# Quality Signaling through Certification. Theory and an application to agricultural seed markets.

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Abstract: We examine the problem of signaling the quality of goods and services when quality is never observable to consumers. The solution to this problem is certification, which acts to transform unobservable credence attributes into observable search attributes. We study the impact of certification systems on market structure and performance. It turns out that the costs of certification, sunk in order to achieve credibility, play a key role in producing an oligopolistic market. We next show that since it involves increasing return to scale, certification is better achieved by an independent body which can either be a private firm or a public agency. We examine the two ways in which quality provision through certification may be financed (i.e. public and private), and identify the conditions under which each is most efficient. Finally we examine the relevance of the model by studying the role of certification in quality seed provision for agriculture. Overall, model predictions are compatible with the conclusions of this empirical study.

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# 1 Introduction.

Increased awareness and concern for health and the environment, coupled with rising living standards, have brought quality attributes of industrial products under the limelight. Increasingly, in the wealthier and more industrialized countries, consumers and public authorities are giving weight to quality attributes such as nutritional content, safety, functionality, and environmental impact. Many people are hence prepared to pay a premium for goods that improve health standards, preserve the environment, or are produce in an ethical way. In the process, problems arise linked to the possibility for consumer deception and, more generally, to the efficient signaling of quality attributes of goods and services. Indeed, confronted with the worldwide division of labor and specialization, individuals and firms can no longer trace the origin or control the composition of consumption goods or inputs. Permanent flows of innovations and the introduction of new products exacerbate the problem. This is obviously true for complex goods like electricity generated from nuclear power, but it is also true for more simple commodities like agricultural produce with, for instance, the appearance of genetically modified organisms (OGMs). This paper proposes a simple theoretical framework to handle the issue of quality signaling in a global market economy and the subsequently rising need for certification. In a second part we illustrate the foregoing model using the seed certification process, and its relation to agricultural productivity.

The issue of quality signaling can be better understood once different categories of goods are acknowledged. Nelson (1970) and Darbi and Karni (1973) developed a useful categorization between search, experience and credence attributes. Search attributes are those for which consumers can assess their quality or qualities before purchasing them. Typical examples are external physical attributes such as color, size, polish and style (e.g. shoes). Experience attributes are those for which consumers cannot assess the qualities until they have purchased and used or consumed them. Typical examples are taste, system functionality, performance, or productivity. It is only by trialing the goods, with experience, that the quality can be assessed (e.g. software, cars). Finally, credence attributes are those for which consumers can assess the quality attributes neither before nor after purchase and use. Typical cases refer to the environmental impact at the production stage, or to health and safety related attributes such as food nutritional composition, or the chemical formula of a drug. Historically, as the set of products and technological processes have broadened to encompass more of credence goods, consumers' awareness and demand for quality have risen over time. As a result, quality signaling to consumers has become a major problem.

One practical solution to this problem is the process known as *certification*. Certification may be defined as a process whereby an unobservable quality level of some product is made known to the consumer through some labeling system, usually issued by a third independent party. There are both product and process certification, the first linked mostly to consumption, the second linked mostly to production. Obviously, a major concern with certification is consumer confidence which depends on the credibility of the certification process and stamp. It must be done by an authority above all suspicion. In developed countries it can be a government agency such as the Food and Drug Administration in the United States, or a private certification firm such as Underwriters Laboratories who is issuing the US Green Seal ecolabel.[1] A second concern which is directly linked to the first one is that to signal quality without uncertainty or with little uncertainty, certification is costly and may indeed be very costly in some cases. Typical examples relate to health and environmental safety. The assessment of biophysical, biochemical, and microbiological attributes usually require costly equipment and highly trained and highly paid personnel. In addition, such assessment procedures take time.

It is natural to assume that the costlier the certification process, the fewer will be the firms able to afford one. However, to what extent this statement is true, and how it affects firms as an incentive to certify or not to certify, is not very clear. Moreover, how these supply factors will meet the demand for certification, which is the driving force behind the whole process, and what the characteristics of a market for certification will be, is not clear either. Particularly, will cost of certification be a major factor in deciding market structure, with very high costs leading to a monopoly for certification? This paper which focuses on the issue of credence attribute, aims to investigate these questions.

There is a substantial body of empirical literature dealing with the issue of labeling and certification. Fields of application relate to food safety and quality and to the environment.[2] In particular, there is a vast applied literature on the ISO 9000 norms on product quality management, and on the

[1] Credibility is sometimes difficult to achieve even for the state. For instance in France the government has lost credibility because it has poorly handled the information related to major incidents such as the HIV-contaminated blood, the bovine spongiform encephalopaty, or the Chernobyl radioactive cloud. Similarly in countries where corruption runs high, the government has little or no credibility.

[2] For instance regarding food safety and quality, the role of labeling (Caswell-Mojduszka, 1996), whether quality management should be mandatory or voluntary (Segerson, 1999; MacDonald et al., 1999), the financing of food safety certification (MacDonald et al., 1999; Crespi-Marette, 2000), and the role of consumer research for food policy initiatives (Tregear et al., 1998) have been explored.

ISO 14000 norms on environmental management systems.[3] By contrast the issue of credence attributes has yielded, until recently, very little theoretical work.[4]

A noticeable exception is the literature on the extent to which the certification process is credible to consumers. Biglaiser (1993) and Lizzeri (1999) specifically focused on certification agents as intermediaries between producers and consumers in the process of quality provision. Albano-Lizzeri (1997) investigate the effect of monopoly on quality provision and certification. These papers focus on the strategic manipulation of information by the certification intermediaries. They show that a monopoly intermediary will not fully disclose its information about quality. It will rather provide noisy signals, but these still increase efficiency with respect to the situation without any signal. They also show that competition among the intermediaries can lead to full information revelation. An other valuable aspect of this literature focuses on the problem of experts (e.g., lawyers, medical doctors, auto mechanics service-persons). Experts' diagnosis and cures are typically credence attributes. Wolinsky (1993) has shown how customers' search for multiple opinions and reputation considerations each play a role in disciplining experts. Emons (1997) and Emons (2000) explores whether in markets for experts, the market mechanism may induce non fraudulent behavior. Evans shows that if consumers have enough information about market data, they are able to infer the expert's incentives. He thus shows that market equilibrium resulting in non fraudulent behavior does exist. However in other cases there is no trade because consumers anticipate fraudulent behavior. These important papers point out to the difficulty in achieving an efficient market for certification. This suggests that public intervention might be a good thing in this area.[5]

[3]Regarding the environment, work has focused on ecolabeling and eco-certification, in particular on consumer preferences and demand for ecolabeled products (Blend-van Ravenswaay, 1999 and Wessels et al., 1999), on the value of eco-labels (Nimon-Beghin, 1999) and eco-certification (Teisl et al., 1999), while Mattoo and Singh (1994) explored policy implications of ecolabeling. See also the paper by Crampes-Ibanez (1996) that is dealing with the issue of green label. Lesourd and Schilizzi (2001: chapter 9) provide an overview. Specific interest has been shown for forestry and forest products certification, especially in Canada (Haener et al., 1998; Lyke, 1996; Mater, 1995), while van Ravenswaay-Blend (1999) explore ecolabeling as a means to encourage adoption of environmental technologies in agriculture, and Foseid (2000) reports on the role of certification in increasing markets for compost.

[4]Most of the theoretical literature has focused on quality signaling for experience attributes (for a discussion of this literature see section 2.1).

