environmentally friendly" products. The first significant effort of environmental certification began in West Germany in 1977 with the Blue Angel program which now certifies 3,000 products in 52 countries.

The forest products industry provides a current example of a significant transformation of a traditional commodity market into a market with products differentiated by both their environmental friendliness and observable product attributes. Recently, for example, the American

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[8]; Milgrom and Roberts [16]; Nelson [17]; Schmalensee[20] and Shapiro[23]).

Forest and Paper Association identified wood products environmental certification as one of the top issues facing the industry (AFPA, 1994).

Though only about 0.5 percent of the international traded forest products are now certified (Baharuddin and Simala [5]), the rate of growth of certification services and of certified products available to the market is high and there is evidence that a significant market for environmentally friendly forest products exists (see Ozanne and Vlosky [16]).

Previous models of environmental quality decisions typically assumed that environmental quality, like other types of quality, is observable to the general public. For example, Arora and Gangopadhyay (1995) have built a theoretical model of voluntary overcompliance with environmental regulations. Assuming consumers have perfect knowledge about environmental quality, they found that a minimum quality standard imposed on the dirty firm improves the performance of the cleaner firm and increases the demand for both products.

In this paper we focus on the certification of an unobservable quality, such as environmental forest certification. We extend previous analyses by (1) considering a multi-dimensional quality (attribute) space, (2) adding an unobservable quality, in addition to an observable quality (type 1), as a decision variable, and (3) assuming a multi-attribute utility function. We investigate the welfare consequences of offering a voluntary certification service in addition to requiring an industry to meet some minimum quality standards (MQS). The introduction of multiple qualities improves the realism of the model and allows analysis of the interactions between different types of quality. Indeed in many situations, including those characterizing forest products, purchase decisions reflect consumer attention to several attributes. Some of these are observable and some are unobservable. For example, competition in the paper industry reflects attempts by firms to differentiate their products by climbing the "quality" scale, producing paper which is stronger, lighter and whiter. Even in the pulp markets, which were purely commodity markets in the past, Northern producers are attempting to differentiate their products through R&D from the cheaper Southern plantation pulps (Globerman et al. [10]). In the past decade, with the increases in consumers' environmental awareness some firms have attempted to differentiate their products not only in terms of the observable quality but also through claims of greenness. For example, the Swedish pulp and paper firm Sodra has attempted to promote its products as environmentally superior, breaking rank with other Swedish firms which attempted to develop an industry-wide standard for environmental certification.

The paper shows that providing an option of certifying a higher quality level instead of requiring all firms to meet and obtain certification at a particular designated level (MQS) is welfare increasing under certain circumstances. Furthermore, it shows that in this situation the optimal MQS will be lower than the optimal MQS when there is only one mandated level of certification while the higher quality level will be higher than it. The paper concludes by exploring the circumstances under which certification can be an effective tool of environmental protection. It points out that certification while removing some aspects of market failure (i.e., asymmetries of information) cannot resolve problems caused by externalities and free riding. It can serve, however, to complement economic instruments (taxes and subsidies) or regulations by tapping voluntary behaviour of some citizens. It also concludes that an industry run environmental certification process (even when it employs credible certifiers) will undersupply environmental goods. A government certification scheme designed to maximize social welfare will raise environmental quality of both the low quality and high quality products and will result in lower demand for the products.

The rest of the paper proceeds as follows. In the next section, we present the model. Section 3 provides the solution to the model using backward induction. There are two sub-sections in this section. In sub-section 3.1 we assume the government offers two certification levels (one MQS and the other voluntary) and each firm obtains a different one. We also investigate the case where the firms can choose the environmental quality levels they wish to certify. In sub-section 3.2, we assume that the government sets up only one certification level (the MQS) and both firms obtain this certification. Section 4 provides a summary of results and discusses their normative implications.

2. The Model

The basic model is duopolistic competition with prices and qualities being the decision variables. We assume that to achieve higher quality the firm has to invest in fixed assets (e.g., to mitigate the effects of environmental demands Annual Allowable Cut will be permanently reduced, thus a larger forest land base will be needed to produce the same level of timber). The certification costs are assumed to be proportional to the value of the fixed assets (e.g., the larger forests will also be more expensive to certify since they involve larger area). The choices of unobservable environmental quality levels to be certified are made by the government while the firms make decisions about their prices and quality levels. Note that the choice of an environmental quality level by a firm is restricted by the certification options made available to it by the government. The government must decide how many certification levels (processes) to establish (in this model, either one or two) and what level of quality each certification must assure.

The model is analyzed as a four-stage game. In the first stage, the government agency sets up the certification level or levels, with the full anticipation of the decisions that will be made by firms in the later stages of the game. In the second stage, after observing the decision of the government, each firm simultaneously chooses to apply for one of the certification levels available for the environmental quality. In stage 3, firms choose their levels of observable quality simultaneously. In the fourth stage, firms simultaneously announce their prices after learning all the information about quality levels of both products[3]. The sequential order of choices of qualities and prices captures the idea that a firm can usually change a product price fairly quickly, while a change in product qualities often takes a much longer time.

There are basically two primary types of multi-attribute utility functions (Fishburn [9]; Pollak [19]; Keeney [14], [15]): Additive and multiplicative. Throughout the paper, consumers' utility functions are assumed to be multiplicative and satisfy the condition of mutual independence. However, we can prove that the main results obtained in this paper are also valid if we assume an additive utility function[4]. The multiplicative utility function suggests that some balance must exist between the quality attributes of a product. Thus, for example, a consumer cannot be easily compensated by improving the reliability or other functional properties of a product when the product may cause significant damage to the environment. Similarly, a product which is completely environmentally friendly but has no satisfactory functional quality may have little value (e.g., a weak or dark paper which does not permit printing).

It is also assumed that each consumer either buys one unit of the product (from either of the two firms) or makes no purchases at all. If we denote y, $y \geq 0$, as the level of the observable quality and x, $x \geq 0$, as the level of the unobservable environmental quality and assume a utility function $U(x, y) = \theta\, x\, y$, then a consumer will have a net surplus function

[3] We can show that the main results of this paper remain valid if we reverse the order of choices of the unobservable and observable qualities.

[4] The proofs are available from the authors.

$S(x, y, p) = \theta\, x\, y - p$, if he (or she) consumes one unit of a product with qualities x, y and pays price p, and 0 otherwise. Here θ is a taste parameter for quality and is assumed to be uniformly distributed across the population of consumers [0, 1][5, 6].

The observable qualities in the case of lumber or paper may be strength, color or other physical qualities. The unobservable environmental qualities may be the degree of the sustainability of the management of the forest from which raw materials are sourced (e.g., harvesting practices) or the damage to the environment through the production process (e.g., the use of chlorine in bleaching paper and the amount of pollution emitted during production).

The utility function postulated in our model reflects the assumption that there are no externalities considered in individual consumption choices, i.e., the initial environmental stock is very large and the only utility to the individual that is derived from the consumption of the environmentally friendlier goods and services accrues from the internalization of social values (i.e., "doing the responsible thing"). As we shall note later in our discussion, this assumption requires us to qualify the normative conclusions which are drawn with respect to the contribution that a certification scheme may make to the protection or enhancement of the environment.

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[5] The assumption of a uniform distribution of the parameter θ is standard in the economics of quality literature (see Shaked and Sutton [22], [23] and Tirole [25]). The main consequence of this assumption is that the results are unbiased with respect to any specific value of θ. The taste parameter θ can also be interpreted as an income or wealth parameter (see, for example, Arora and Gangopadhyay [3] and Tirole [25: p96]).

[6] The assumption that taste parameters are allocated along a unit line [0, 1] implies that the range of taste for quality is very wide. This allows the entry of many products with different qualities. If we assume consumers' taste parameters are uniformly distributed over some range $[a, b]$, where $0 < a \leq \theta \leq b$, then the number of products with different qualities that can be sustained by the market depends on the ratio of b over a. The larger the ratio, the more the products with different qualities can be sustained by the market (see Shaked and Sutton [22], [23] and Tirole [25]).

Since the qualities of most products depend largely on the start-up cost (which are sunk costs), for simplicity, we assume that the unit production cost is zero while the fixed costs of production depend on the quality level set for each quality type independently. To focus on the effects of different quality levels on firms' profits, it is further assumed that firms are identical in most respects. The total cost of production is $TC^i(x, y) = F^i(x) + G^i(y)$, where $i = 1, 2$ and both $G^i(y)$ and $F^i(x)$ are convex functions[7], $G^1(y) = G^2(y) = G(y)$; $F^1(x) = F^2(x) = F(x)$; $G'(y) > 0$, $G'''(y) \geq 0$, $F'(x) > 0$, $F'''(x) \geq 0$. The only difference between these two firms is that they can supply products with different qualities. The certification cost of the environmental quality ($K(x)$) is assumed to be proportional to the fixed cost of the environmental quality, i.e. $K(x) = \alpha F(x)$, where $\alpha > 0$.

Let Q be the total-quality of a product, then $Q = x\, y$. It is obvious that, if both firms supply products with the same total-qualities, then they must charge the same prices and earn zero profits, this is of course one of the equilibria. We ignore this trivial case and only consider the case where the total-quality is different. Assume, without loss of generality, that firm 2 supplies a high total-quality (Q^2) product with a price p^2 while firm 1 supplies a low total-quality (Q^1) with price p^1. It is obvious that if firm 1 wants to attract any demand, its price must be less than that of firm 2, that is $p^1 < p^2$.

A consumer will choose the low total-quality product if

$$\theta\, Q^1 - p^1 \geq 0, \quad \theta\, Q^1 - p^1 \geq \theta\, Q^2 - p^2 \qquad \textbf{(1a), (1b)}$$

[7] Throughout the paper, we use superscripts to denote firms and subscripts to denote derivatives.