[5]Along these lines, Anania-Nistico (2000) focus on public regulation to solve the problem of quality signaling in food markets. They consider the problem of an only partially credible regulation. There is also the paper by Crespi-Marette's (2000) which focuses on

The present paper aims to complement this literature by completely abstracting from the issue of the credibility of the certification process. Instead, it focuses on the impact of certification costs on market structure and performance. The paper contains a theoretical and an empirical investigation. Theoretically, it analyses the problem of quality provision when the quality is costly to produce and unobservable by the consumer. To credibly signal quality firms need to rely on the costly process of certification. We show that the private incentives to self-certify quality are sub-optimal. We next study the optimal certification policy both under private and public control. The paper examines where on the public-private and on the monopoly-competitive spectra optimal certification is to be identified and achieved. Empirically, it investigates the as yet unexplored topic of seed certification and how its cost may be affecting agricultural performance in developed and developing countries.

The paper is organized as follows. A first part presents a simple model that describes the relationship between demand for certified goods and services, population wealth, certification costs, and market structure. A second part examines the relevance and role of external provision of certification when self-certification is inefficient. A third part examines agricultural seed certification in the light of the results of the model, and compares government vs. private certification in developed and developing countries.

# 2 The model

We consider a supply problem of a commodity with variable quality. The demand stems from a continuum of consumers. For a given quality $v \geq 0$, the individual's demand function is assumed to be linear in price $p \geq 0$:

$$d_i(p, v) = \beta_i v(a - p) \tag{1}$$

The individuals' demand is parameterized by $\beta_i \in [\underline{\beta}, \overline{\beta}]$ with density function $f(\beta)$ and mean $E\beta_i = b$ which is a scale factor (a larger $b$ corresponds to a larger population), and by $a \geq 0$ which corresponds to a wealth index (a larger $a$ corresponds to a richer population). The price elasticity of $i$'s demand is $\epsilon_{p,d_i} = -\frac{p}{a-p}$. It decreases with $a$ in absolute terms. The larger $a$ is, the less the consumer behavior is affected by price increase. On the other hand, the price elasticity is independent of $\beta_i$ which is a scale factor reflecting heterogeneous need and size in the consumer population.

Quality is a vertical differentiation variable. The consumers have unanimous preference over the quality set. They all prefer high quality to low

certification by the public sector.

quality at given price. Then the elasticity of demand with respect to quality is constant no matter what the consumers' wealth, measured by $a$, or their taste or need for the commodity, measured by $\beta_i$, in the total population. That is, $\epsilon_{v,d_i} = 1$ for all $(a, \beta_i)$ positive.

Consumers maximize their surplus. Let $P_i(q, v) = a - \frac{q}{\beta_i v}$ be the inverse demand function, when an individual consumes a quantity $q \geq 0$ of the commodity with quality $v > 0$. The gross surplus for consumer $i$, defined as the integral of $P_i(q, v)$ is: $S_i^g(q, v) = aq - \frac{q^2}{2v\beta_i}$. We deduce the net surplus of consumer $i$ when purchasing a quantity $q_i = d_i(p, v)$ of the commodity with quality $v$ and unit price $p$ is:

$$S_i(p, v) = \beta_i \frac{v(a - p)^2}{2}. \tag{2}$$

Consumers maximize their net surplus when choosing which quality specification of the commodity to purchase. It implies from equation (2) that confronted with the quality/price bundles $(v_j, p_j)$ and $(v_{j'}, p_{j'})$ any consumer in the group of wealth $a$ chooses to purchase specification $j$ if and only if $v_j(a - p_j)^2 \geq v_{j'}(a - p_{j'})^2$. The consumer chooses $j'$ otherwise. In other words, the choice of the commodity is not dependent on $\beta_i$, whereas the quantity purchased by each individual increases with $\beta_i$. We deduce easily the following preliminary result.

**Lemma 1** *The consumers in wealth group $a$ have unanimous preference, represented by the function $v(a - p)^2$, over the quality/price set $(v, p)$.*

This result will prove to be useful. In particular it implies that all consumers in population $a$ purchase the same specification of quality $v$ of the commodity. The total demand in wealth group $a$ is then $D_{a,b}(p, v) = v(a-p)b$ where $b$ reflects the population size (e.g., the number of consumer in group wealth $a$).

On the supply side we assume that the production of the commodity involves a constant returns to scale technology. That is, the market is *a priori* competitive. If a distortion appears, it can be ascribed to the unobservable aspect of quality (i.e. to the fact that it is a credence attribute). We can hence isolate the impact of the quality signaling problem on market structure and on industry performance. The minimal quality level that can be provided by the firm is $\underline{v}$ ($\underline{v} \geq 0$). The cost function of producer $j$ ($j \in N^+$) may be assumed to be linear:

$$C(q_j, v_j) = c(v_j)q_j \tag{3}$$

where $q_j \geq 0$ is the quantity produced by firm $j$ at quality $v_j \geq \underline{v}$, and $c(v)$ is increasing and convex.

In the next section, which describes a benchmark case, we assume that quality is observable prior to purchasing -search attribute- or equivalently verifiable through use -experience attribute-.

## 2.1 Quality is observable

Consider first the case of a search attribute. Under the constant returns to scale assumption, when quality is observable prior to purchase, there is no quality signaling problem: the market is perfectly competitive. At equilibrium, prices are equal to marginal cost $p = c(v)$. At this price firms are free to produce any quantity. However with respect to a standard Walrasian production unit, the firms still have a strategic variable to set: the quality level. As quality is observable prior to purchase, it is a strategic variable in the same way as price is. If a firm fails to choose the right level of quality for the product, it will go bankrupt (exactly as if it fails to price the commodity at marginal cost). Indeed, by virtue of lemma 1, consumers in group $a$ have unanimous preferences over the quality/price set, embodied in the $v(a-p)^2$ function. When price is set at marginal cost, the consumers in group $a$ choose the specification of the commodity that maximizes $v(a-c(v))^2$. The optimal quality level from consumer's $a$ point of view, denoted $v_a$, is solution to the following equation:

$$c(v) + 2vc'(v) = a \tag{4}$$

The optimal quality level increases with $a$ (i.e., $\frac{dv_a}{da} \geq 0$). The wealthier the population is, the larger the level of quality it seeks, - a rather intuitive point. Then, on segment $a$ of the market either a firm sells quality $v_a$ defined in equation (4) at marginal cost $p_a = c(v_a)$, or else it disappears. At equilibrium $q_{a,b} = D_{a,b}(v_a, c(v_a))$ and the firm's profit is 0 no matter the group $(a, b)$ it serves. Optimizing the net surplus of trade associated to group $a$ of consumers, $S = aq - \frac{q^2}{2vb} - c(v)q$, with respect to $v$ and $q$ yields $v_a$ and $q_{a,b}$. The market allocation is Pareto efficient. We denote by $S^*$ the associated surplus from trade.

$$S^* = \frac{bv_a\Big(a - c(v_a)\Big)^2}{2} \tag{5}$$

Now if quality is an experience attribute (i.e. if it is observable only after purchasing the good) there is a potential quality signaling problem. Since the firms can pretend to sell high quality and shirk, the consumers are not ready to pay a high price for quality. However, when consumers are able to detect ex-post fraudulent claims, there are several ways to successfully signal quality to them. The most common, and cheapest one, consists in offering a warranty contract along with the commodity. In case of repeated purchase reputation, sunk investments such as advertising, quality grading or prices are other ways, though distortive, to signal quality.[6] In this paper we consider a guarantee system, assuming quality is ex-post verifiable. That is, the product is sold with a guarantee specifying the quality level $v_a$ and a penalty rule in case of consumer deception. The credibility of the guarantee contract depends upon the cost of deviating for the producer. It has to be high enough so that providing quality is a dominant strategy for the firm. This depends on the possibility to enforce the contract for the consumers and on the amount of the penalty. This in turn depends on the efficiency of the justice system, and on the existence of organizations, administrations or associations, dedicated to the defense of consumers. In advanced economies such public goods exist and guarantee contracts are commonly used to signal quality in many different markets and for many different commodities (e.g., car, electrical appliance, construction, electronic, furniture, food). "Satisfied or reimbursed" is an extreme case of such a contract. It is not based on anything verifiable, since individual satisfaction is not, but it is a credible – because costly to enforce– signal of product quality which is experienced by consumers.