That is, a consumer with a taste parameter θ obtains a higher (non-negative) surplus by consuming the low total-quality product. Similarly, a consumer will choose the high total-quality product if:

$$\theta Q^2 - p^2 \geq 0, \quad \theta Q^1 - p^1 \leq \theta Q^2 - p^2 \qquad \textbf{(2a), (2b)}$$

Let $\underline{\theta}$ define the consumer for whom (1a) holds as an equality and (1b) holds as a strict inequality, and $\hat{\theta}$ define the consumer for whom (2b) holds as an equality and (2a) holds as a strict inequality. Then we have:

$$\underline{\theta} = \frac{p^1}{Q^1}, \qquad \hat{\theta} = \frac{p^2 - p^1}{Q^2 - Q^1}$$

We can easily show that any consumer with a taste parameter $\theta > \hat{\theta}$ will purchase the high total-quality product, any consumer with a taste parameter $\underline{\theta} < \theta < \hat{\theta}$ will purchase the low total-quality product and consumers with taste parameters $\theta < \underline{\theta}$ will not purchase any product.

In addition, define $\overline{\theta} = p^2/Q^2, \; r = Q^2/Q^1,$ where $\overline{\theta}$ is the quality-adjusted price of the high total-quality product and r is the ratio of the high total-quality to the low total-quality. Then we have $\hat{\theta} = (r\,\overline{\theta} - \underline{\theta})/(r - 1)$.

The demand functions for the low and high total-quality products then become:

$$D^1 = \hat{\theta} - \underline{\theta} = \frac{p^2 - p^1}{Q^2 - Q^1} - \frac{p^1}{Q^1}, \qquad D^2 = 1 - \hat{\theta} = 1 - \frac{p^2 - p^1}{Q^2 - Q^1} \qquad \textbf{(4)}$$

3. The Solution

There are two cases with respect to the number of certification levels set by the government. In the sub-section 3.1, we examine the case in which the government sets up two different levels of certification (the lower level is mandatory while the higher level is voluntary). We also consider the case where both firms can choose freely the levels of environmental quality they want to produce and certify. In sub-section 3.2, we consider the case in which only one certification level is set up and both firms must meet this certification level. The solution concept employed here is sub-game perfect equilibrium and it is solved by backward induction.

3.1 The Case of Two Different Certification Levels

In this case, the ratio of the high total-quality to the low total-quality is $r = \dfrac{x^2 y^2}{x^1 y^1}$. We start with stage 4.

Stage 4: The Choices of the Price

In stage 4 firms engage in price competition. The low total-quality firm maximizes its revenue with respect to p^1, taking its qualities and its rival's price and qualities as given, while the high total-quality firm maximizes its revenue with respect to p^2, taking its qualities and its rival's price and qualities as given. That is:

$$\begin{aligned} &\underset{p^1}{Max} \quad R^1(p^1,\, p^2) = \underset{\underline{\theta}}{Max} \quad R^1(\underline{\theta},\, \overline{\theta}) = \underset{\underline{\theta}}{Max} \quad Q^1\, \underline{\theta}\, \left(\frac{r\,\overline{\theta} - \underline{\theta}}{r - 1} - \underline{\theta} \right) \\ &\underset{p^2}{Max} \quad R^2(p^1,\, p^2) = \underset{\overline{\theta}}{Max} \quad R^2(\underline{\theta},\, \overline{\theta}) = \underset{\overline{\theta}}{Max} \quad Q^2\, \overline{\theta}\, \left(1 - \frac{r\,\overline{\theta} - \underline{\theta}}{r - 1} \right) \end{aligned} \tag{5}$$

The solutions to the above problems are: $\underline{\theta} = \dfrac{r-1}{\beta}$, $\overline{\theta} = \dfrac{2(r-1)}{\beta}$, $\hat{\theta} = \dfrac{2r-1}{\beta}$, where $\beta = 4r - 1$.

The corresponding demand for the low and high total-quality products are:

$$D^1 = \hat{\theta} - \underline{\theta} = \frac{r}{\beta}, \quad D^2 = 1 - \hat{\theta} = \frac{2r}{\beta} = 2D^1 \tag{6}$$

Substituting these values into the revenue functions of both firms yields, after some simplification:

$$R^2 = \frac{4r(r-1)}{\beta^2} Q^2, \quad R^1 = \frac{r(r-1)}{\beta^2} Q^1 \tag{7}$$

The Consumers' Surplus (CS) is:

$$CS = Q^1 \int_{\underline{\theta}}^{\hat{\theta}} \theta \, d\theta + Q^2 \int_{\hat{\theta}}^{1} \theta \, d\theta - p^1 (\hat{\theta} - \underline{\theta}) - p^2 (1 - \hat{\theta}) = \frac{r(4r+5)}{2\beta^2} Q^2 \tag{8}$$

We can now move to the third-stage: the observable quality game.

Stage 3: The Choices of the Observable Quality

In the third stage, each firm chooses its observable quality to maximize its profit, taking the rival's observable quality and both environmental qualities as given. Substituting the above price equilibrium into firms' profits, we obtain the following profit functions[8]:

$$\begin{aligned}\pi^2 &= R^2(x^1, y^1; x^2, y^2) - TC^2(x^2, y^2) = \frac{4r(r-1)}{\beta^2}(x^2y^2) - G(y^2) - (1+\alpha)\, F(x^2)\\ \pi^1 &= R^1(x^1, y^1; x^2, y^2) - TC^1(x^1, y^1) = \frac{r(r-1)}{\beta^2}(x^1y^1) - G(y^1) - (1+\alpha)\, F(x^1)\end{aligned} \tag{9}$$

[8] Here we assume the certification fees are the same as the certification costs. However, the results in this paper are valid for any amount of certification fees. The certification fees can even be negative (in which case they are certification subsidies).

The Kuhn-Tucker first-order conditions are:

$$\pi_i^i + u^i = 0, \quad u^i y^i = 0, \quad y^i \geq 0, \quad u^i \geq 0, \quad i = 1, 2$$

where u^i, $i = 1, 2$ are Lagrange multipliers.

It follows that the first-order conditions for the high total-quality firm are:

$$\pi_2^2 = x^2 f(r) - G'(y^2) = 0, \quad if \quad y^2 > 0; \quad \pi_2^2 = x^2 f(r) - G'(y^2) < 0, \quad if \quad y^2 = 0 \qquad \textbf{(11)}$$

The first-order conditions for the low total-quality firm are:

$$\pi_1^1 = x^1 g(r) - G'(y^1) = 0, \quad if \quad y^1 > 0; \quad \pi_1^1 = x^1 g(r) - G'(y^1) < 0, \quad if \quad y^1 = 0 \qquad \textbf{(12)}$$

where $f(r) = \dfrac{1}{x_2} \dfrac{dR^2}{dy^2} = \dfrac{4\, r\, (4\, r^2 - 3\, r^2 + 2)}{\beta^3}$, $\quad g(r) = \dfrac{1}{x_1} \dfrac{dR^1}{dy^1} = \dfrac{r^2\, (4\, r - 7)}{\beta^3}$.

From (12) we notice that, in equilibrium, the low total-quality firm will enter the market (earn a positive profit) if and only if there is a sufficient quality differentiation ($r > 7/4$) between the low and high total-quality products. In other words, fixed costs are compatible with Bertrand price competition if and only if the products are sufficiently differentiated. The intuition behind this is clear: If firms offer similar products ($r \leq 7/4$) then severe price competition will dilute the low total-quality firm's revenue to such an extent that it cannot cover its fixed cost (because it serves the lower end of the market).

We can prove (see theorem 1 in Ronnen 1991) that for any convex cost function $G(y)$, where $G'(y) > 0, \quad G'''(y) \geq 0$, there exists a unique Nash equilibrium in which $y^2 > y^1 > 0$ and both firms earn positive profits.

<u>Lemma 1</u>. A firm will produce a high total-quality product if and only if it chooses to produce a high observable quality. That is, $Q^2 > Q^1 \Leftrightarrow y^2 > y^1$.

Proof.

1. $Q^2 > Q^1 \Rightarrow y^2 > y^1$. From (11) and (12) we have

$$y^2 \ G'(y^2) = y^2 \ (x^2 \ f(r)) = (Q^2 \ f(r)) > (Q^1 \ f(r)) > Q^1 \ g(r) = y^1 \ G'(y^1)$$

Since $(y \ G'(y))' > 0$, we conclude that $y^2 > y^1$.

2. $y^2 > y^1 \Rightarrow Q^2 > Q^1$. If not, that is $Q^2 < Q^1$, then we have $r = \dfrac{Q^1}{Q^2} > 1$, the first-order conditions become $x^1 \ f(r) = G'(y^1)$, $x^2 \ g(r) = G'(y^2)$. Using a similar method as that in 1, we conclude that $y^1 > y^2$, a contradiction.

We later show that in fact firms will specialize in high or low quality products. The reason for this is quite obvious. The benefits of producing different qualities are in the reduced competition resulting from product differentiation. The reduced competition allows the firms to charge higher prices. If one firm produces a product with higher quality in one dimension while the other produces a product with higher quality in another dimension, the benefits of differentiation will erode.

Next, we examine the comparative static effects of the environmental quality (x^i) on the observable quality (y^j), where $i, j = 1, 2$. Totally differentiating equation (11), (12), we have:

$$\begin{aligned} g(r) \ dx^1 + x^1 \ dg(r) \ \frac{y^2 \ dx^2 + x^2 \ dy^2 - r \ (x^1 \ dy^1 + y^1 \ dx^1)}{x^1 \ y^1} &= G''(y^1) \ dy^1 \\ f(r) \ dx^2 + x^2 \ df(r) \ \frac{y^2 \ dx^2 + x^2 \ dy^2 - r \ (x^1 \ dy^1 + y^1 \ dx^1)}{x^1 \ y^1} &= G''(y^2) \ dy^2 \end{aligned} \qquad \textbf{(13)}$$

where $df(r) = \dfrac{df(r)}{dr} = -\dfrac{8 \ (5 \ r + 1)}{\beta^4} < 0, \quad dg(r) = \dfrac{dg(r)}{dr} = \dfrac{2 \ r \ (8 \ r + 7)}{\beta^4} > 0.$

Lemma 2. In equilibrium, the observable quality of the high total-quality firm is positively correlated to both its own and its rival's environmental quality; while the observable quality of the low total-quality firm is positively correlated to its rival's environmental quality, its relationship with its own environmental quality is ambiguous.