With a guarantee added to the basic contract the consumers are willing to pay for quality because it is in the best interest of the firms to produce it. At equilibrium, the quality is as specified, and the guarantee contract is not used. Then the cost to signal quality is low (basically the cost to write the guarantee contract), though the cost to deviate from providing it is potentially high (the penalty in case of consumer deception plus the loss of reputation). When quality is observable by the consumers after purchasing (e.g. through use), the under-provision problem can be solved at virtually zero cost. Quality signaling does not change the market structure.

**Proposition 1** *When quality is verifiable, either before or after the purchase, there is no signaling problem. Quality $v_a$, solution of equation (4), is sold at marginal cost $p_a = c(v_a)$ so that the equilibrium quantity is $q_{a,b} = v_a(a - c(v_a))b$ for the population in group $(a, b)$. The outcome $\left[(v_a, q_{a,b})\right]$ is Pareto efficient.*

[6] Grossman (1981) has studied the role of warranty. The role of price signals for experience goods was studied by Milgrom-Roberts (1986), Bagwell-Staiger (1989), Bagwell-Riordan (1991) and Daughety-Reinganum (1995), and that of advertising by Schmalensee (1979). In the same spirit Mahenc-Meunier (2000) look at the role of forward markets in signaling quality and enhancing spot market efficiency. The role of reputation building over time was first studied by Shapiro (1982,1983), and later by Grossman-Shapiro (1988) and Falvey (1989). Jovanovic (1982) and Matthews-Postlethwaite (1985) were the first to investigate the role of grading in signaling experience attribute, followed by Bourgeon-Coestier (1996) and Hollander et al (1999).

In the next section we study what happens to this outcome when quality is unobservable.

## 2.2 Quality is a credence attribute

In this section, we assume that consumers never observe the quality level of the products they purchase. This is true whether prior or after purchase. There are many attributes of goods that are of this type. Examples include nutritional contents of food, aircraft safety, chemical composition of a drug, impact of a production process on the environment, age and working conditions of the labor force... Then producers of poor quality can pretend to offer high quality products; from the consumers' perspective, they are not discernable. For instance, whether a shirt was manufactured by a child or by an adult, it is the same shirt in the end. Yet many people disapprove of children being put to work and are willing to pay a premium to avoid that happening. It is the same with an environmentally friendly versus a polluting technology. They cannot be told apart based on the final product. In this context, a firm that would think of producing high quality $v > \underline{v}$ anticipates that it will not be able to recover its cost, since consumers cannot discriminate between low and high quality products (whether before or after purchasing). It then supplies the minimal level. On the other hand, consumers anticipate that since firms' profits decrease with higher quality, they are going to offer the minimum level, $\underline{v}$, no matter which prices are posted or which quality is claimed. They therefore purchase from the cheapest producers. At equilibrium there is a unique quality level offered which is the minimum one. It is competitively supplied at price $\underline{p} = c(\underline{v})$. A firm that would deviate from this low quality/marginal cost pricing strategy would go bankrupt. The net surplus falls to the level $\underline{S}$.

$$\underline{S} = \frac{b\underline{v}\Big(a - c(\underline{v})\Big)^2}{2} \tag{6}$$

The next proposition summarizes the results.

**Proposition 2** *When quality is not observable, there is a signaling problem. The quality supplied falls to the minimum level $\underline{v}$ which is competitively offered at marginal cost $p = c(\underline{v})$. The equilibrium quantity is for the group $(a, b)$: $\underline{q}_{a,b} = \underline{v}\Big(a - c(\underline{v})\Big)b$.*

In the context of credence attributes, there is an incentive for the producer to reduce quality, since reducing quality reduces cost but not demand. As an extreme case, whenever the minimum quality that can be supplied is very low, the market collapses. That is, when $\underline{v} = 0$, $D_{a,b}(\underline{v}, c(\underline{v})) = 0$ for any $a$. Finally, by virtue of proposition 1, if there are different groups of wealth $a$ in the population, for instance rich and poor, there would, in the absence of signaling problems, be as many quality levels offered as groups of wealth $a$. Proposition 2 implies that not only does the quality level itself fall, but also the variety of qualities offered.

# 3 Certification

When the quality is a credence attribute the market for quality collapses, no matter what price consumers are willing to pay, and no matter what quality producers are willing to provide. We may wonder whether traditional ways of solving this quality problem can be helpful here. Unfortunately, with credence attributes guarantee contract, signaling through prices or reputation building are inefficient. Consumers cannot send back the product or boycott it based on a poor quality since they do not experience it. In particular they are unwilling to pay a premium based on the fact that the product they purchase comes with a guarantee. With credence attributes, the solution is *certification*. As explained in the introduction, certification may be defined as a process whereby an unobservable quality level of some product is made known to the consumer through some guarantee system, usually issued by a third independent party. In other words, certification is a process for transforming a credence attribute into a search attribute.

There are both product and process certification. Product certification is linked mostly to consumption. For instance various certification or labeling systems do occur in food and drink industries. This is the case with traditional drinks, such as French wines from Bordeaux or Burgundy. They are signaled through a system of *Appellation d'Origine Contrôlée*, which refer to both the origin and the wine-making process. On the other hand process certification is linked mostly to production. For instance the environmental quality of goods, which refer to the impact of these goods on the natural environment throughout their life cycle (their production, their consumption, and their disposal), are typically credence attributes. In this case, a way of signaling environmental quality are ecolabels. For instance in the US, two private ecolabel organizations are Underwriters Laboratories, who is in charge of the certification task for issuing the US Green Seal ecolabel, and Scientific Certification Systems, who issues so-called "Environmental Report Cards" that gives a product score related to its environmental quality. A firm may also submit itself to an environmental management certification process, such as the ISO 14000 norms system. Finally, whenever safety issues are at stake, the certification process is usually put under government supervision. Mandatory certification processes may then be imposed by regulation as is for instance the case with pharmaceutical drugs (e.g. the Food and Drug Administration in the USA.)

In all these cases, the cost of quality signaling is the cost of creating and running a credible, independent, authority to enforce the denominations, labels and brands. This cost is independent of the production cost of the commodity to be certified. From the perspective of the firm, it is basically a fixed cost, potentially a very high one. For instance the assessment of biophysical, biochemical, and microbiological attributes of food and drugs usually require costly equipment and highly trained and expensive personnel. The monitoring of the resilience of pesticides in agricultural products is a good example. In what follows, we study the incentives for an individual firm to set up its own certification process. We will then turn to the study of certification as a separate activity, whether under regulation or under private supply.

3.1 Private self-certification

The certification cost is modeled as a fixed cost. We assume that the quality level can be publicly assessed at cost $K > 0$. It is important to distinguish the certification cost $K$ from the cost of production $c(v)$.