Proof. See appendix 1.

When the high total-quality producer raises its environmental quality differentiation increases allowing, in a subsequent move, the low total-quality producer to increase its observable quality while maintaining its optimal differentiation. The high total-quality firm expects such a move and therefore will adjust higher its obserable quality to maintain optimal differentiation from its perspective. On the other hand, when the low total-quality firm increases its environmental quality it reduces differentiation and thus induces its rival to increase its obserable quality to compensate for this reduction. Expecting such a move the low total-quality firm adjusts its observable quality. The low total-quality firm's observable quality may be increased or reduced depending on whether the net benefits from increased quality compensate for the reduction in differentiation.

From the results in lemma 2, we can obtain the effects of the changes in the environmental qualities on the ratio of total-qualities as follows:

$$\begin{aligned} \frac{dr}{dx^2} &= \frac{r\ f(r)\ G''(y^1)\ y^1}{\Delta} + \frac{G''(y^1)\ G''(y^2)\ (y^2)^2}{x^1\ \Delta} > 0 \\ \frac{dr}{dx^1} &= -\frac{r\ g(r)\ G''(y^2)\ y^2}{\Delta} - \frac{r\ G''(y^1)\ y^1\ G''(y^2)\ y^2}{x^1\ \Delta} < 0 \end{aligned} \tag{14}$$

That is, the high environmental quality has a positive effect on the ratio of total-qualities r while the low environmental quality has a negative effect on that ratio. We will use this result in the proof of proposition 3.

Stage 1 and 2: The Government's Decision about Certification Option and Firms' Choices of the Environmental Quality.

In stage 1, the government sets up the optimal levels of the environmental quality to be certified so as to maximize the social welfare. The social welfare function (W) is defined as the summation of the firms' profits and consumers' surplus. By straightforward calculation, we have:

$$W = \frac{r(6r-2)}{\beta^2}\ x^2 y^2 + \frac{r(3r-2)}{2\ \beta^2}\ x^1 y^1 - G(y^1) - G(y^2) - (1+\alpha)\ F(x^1) - (1+\alpha)\ F(x^2) \tag{15}$$

Its corresponding first-order conditions with respect to $x^1,\ x^2$ are:

$$\begin{aligned} \frac{dW}{dx^2} &= \frac{3r^2}{2\beta^2}\ x^1 \frac{dy^1}{dx^2} + \frac{8r^3-6r^2-3r+1}{\beta^3}\ x^2 \frac{dy^2}{dx^2} + \frac{24r^3-18r^2+5r+1}{\beta^3}\ y^2 - (1+\alpha)\ F'(x^2) = 0 \\ \frac{dW}{dx^1} &= \frac{3r^2}{2\beta^2}\ x^1 \frac{dy^1}{dx^1} + \frac{8r^3-6r^2-3r+1}{\beta^3}\ x^2 \frac{dy^2}{dx^1} + \frac{20r^3-17r^2}{2\ \beta^3}\ y^1 - (1+\alpha)\ F'(x^1) = 0 \end{aligned} \tag{16}$$

Lemma 3. It is socially optimal to have the firm with the high total-quality product obtain a high environmental quality certification.

Proof. See appendix 2.

Combining the results in lemma 1, lemma 3 amounts to saying that it is socially optimal to have the firm with the high (low) total-quality supply both high (low) observable and environmental quality. By supplying both high (low) observable and environmental qualities, products are further differentiated and thus maximum product differentiation occurs. There are several forces at play here. The quality adjusted prices are higher which leads to a loss in Consumers' Surplus. This loss is, however, more than compensated by increases in firms' profits.

It is interesting to compare the optimal choices made by the government about the environmental quality levels to be certified with the optimal choices of firms had they been allowed to choose the environmental quality without constraints. If firms can choose freely their environmental qualities (rather than just picking up one of the two points set up by the government), then each firm will choose its environmental quality so as to maximize its profit (considering the consequences of this choice on the choice of the observable qualities)[9]. The corresponding first-order conditions are:

$$\begin{aligned} \frac{d\pi^2}{dx_f^2} = 0: \quad & (1+\alpha)\, F'(x_f^2) = f(r)\, y^2 - \frac{4\, r^2\, (2\, r+1)}{(4\, r-1)^3}\, \frac{dy^1}{dx_f^2}\, x_f^1 \\ \frac{d\pi^1}{dx_f^1} = 0: \quad & (1+\alpha)\, F'(x_f^1) = g(r)\, y^1 + \frac{(2\, r+1)}{(4\, r-1)^3}\, \frac{dy^2}{dx_f^1}\, x_f^2 \end{aligned} \qquad \textbf{(17)}$$

Lemma 4. The firm supplying the high total-quality product has an incentive to choose a high environmental quality while the low total-quality firm will offer a low environmental quality product. That is, if $Q^2 > Q^1$, we must have $x_f^2 > x_f^1$.

Proof. See appendix 3.

Although it is optimal, from both the government's and firms' points of view, to have the high (low) total-quality firm supply the high (low) environmental quality, the optimal levels of the environmental quality chosen by the government are different from those chosen by the firms.

[9] We use subscript f to denote the environmental quality to be chosen freely by firms.

Proposition 1. If firms can choose any level of the environmental environmental quality, then they will undersupply the environmental quality, that is $x_f^1 < x^1$, $x_f^2 < x^2$.

Proof. See appendix 4.

When a firm chooses a production quality level it considers three effects. The effect that its decision has on (1) competition, (2) the demand it faces and (3) the costs that accrue. The firms choose quality levels to differentiate and to reduce competition. Higher quality will generally increase demand but also accrue higher costs. Because the costs of quality improvements rise at increasing rates (convex cost functions), both firms are better off, everything else being equal, adjusting quality levels down to maintain differentiation and reduce competition. The absolute levels of quality chosen will reflect the trade-off between the benefits of improved demand from higher qualities and the costs of producing higher qualities. Since the convex cost functions of environmental quality lead to the undersupply of environmental quality, the government can correct the market failure by imposing higher quality levels so as to maximize social welfare.

3.2 The Case of One Required Certification Level

In this case, there is only one certification level (x) and the ratio of the total-qualities becomes $r = (x\, y^2)/(x\, y^1) = (y^2)/(y^1)$. Note that here r does not depend directly upon the level of the environmental quality. Taking similar steps as those in the previous sub-section, we have the effects of the environmental quality on the observable qualities as follows:

$$\begin{aligned} \frac{dy^1}{dx} &= \frac{x\; dg(r)\; y^2\; f(r) - y^1\; g(r)\; (x\; df(r)\; r - y^2\; G''(y^2))}{\Delta} > 0 \\ \frac{dy^2}{dx} &= \frac{y^2\; f(r)\; (x\; dg(r)\; r + y^1\; G''(y^1)) - y^1\; g(r)\; r^2\; x\; df(r)}{\Delta} > 0 \end{aligned} \tag{18}$$

where $\Delta = r\; dg(r)\; x\; y^2\; G''(y^2) + y^1\; y^2\; G''(y^1)\; G''(y^2) - r\; df(r)\; x\; y^1\; G''(y^1) > 0$

The social welfare function in this sub-case becomes:

$$W = \frac{r\ (6r - 2)}{(4r - 1)^2}\ (x\ y^2) + \frac{r\ (3r - 2)}{2\ (4r - 1)^2}\ (x\ y^1) - G(y^1) - G(y^2) - 2(1 + \alpha)\ F(x) \quad \mathbf{(19)}$$

The optimal certification level is characterized by the following equation:

$$\frac{dW}{dx} = \frac{\partial W}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial W}{\partial y^1}\frac{\partial y^1}{\partial x} + \frac{\partial W}{\partial y^2}\frac{\partial y^2}{\partial x} + \frac{\partial W}{\partial x} = 0 \quad \mathbf{(20)}$$

From which, we have:

$$2(1 + \alpha)\ F'(x) = \frac{3r^2}{2\beta^2}\frac{dy^1}{dx} + \frac{8r^3 - 6r^2 - 3r + 1}{\beta^3}\frac{dy^2}{dx} + \frac{12r^2 - r - 2}{2\beta^2}\ y^2 \quad \mathbf{(21)}$$

<u>Proposition 2</u>. If both firms must obtain certification, it is socially optimal to set two different certification levels of the environmental quality.

Proof. To prove proposition 2, we need only to prove that it is welfare improving to marginally increase (decrease) the certification level from the optimal level (x) obtained in sub-section 3.2 for the high (low) total-quality supplier. This is equivalent to proving that $F'(x^2) > F'(x)$, $F'(x^1) < F'(x)$ at the point $x^1 = x^2 = x$. This is shown in appendix 5.

From the above proof we know that $x^1 < x < x^2$, where x^1, x^2 satisfy (16) while x satisfies (21). Using the results in (14), we conclude that the ratio of total-qualities in the two-level certification case will be higher than that in the single-level certification case.

The introduction of a multiple level environmental certification as opposed to just imposing an MQS can improve social welfare when no externalities are created from the consumption of higher quality products. The MQS can be set at a lower level than the one that would have been set if only one level of certification was considered. These normative implications must be qualified. The target of certification in many situations (e.g., forest certification) is not to guard only the interests of the current generation but to protect the heritage of future generations. Governments acting as guardians of future generations may impose constraints upon the consumption of the current generation. It can use, however, environmental certification as a means to achieve its goal through voluntary actions (softer means than direct regulation, see [4]). The normative implications of the model remain valid if: (1). Consumers internalize their social responsibilities to future generations; (2). "Doing the right thing" is utility generating; and (3). Consumers' willingness to pay leads to consumption patterns that meet or exceed the targets of environmental quality set by the government. If, however, the average environmental quality achieved through the certification scheme is lower than the one deemed socially optimal by the government, then there is no other choice than direct government intervention to achieve its target. This may involve regulation or the use of subsidies or taxes to affect producer and consumer choices.

Proposition 3. There will be less demand for both products in the two-level certification case than in the single-level certification case.