A firm can decide to invest $K$ in order to make its quality credible to the consumers.[7] The important point here, is that no matter what way certification is achieved, and contrary to a guarantee contract which is never used at equilibrium, the certification cost has to be paid *before* the purchase can take place. For quality to be a credible signal, the certification cost has to be sunk. This implies that even if the market is *a priori* competitive, because of the certification cost which adds to the production cost, it becomes oligopolistic with $N$ producers. That is, with a given number of firms, perfect competition is impossible if $K > 0$. Indeed the firm that chooses to certify its quality needs to invest $K$. For certification to be worthwhile, the profit of the firm must be greater than $K$. Depending on $K$ (and on consumers' wealth $a$ and market size $b$) the market structure that is going to emerge varies widely. We model competition among firms as a Cournot oligopoly (i.e., a Nash equilibrium). Since in general it is easier for a firm to change the price or the quantity it produces than the production process itself, we consider that quality choice is irreversible with respect to the price or quantity decision

[7] We assume that the certification process is perfect. In reality the certification process is imperfect such that the quality is in probability (for a discussion on this point see the literature quoted in the introduction).

which is flexible. This implies that in the strategic game they play the firms choose first quality and then quantity. We may establish the following preliminary result:

**Lemma 2** *The firm that decides to certify its production chooses to supply to group $a$ of consumers the quality level $v_a$ defined by equation (4).*

Proof: Consider first the case of a single producer that has sunk $K$. The monopoly maximizes with respect to $v$ and $p$: $\Pi_M = v(a-p)b(p-c(v))$. It is straightforward to check that he chooses $v_M = v_a$ solution of equation (4) and that $p_M = \frac{1}{2}(a + c(v_a))$. Now if several firms enter the market for a certified good, the individual profit depends on the competitor's quality/price strategy. We solve it backwards. We consider the price of any firm $j = 1, .., N$ given a quality vector $(v_1^*, ..., v_N^*)$. By virtue of lemma 1 consumers purchase from the firm that maximizes $v_h(a-p_h)^2$. It implies that if there exists a firm $h = 1, .., N$ such that $p_j > a - (\frac{v_j^*}{v_h^*})^{0.5}(a - p_h^*)$ then $q_j = 0$ and $\Pi_j = -K$. At the equilibrium $p_j = a - (\frac{v_j^*}{v_h^*})^{0.5}(a - p_h^*)$ for any $j, h \in \{1, .., N\}$. Substituting $p_j$ in the profit expression, and denoting $\alpha_j$ the firm's market share in the total demand, we get $\Pi_j = \alpha_j v_j(a - p_j)b(p_j - c(v_j)) - K$. Optimizing $\Pi_j$ with respect to $v_j$ yields $v_j = v_a$ with $v_a$ solution to equation (4). QED

By virtue of lemma 2, at any certification equilibrium, the quality equilibrium is $v_a$. Then on the market segment $(a, b)$ the firms' production are perfect substitutes. There remains to consider the firm's choice in quantity. The relevant equilibrium concept is Nash. Let $Q_{-j} = \sum_{h \neq j} q_h$ denote total production excluding that of firm $j$ and $Q = \sum_{j=1}^N q_j$ the total quantity including firm j. The firm $j(= 1, .., N)$ chooses its quantity $q_j$ such as to maximize: $\text{Max}_{q_j} \Pi_j(q_j, Q_{-j}) = P(q_j + Q_{-j}, v_a)q_j - c(v_a)q_j$. Since $P(q, v) = a - \frac{q}{bv}$, this yields $q_j = v_a(a - c(v_a))b - Q$. The firms are therefore symmetric, and the equilibrium is symmetric: $q_j = Q/N$. Hence, the equilibrium quantity, depending on $N \geq 1$, the total number of firms in the industry, is $Q(N) = \frac{N}{N+1} v_a \Big(a - c(v_a)\Big) b$. That is, $Q(N) = \frac{N}{N+1} q_{a,b}$, with $q_{a,b}$ being the first best outcome. Accordingly the total quantity supplied increases with the intensity of the competition. For $N = 1$ we get the traditional monopoly solution, for $N = 2$ the Cournot duopoly solution, and for $N \to \infty$ the competitive outcome as described in section 2.1. The consumers' surplus, denoted $S^N$, when they purchase the certified commodity, is $S^N = \frac{bv_a}{2}(a - P(Q(N), v_a))^2$. Substituting $Q(N)$ by its value, and recalling that $S^*$ defined (5) is the first best surplus, it is straightforward to check that

$$S^N = \left(\frac{N}{N+1}\right)^2 S^*. \tag{7}$$

We deduce that if $N \geq 1$ the consumers in group wealth $a$ have the choice between purchasing a relatively expensive, high quality certified commodity which yields net surplus $S^N$, or a cheap, low quality uncertified version which yields $\underline{S}$ defined by (6). They will purchase the certified commodity if and only if $S^N \geq \underline{S}$. This condition is equivalent to $\frac{N}{N+1} \geq (\frac{\underline{S}}{s^*})^{0.5} = \frac{(\underline{v})^{0.5}}{(v_a)^{0.5}} \frac{a-c(\underline{v})}{a-c(v_a)}$. By definition of $v_a$, we have $v_a(a - c(v_a))^2 \geq \underline{v}(a - c(\underline{v}))^2$ which implies that $\frac{(\underline{v})^{0.5}}{(v_a)^{0.5}} \frac{a-c(\underline{v})}{a-c(v_a)} \leq 1$. Then if $\underline{v}$ is very low (close to zero), from the consumers' point of view, certification, even with a monopoly, is always better than perfect competition without certification. Moreover, for a given number of firms, $N$, in the industry, certification will be preferred more often by a rich population than by a poor one. That is, from the definition of $v_a$ defined in equation (4) the gap between $v_a(a - c(v_a))^2 - \underline{v}(a - c(\underline{v}))^2$ increases with $a$. Then everything else being equal, a richer population prefers more often a certified commodity than a poor one, an intuitive result.

We compute next the per capita profit assuming that consumers decide to purchase the certified commodity. The profit of a firm, which depends on $N$, the total number of firms in competition, is $\Pi(N) = v_a b(\frac{a-c(v_a)}{N+1})^2$. That is: $\Pi(N) = \frac{2}{(N+1)^2} S^*$. Accordingly, the individual profit decreases in $N$ and converges to zero as competition intensifies (i.e., when $N$ goes to infinity). At the certification equilibrium the number of firms, denoted $N(K)$, is the maximal integer such that $\Pi(N) - K \geq 0$. That is,

$$N(K) = \text{INT}\Big\{\Big(\frac{2S^*}{K}\Big)^{0.5} - 1\Big\}. \tag{8}$$

The next proposition provides a necessary and sufficient condition for the certification equilibrium to hold.