Proof. From (6), we have: $\frac{dD^2}{dr} = 2\frac{dD^1}{dr} = -\frac{2}{\Delta^2} < 0$**.** Since the ratio r in the two-level certification case is larger than the one in the single-level certification case, we conclude that the demands for both products will be smaller in the two-level certification case.

This result differs significantly from Arora and Gangopadhyay (1995) where government intervention leads to larger demand for both products. This is because in our model, the government sets up certification levels for the environmental quality that are higher than the ones that would have been chosen by the firms. Higher qualities lead to higher prices and as a result fewer people buy the products.

4. Discussion and Conclusions

Consumers interested in the environmental impacts of products they consume may be willing to pay more for such products. Market failures resulting from information asymmetries between producers and consumers reduce the incentives of firms to offer more environmentally friendly products. Environmental certification of products by credible third parties is a solution to this market failure that is being promoted by governments, industry and some environmental non-governmental organizations. Our analysis showed that the use of multi-level environmental certification can be welfare increasing (as opposed to one level of mandatory certification). This is true if consumers internalize social values (and there is evidence that with a shift to post-materialistic value systems many consumers derive utility from consuming in a socially responsible way, see Inglehart [11], [12], Ozanne and Vlosky [16]), or the environmental stock is large and there are no externalities.

Our analysis also indicated that a multiple level environmental certification scheme may have some distributional consequences. First, all consumers will pay higher quality adjusted prices because differentiation will reduce competition. As a consequence firms may be making higher profits. If we interpret the taste parameter θ as related to wealth or income distribution then our results show that the richer segment of the population will consume "greener" and higher quality products than they would have if only one level of environmental certification was mandated. The poorer segment will consume generally lower quality products that are less environmentally friendly than they would have if one level of certification was introduced (The nominal price they pay, however, may be higher, lower or the same, depending on the optimal differentiation strategies of the firms). The firms will tend to differentiate their products specializing either in high quality more environmentally friendly goods and services or low quality less environmentally friendly goods and services.

The enthusiasm of industry for an industry run certification scheme is rather obvious (a chance to reduce competition and make higher profits). The paper, however, concludes that a purely industry driven certification process (even when employing credible certifiers) may result in a market failure where environmental quality is undersupplied. A government certification scheme designed to maximize social welfare will see all firms meeting higher environmental quality standards. Some environmental groups also point out that product certification, unless it is comprehensive, may affect consumption of other goods (e.g., through substitution) in ways which may be deleterious to the environment.

Appendix

1. Lemma 2. Solving the equations of (13) in terms of dx^1, dx^2, we obtain:

$$\frac{dy^2}{dx^2} = \frac{y^2\,(f(r)\,dg(r)\,r\,x^1 + f(r)\,G''(y^1)\,y^1 + r\,df(r)\,G''(y^1)\,y^1)}{\Delta} > 0$$

$$\frac{dy^2}{dx^1} = -\frac{r^2\,df(r)\,y^1\,(g(r)\,x^1 + G''(y^1)\,y^1)}{\Delta} > 0$$

$$\frac{dy^1}{dx^2} = \frac{y^2\,dg(r)\,(f(r)\,x^2 + G''(y^2)\,y^2)}{\Delta} > 0 \qquad \textbf{(22)}$$

$$\frac{dy^1}{dx^1} = \frac{y^1\,(-\,r\,df(r)\,g(r)\,x^2 - G''(y^2)\,y^2\,dg(r)\,r + G''(y^2)\,y^2\,g(r))}{\Delta} > (<)\ 0$$

where $\Delta = r\,dg(r)\,G''(y^2)\,y^2\,x^1 + y^1\,y^2\,G''(y^1)\,G''(y^2) - r\,x^2\,df(r)\,y^1\,G''(y^1) > 0$.

2. Lemma 3. To prove $x^2 > x^1$, we need only to prove $F'(x^2) - F'(x^1) > 0$, where $F'(x^2)$, $F'(x^1)$ are obtained from (16).

$$(1+\alpha)\ [F'(x^2) - F'(x^1)] = \frac{3r^2}{2\beta^2}\, x^1 \left(\frac{dy^1}{dx^2} - \frac{dy^1}{dx^1}\right) + \frac{8r^3-6r^2-3r+1}{\beta^3}\, x^2 \left(\frac{dy^2}{dx^2} - \frac{dy^2}{dx^1}\right)$$
$$+ \frac{24\ r^3 - 18\ r^2 + 5\ r + 1}{\beta^3}\, y^2 - \frac{20\ r^3 - 17\ r^2}{2\beta^3}\, y^1$$
$$= \frac{3r^2}{2\beta^2}\, x^1[y^2 dg(r)\ f(r)\ x^2 + y^2 dg(r)\ G''(y^2)\ y^2 + y^1 r\ df(r)\ g(r)\ x^2 + y^1 G''(y^2)\ y^2 dg(r)\ r$$
$$- y^1 G''(y^2)\ y^2 g(r)] + \frac{8r^3-6r^2-3r+1}{\beta^3} x^2[y^2 f(r) g(r) r x^1 + y^2 f(r)\ G''(y^1) y^1 + y^2 r df(r)\ G''(y^1) y^1$$
$$+ r^2 df(r)\ y^1 g(r)\ x^1 + r^2 df(r)\ y^1\ G''(y^1)\ y^1] + \frac{24r^3-18r^2+5r+1}{\beta^3} y^2 - \frac{20r^3-17r^2}{2\beta^3}\, y^1$$
$$> m\ (G''(y^2)\ x^1 y^1 y^2 g(r)\ (-12r^3) + (G''(y^2)\ x^1 y^1 y^2 g(r)\ (28r^3 - 19r^2 + 10r + 2)))$$
$$= m\ (G''(y^2)\ x^1\ y^1\ y^2\ g(r)\ (16\ r^3 - 19\ r^2 + 10\ r + 2)) > 0$$