**Proposition 3** *When quality is a credence attribute, the self-certification equilibrium prevails if and only if*

$$S^* \geq \left[\frac{\underline{S}^{0.5} + (2K)^{0.5} + (\underline{S} + 2K)^{0.5}}{2}\right]^2 \tag{9}$$

*Then the market structure is oligopolistic with $N(K)$ producers defined by equation (8). Otherwise, the low quality/low price equilibrium prevails.*

Proof: The certification equilibrium prevails if and only if there exists an $N \geq 1$ integer such that **(i)** $S^* \geq \frac{(N+1)^2}{2} K$ (i.e., the producers are willing to produce) and **(ii)** $S^* \geq (1 + \frac{1}{N})^2 \underline{S}$ (i.e., the consumers are willing to purchase) hold simultaneously. Inequality (i) is equivalent to $N \leq \left(\frac{2S^*}{K}\right)^{0.5} - 1$, and (ii) to $N \geq \frac{1}{\left(\frac{2S^*}{K}\right)^{0.5} - 1}$. Since $S^* < \underline{S}$, (i) and (ii) hold simultaneously if and only if there exists $N \geq 1$ integer such that: $\frac{1}{\left(\frac{2S^*}{K}\right)^{0.5}-1} \leq N \leq \left(\frac{2S^*}{K}\right)^{0.5} - 1$. A necessary and sufficient condition for such an integer to exist is that: $\left(\frac{2S^*}{K}\right)^{0.5} - 1 - \frac{1}{\left(\frac{2S^*}{K}\right)^{0.5}-1} \geq 1.5$ This is equivalent to: $S^* - (S^*)^{0.5}[\underline{S}^{0.5} + (2K)^{0.5}] + (K\underline{S})^{0.5} \geq 0$. We solve the second degree equation in $(S^*)^{0.5}$ and find two roots $(S^*_-)^{0.5} = \frac{\underline{S}^{0.5}+(2K)^{0.5}-(\underline{S}+2K)^{0.5}}{2}$ and $(S^*_+)^{0.5} = \frac{\underline{S}^{0.5}+(2K)^{0.5}+(\underline{S}+2K)^{0.5}}{2}$. Condition (i) and (ii) hold simultaneously if and only if $S^* \leq S^*_-$ or $S^* \geq S^*_+$. Since $S^*_-$ is lower than $\underline{S}$, we are left with $(S^*_+)^{0.5}$. We deduce easily condition (9).QED

We deduce from (9) a necessary condition for voluntary certification to hold by putting $\underline{S} = 0$.

$$S^* \geq 2K. \tag{10}$$

By virtue of proposition 3 the larger is $a$ or $b$, the easier it is for condition (9) to hold. Figure 1 illustrates these results. It represents the $N(K)$ function for two different levels of wealth $a' > a$. We deduce that the certification equilibrium appears less often for poorer populations. It appears also less often for smaller populations. That is, the critical level of the fixed cost K, such that the certification equilibrium is no longer sustainable, increases with $a$ and $b$. This implies that if the fixed certification cost, $K$, is such that $\hat{K} < K < \hat{K}'$, a rich (and/or large) population purchases high quality/certified commodities and a poor (and/or small) one low quality/uncertified commodities.

**[Figure 1]**

Proposition 3 then helps us to understand that in a given population there might be a market segmentation. The rich choose to purchase certified commodities while the poor buy low quality, uncertified commodities. More importantly, it helps us to understand the difference in certification levels *across* countries. Indeed developed countries consume more certified commodities than developing ones. The last section of the paper, which deals with the example of agricultural seed certification, provides a detailed illustration of this segmentation problem. Comparing the self-certification equilibrium with the optimum yields the following result.

**Corollary 1** *The level of self-certification is sub-optimal.*

Proof: By virtue of proposition 3, the certification equilibrium prevails if and only if $S^* \geq \left[\frac{\underline{S}^{0.5}+(2K)^{0.5}+(\underline{S}+2K)^{0.5}}{2}\right]^2$. On the other hand certification is efficient if and only if $S^* \geq K + \underline{S}$. One can check that $K + \underline{S} \leq \left[\frac{\underline{S}^{0.5}+(2K)^{0.5}+(\underline{S}+2K)^{0.5}}{2}\right]^2$.QED

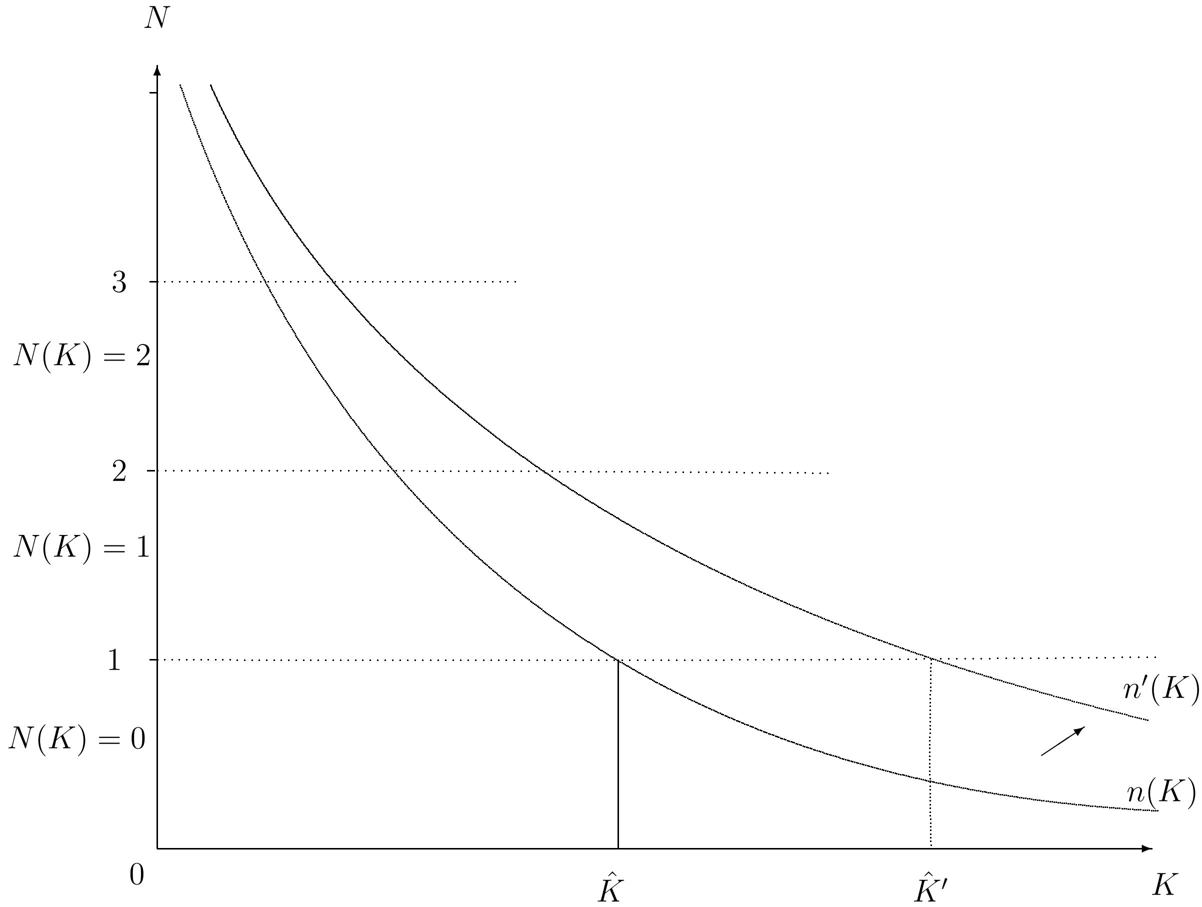


Figure 1: Self-Certification Equilibrium

$$n(K) = (b/K)^{1/2}[a - c(v_a)](v_a)^{1/2} - 1$$

The welfare losses involved in the self-certification equilibrium are potentially high. The problems surrounding pharmaceutical practice in developing countries illustrates this phenomenon. The people who are too poor to buy official medicines in drugstores have to rely on those available on the street. Of course, market drugs sold out on the street are uncertified. A study in Nigeria concluded that up to 60% of medicines on the street market were counterfeit. Unchecked counterfeit drugs can be very dangerous. It is simply safer not to consume them. This leaves the population with traditional remedies.[8] The social cost of this equilibrium is very high. A centralized intervention, such as government regulation, can be a valuable remedy to this type of market failure. This leads us to the study of an optimal certification policy.

3.2 Optimal certification policy

There are increasing returns to scale in certification. Self-certification leads to wasteful duplication of certification costs among downstream firms. To strengthen the credibility of the certification process, the government should thus encourage the creation of an independent certification firm or firms, depending on market size, and regulate it to avoid consumer deception or abuse of monopoly power. If this is not sufficient (i.e., if no private entity is eager to enter the certification business), the government might choose to monopolize the market for certification while setting up a public certification agency.

Setting up an independent certification body costs $K$. We study the optimal certification policy under two financial arrangements. In the first one, the state takes directly in charge the certification cost. It relies on public funds to finance the cost of the process. As illustrated in the last section of the paper, this solution is often favored by developing countries generally with the help of international aid. On the other hand, wealthy nations are reluctant to rely on their public funds to finance the certification of private commodities. Indeed this solution would increase the tax burden that is already quite heavy. Moreover it raises the issue of cross-subsidies when the general taxpayers do not directly benefit from the certification process. Rich countries favor a self-financed certification system with a fee levied on the certified good.

3.2.1 We first consider the case of public funded certification. We assume that the government is utilitarian. It maximizes the sum of consumers' surplus, $S(p, v) = \frac{bv}{2}(a-p)^2$, plus the firms' profits, $\Pi(p, v) = (p-c(v))bv(a-p)$,

[8] Then a survey in Zimbabwe suggests that 80% of the population relies on traditional remedies because people are too poor to buy official medicines and those available on the street are very unreliable.

minus the cost of funding the certification fixed cost, $-(1+\lambda)K$. The term $\lambda \geq 0$ denotes the shadow cost of public funding. It is greater than 0 because it is distorting to raise taxes. Since the firms' cost function is linear, the utilitarian objective function is maximized by setting price equal to the marginal cost $p = c(v)$. In the case of a direct public funding of $K$, the regulator solves:

$$\underset{v}{\text{Max}}\, W(v) = \frac{bv}{2}\Big(a - c(v)\Big)^2 - (1+\lambda)K. \tag{11}$$

The solution to problem (11) is the first-best level quality $v_a$ defined in equation (4). The quantity produced is that of the first best level $q_{a,b}$ defined in proposition 1. We deduce the value of the net social surplus of public funded certification $S^\lambda$.

$$S^\lambda = S^* - (1+\lambda)K \tag{12}$$

When $\lambda$ is close to 0, this solution is close to the first best. On the other hand, when $\lambda$ is large, the net surplus decreases and might even become negative. For the certification of private goods, wealthy nations, whose $\lambda$ (often assessed to be around 0.3) is quite high, prefer to rely on the final users.

3.2.2 We next consider the case of a self-funded regime. The certification process is funded by a fee, denoted $\tau(v)$, on the quantities certified. It is linear in quantity, but it depends non linearly on the level of quality to be ascertained. It can be implemented by a public or by a private body.[9] We assume that the certification firm or agency chooses $\tau(v)$ such as to break even. This assumption is consistent with the market for certification being either regulated or contestable. The optimal tax rate, chosen to just cover the certification cost, satisfies the following equation.

$$\tau(v)bv\Big(a - [c(v) + \tau(v)]\Big) = K \tag{13}$$

We deduce from equation (13) that

$$\tau'(v) = \frac{-\tau\Big[\Big(a - [c(v) + \tau(v)]\Big) - c'(v)v\Big]}{v\Big(a - [c(v) + 2\tau(v)]\Big)} \tag{14}$$

Certification is now an input in the production process to the downstream firms. The generalized marginal cost of the commodity for the producers is $c(v) + \tau(v)$ if they choose to certify, and $c(\underline{v})$ otherwise. Therefore the cost

[9] For practical matters there can be several certification firms if the demand is large, and they have fixed maximal capacity.

function, $C(q) = (c(v) + \tau(v))q$, is linear in quantity. It remains compatible with perfect competition. Under the competitive pressure the firms set their price at $p = c(v)+\tau(v)$ and they choose quality to maximize the net consumer surplus $S(p, v)$. They solve:

$$\underset{v}{\text{Max}}\, \frac{bv}{2}\Big(a - [c(v) + \tau(v)]\Big)^2. \tag{15}$$

Using equation (14), one can check that the solution to the level of quality in (15) is the first best level $v_a$ defined in equation (4). Then at equilibrium the optimal tax rate, chosen to cover the certification cost, satisfies $\tau b v_a\Big(a - [c(v_a) + \tau]\Big) = K$. This second degree equation admits 2 roots. Solving it for $\tau_a \in [0, 1]$, we find that a necessary condition for the project to be profitable is $[a - c(v_a)]^2 - \frac{4K}{bv_a} \geq 0$. This is equivalent to $S^* \geq 2K$ which is also a necessary condition for self-certification being profitable (see equation (10)). Then the equilibrium tax level is

$$\tau_{a,b} = \frac{\Big(a - c(v_a)\Big) - \Big([a - c(v_a)]^2 - \frac{4K}{bv_a}]\Big)^{1/2}}{2}. \tag{16}$$

The equilibrium quantity is $q_{\tau_{a,b}} = bv_a\Big(a - [c(v_a) + \tau_a]\Big)$ which is less than the first best level $q_{a,b} = bv_a\Big(a - c(v_a)\Big)$. Due to the substitution effect, there is a deadweight loss of the tax $\tau_{a,b}$. We deduce the net social surplus when relying on a self-funded regime.

$$S^\tau = \frac{S^*}{4}\Big(1 + (1 - \tfrac{2K}{S^*})^{0.5}\Big)^2 \tag{17}$$

Comparing this regime with self-certification yields the following result.

**Lemma 3** *Private self-certification is never optimal.*

Proof: Comparing $S^\tau$ defined in equation (17) with $S^N$ defined in equation(7) at $N = N(K)$, that is $S^N = (\frac{(\frac{2S^*}{K})^{0.5} - 1}{(\frac{2S^*}{K})^{0.5}})^2 S^*$, yields $S^N \leq S^\tau$ as soon as $2K \leq S^*$. QED

This result is very natural. The existence of an independent body to carry out the certification process is preferable to individual firms trying each to perform self-certification. Self-certification is inefficient because individual firms need to invest heavily in order to make the outcome of certification credible. On the other hand an independent certification agency has no