where $m = \dfrac{1}{2\ \beta^3\ \Delta}$. We have used the facts $y^2 > y^1$, $y^1\ G''(y^1) > G'(y^1) = x^1\ g(r)$.

3. Lemma 4. Noticing that $dg(r)\ G''(y^2) < \Delta$, $-\ df(r)\ G''(y^1) < \Delta$, we have $\dfrac{dy^1}{dx_f^2} < 1$, $\dfrac{dy^2}{dx_f^1} < r$.

$$(1+\alpha)\ [F'(x_f^2) - F'(x_f^1)] > f(r) - g(r) - \frac{4r^2(2r+1)}{\beta^3} - \frac{(2r+1)r}{\beta^3} = \frac{r(r-1)\ (4r-7)}{\beta^3} > 0$$

Since $F(x)$ is convex, from $F'(x_f^2) > F'(x_f^1)$, we conclude that $x_f^2 > x_f^1$.

4. Proposition 1. From (16) and (17), we have:

$$(1+\alpha)\ F(x^2) - (1+\alpha)\ F(x_f^2)$$
$$= \frac{3r^2}{2\beta^2}\, x^1\, \frac{dy^1}{dx^2} + \frac{8r^3-6r^2-3r+1}{\beta^3}\left(x^2\, \frac{dy^2}{dx^2} + y^2\right) + \frac{4r^2(2r+1)}{\beta^3}\, x^1\, \frac{dy^1}{dx^2} > 0$$

$$(1+\alpha)\ F(x^1) - (1+\alpha)\ F(x_f^1)$$
$$= \frac{y^1\ (y^1 G''(y^1) + x^1 g(r))\ [\beta\ y^2 G''(y^2) - r^2 x^2\ df(r)\ (16r^3-12r^2+3r-3)]}{2\ \beta^3\ \Delta} > 0$$

5. Proposition 2. If both firms must obtain certification, it is socially optimal to set two different certification levels of the environmental quality.

Proof. As argued before, here we need only to prove $x^2 > x > x^1$. Using (16) and (21), We have:

$$
\begin{aligned}
2(1+\alpha)\,[F'(x^2) - F'(x)] &= \frac{3r^2}{2\beta^2}\,x\,\left(2\,\frac{dy^1}{dx^2} - \frac{dy^1}{dx}\right) + \frac{8r^3-6r^2-3r+1}{\beta^3}\,x\,\left(2\frac{dy^2}{dx^2}-\frac{dy^2}{dx}\right)\\
&\quad + 2\,\frac{24\,r^3 - 18\,r^2 + 5\,r + 1}{\beta^3}\,y^2 - \frac{12\,r^2 - r - 2}{2\,\beta^2}\,y^2\\
&= m\,(G''(y^2)\,x\,(y^1)^2\,r^2\,\frac{r^2\,[576\,r^4 + 592\,r^3 - 292\,r^2 + 347\,r + 28]}{\beta^4}\\
&\quad + G''(y^1)\,x\,(y^1)^2\,r\,\frac{16\,r\,[64\,r^6 - 112\,r^5 + 108\,r^4 - 81\,r^3 + 63\,r^2 + 23\,r - 2]}{\beta^4}\\
&\quad + \frac{8\,r^4\,[128r^5 - 32r^4 + 24r^3 + 142r^2 - 31r - 42]}{\beta^6}\,(x)^2\,y^1\\
&\quad + r\,[48r^3 - 56r^2 + 27r + 2]\,G''(y^1)\,G''(y^2)\,(y^1)^2\,y^2) > 0
\end{aligned}
$$

The above inequality is because each item in the square bracket is positive. Similarly,

$$
\begin{aligned}
2(1+\alpha)\,[F'(x) - F'(x^1)] &= \frac{3r^2}{2\beta^2}\,x\,\left(\frac{dy^1}{dx}-2\frac{dy^1}{dx^1}\right) + \frac{8r^3-6r^2-3r+1}{\beta^3}\,x\,\left(\frac{dy^2}{dx}-2\frac{dy^2}{dx^1}\right)\\
&\quad + \frac{12\,r^3 - r^2 - 2\,r}{2\,\beta^2}\,y^1 - \frac{20\,r^3 - 17\,r^2}{\beta^3}\,y^1\\
&= 2\,(1+\alpha)\,[F'(x^2) - F'(x)] > 0
\end{aligned}
$$

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