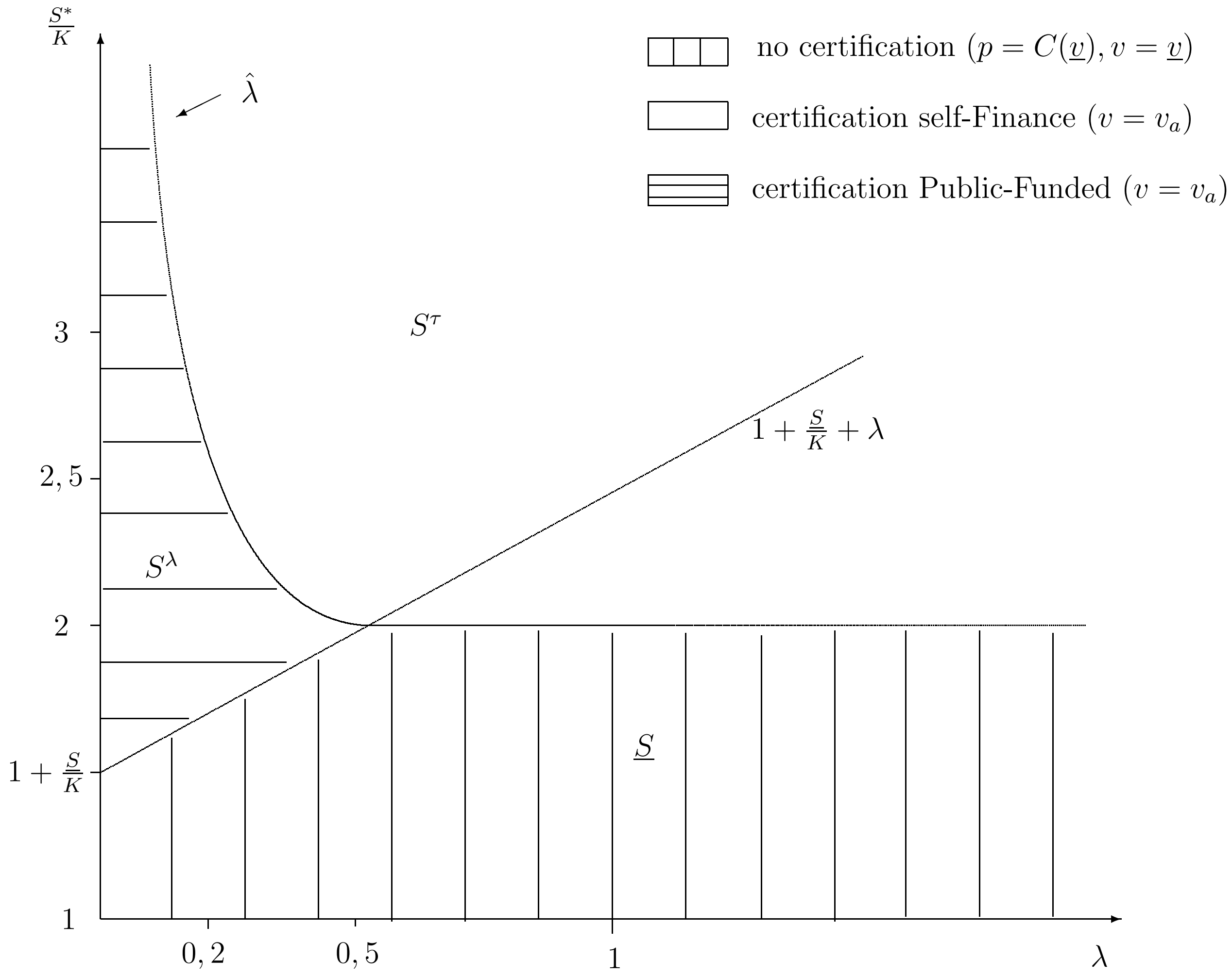


Figure 2: Optimal Certification Policy

conflict of interests in the certification process. It is the cheapest way to generate consumer confidence. With a single certification firm or agency the fixed costs are not duplicated (the two regimes are equivalent when $N = 1$). Accordingly in free-market economies voluntary certification is generally carried out by independent firms or organizations.

3.2.3 Finally we compare independent certification, either publicly or privately funded, with no certification at all, to derive the optimal certification policy.

**Proposition 4** *Under the assumption that $2\underline{S} \leq K$, the optimal certification policy is not to certify if $\frac{S^*}{K} \leq min\Big\{\frac{\underline{S}}{K} + 1 + \lambda, 2\Big\}$, and to certify otherwise. In the latter case the publicly funded regime is preferable to the self-funded regime if and only if*

$$\lambda \leq \hat{\lambda} = \frac{(\frac{S^*}{K} - 1) - \Big((\frac{S^*}{K} - 1) - 1\Big)^{0.5}}{2}. \tag{18}$$

<u>Proof</u>: Certification through public funding is better than no certification if and only if $S^\lambda \geq \underline{S}$. This is equivalent to $\frac{S^*}{K} \geq \frac{\underline{S}}{K} + 1 + \lambda$. Similarly market funded certification, which requires $S^* \geq 2K$, is better than no certification if and only if $S^\tau \geq \underline{S}$. This is equivalent to $\Big(1 - \frac{2K}{S^*}\Big)^{0.5} \geq 2\Big(\frac{\underline{S}}{K}\Big)^{0.5} - 1$ when $S^* \geq 2K$. Under the assumption $2\underline{S} \leq K$, $S^* \geq 2K$ implies that $S^* \geq 4\underline{S}$ and thus that $2\Big(\frac{\underline{S}}{K}\Big)^{0.5} - 1 \leq 0$. We deduce that market funded certification through a linear tax is better than no certification if and only if $\frac{S^*}{K} \geq 2$. Finally a publicly funded regime is preferable to a self-funded regulation regime if and only if $S^\tau \leq S^\lambda$ as defined equations (17) and (12). This is equivalent to: $\lambda \leq \frac{S^*}{4K}\Big(1 - (1 - \frac{2k}{S^*})^{0.5}\Big)^2$. Developing the right hand side yields (18). QED

The next figure illustrates proposition 4. It represents the optimal certification policy in the $(\frac{S^*}{K}; \lambda)$ space.

**[FIGURE 2]**

The optimal choice between market funded certification (i.e. market oriented certification) or public funded certification, depends on the value of the shadow cost of public funding. For a low value of $\lambda$, public funding is less distorting than a linear tax levied on certified product. On the other hand, when $\lambda$ increases it is more and more costly to rely on public funds. The market oriented regime becomes preferable. Finally when the ratio of the net social surplus over the fixed cost of certification becomes small, it is preferable not to certify at all.

# 4 Agricultural seed certification

We now propose to illustrate the foregoing model using the certification of agricultural seed. One reason for this choice is its importance in a world of increasing populations in need of food and fiber. Another is that such an investigation has not, to our knowledge at least, yet been undertaken. The fact that seed is a production input, rather than a consumer good, is not important: in both cases, we are interested in the *demand* of the certified good as a function of cost. Even if production is exported, we are still interested in whether farmers will choose to invest in certified seed or not.

4.1 Background, problem and hypotheses

Farmers around the world can have access to several sorts of seed for a given produce. They can use home-grown seed, saved from last year's harvest, or they can purchase it on the market. If purchased on the market, they can choose, at some extra cost, certified seed, or be content with uncertified seed. The value of certified seed is twofold. Firstly, it guarantees a minimum quality, and secondly, it guarantees a maximum sensitivity to specific agronomic conditions (climate, disease, pest tolerance). The seed embodies the outcome of scientific investments. It leads to substituting new genetic material and knowledge to land, labor and capital. Then certification should provide reliable and credible information on the productive performance of the seed. Highly trained plant scientists equipped with sophisticated equipment in dedicated private or public laboratories provide reliability and credibility in rich countries.

To some, seed may appear to be a good characterized by experience attributes rather than credence attributes. However, increased yields and productivity remain conditional on how the cropping system is managed. Certified seed provides the potential for improvements, not the improvements themselves. These need an appropriate technological package, which includes the timing and conditions of seeding, follow-up cultivation, the type and timing of fertilizer, herbicide and pesticide applications, up to the timing and conditions of harvest. This is why certified seed suppliers usually provide such an information package along with the seed material itself. Farmers pay for the whole package, not just the genetic material. Now if seed performs poorly, it will be difficult to decide whether this is due to poor farmer decision-making or to poor seed potential. However, after several years of trials by several farmers in a given region, the seed may become something of a hybrid containing both credence and experience attributes. Until then, it must be considered as a credence good. Then, if the logic of the model is correct, there are at least two hypotheses that we would like to test when applied to national scale seed certification.

Hypothesis 1 : Under laissez-faire there is a high correlation between a nation's wealth, and the degree to which its farmers use certified seed.

Hypothesis 2 : Under a public funded program the level of certification is much higher than what would have occurred under laissez-faire. Such a program occurs when the funds used to finance it come at a low cost (e.g., through foreign aid).

Finally there is an additional hypothesis that we would like to consider. It is not a direct implication of the formal analysis, but it is relevant for the particular application we are considering.

Hypothesis 3 : Seed certification is an important factor in achieving high agricultural productivity.

If hypotheses 1 and 3 turn out to be true, a corollary is that under laissez-faire richer countries achieve, for similar products, higher productivity whereas poorer countries should be trapped in low-performance levels. By the same reasoning, if hypotheses 2 and 3 turn out to be true, a corollary is that under public funded certification, poor countries should also be able to achieve high-performance levels.

4.2 The data

To investigate the validity of the foregoing hypotheses, and, through this, the empirical relevance of the theoretical model applied to seed certification, data was found and compiled from an FAO database, downloadable from the Internet.[10] The data set consisted of files on seed certification for a number of countries around the world. Not all files contained useful quantitative information. Many, if not most OECD countries were not represented, or had inadequate data, with the most conspicuous absence being the USA.[11] Only 40 files contained exploitable information, generating a total of 40 data points. Unfortunately, no data set more recent than 1990 was found, and its general quality and reliability must be seen as poor. Conclusions to this study will need to be qualified by this proviso.

Useful information came in the form of tables giving, for each major crop grown in the country, the quantities of non-certified, certified and total seed used, and the areas sown with non-certified and certified seed. This allowed

[10]This data needs to be downloaded separately for each country and reformatted appropriately in order to allow for statistical calculation.

[11]All efforts to obtain information on seed certification in the USA, whether from public or private sources, failed. It seems that the USA has no organized database on seed certification, presumably because the market for certification being very large (i.e., because $a$ and $b$ are both very large in the USA), it is left to a decentralized and competitive private sector that views such information as sensitive.

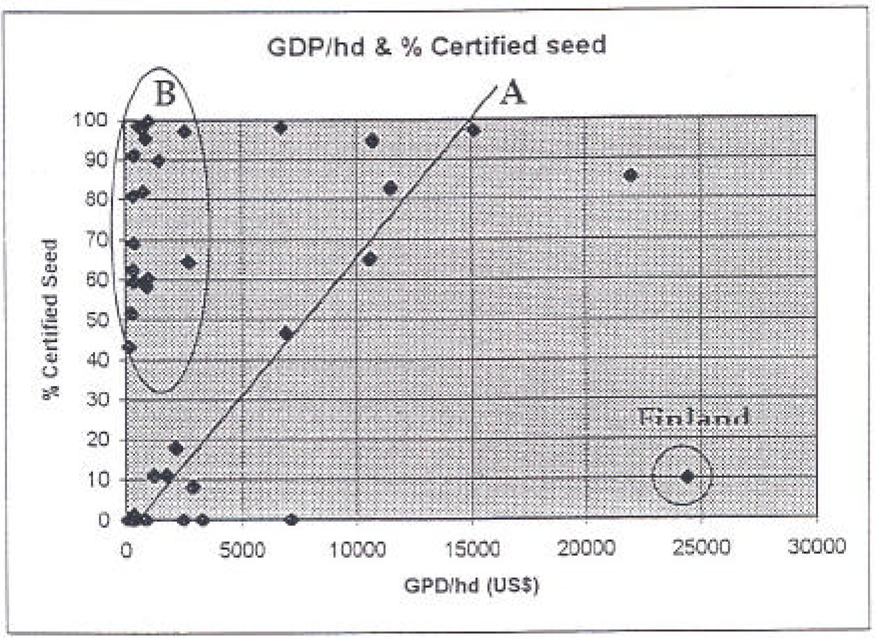


Figure 3 : Certified seed ratio and GDP/head

the calculation of certification ratios for each crop and each country. There was a choice between using quantity-based and area-based certification ratios. The former appeared the better one as it better represents the total use of certified seed, and therefore the costs incurred. Two equal land areas may represent two very different quantities of seed used.

Because different countries grow different crops, overall certification ratios had to be computed, providing aggregate figures. At the same time, specific ratios were computed for staple crops like wheat and rice. Maize was left out because of technical reasons: it is a hybrid crop for which certification is a necessity. The correlation between the certification of staple crops and overall certification seems to be good.

Auxiliary data included GDP per head (a measure for $a$), plus arable land area, agricultural output, and agricultural production factors: labor, tractors, fertilizers, and irrigation. This information is available in the FAO Production Yearbook series and the FAO Fertilizer Yearbook series. The dates used were 1985, 1990 and 1995. To minimize problems of climatic variability, three-year moving averages were used (1984-86, 89-91, 94-96). Three levels of aggregation were considered for agricultural production: cereals only, all crops, and aggregate agricultural produce. We considered tractors and fertilizer use per arable hectare, and percentage of farmland irrigated. Labor was recorded as the active population in agriculture per hectare of arable land. Data was recorded only for those countries for which certification data was available.

4.3 Analysis

Hypothesis 1 and 2

Firstly, some simple statistics were carried out to examine the empirical relationship between GDP/head and quantity-based certification ratios. Figure 3 shows the quantity-based certification ratios as a function of the GDP/head.

**[FIGURE 3]**

Figure 3 actually reveals two different groups of countries. One group is clustered in the upper left-hand part of the graph, while the other roughly follows a direct positive relationship between GDP/head and quantity-based certification ratios. We dubbed this latter set 'Group A countries' and those clustered around the upper left-hand corner 'Group B countries'.[12] The original FAO information files were re-examined, only to find out that

[12]Finland appears as a clear outlier. It has one of the highest GDP/head yet only 10% quantity-based certification ratio. However, it hails 94.6% certification for its cropped land, a discrepancy not obvious to unravel.

group B countries were those that had developed a strong, voluntary state-controlled certification program usually with the international aid from organizations such as the FAO. They all represent so-called less developed countries (LDCs). A distinction was made between the wealthier and the poorer end of the spectrum in group A countries.[13] In terms of GDP/head, poor group A and group B are similar; in terms of certification ratios, rich group A and group B are similar. The similarity holds for staples like wheat and rice. Thus, in group B, the state substitutes itself for the market to provide certification. In this case, high certification ratios are correlative with low GDP/head as predicted by the model.

We next ran simple linear regressions to evaluate the influence of GDP/head on certification.[14] An initial model was run without the use of a dummy variable representing a country's belonging to group A or B. Such a model performs very poorly ($R^2 = .06$). By adding a dummy identifying group A and B, things improve dramatically. Even so, as expected, GDP is a poor predictor for group B countries, but a good predictor for group A countries. For the whole sample: Adjusted $R^2 = 0.81$ ($Prob > F$ at 1%)

$$CERT = -65 + 0.0045GDP + 68DUM$$

(-6.8) (9.7) (11.9) (t values)

For group A: Adjusted $R^2 = 0.82$ ($Prob > F$ at 1%)

$$CERT = 2.8 + 0.0045GDP$$

(-0.6) (9.9) (t values)

According to these regressions an increase of one point of GDP/head increases the quantity-based certification ratio by 0.0045. Moreover, as predicted by the theory, in countries where a public funded certification program exists, the certification ratio is much higher than the level predicted otherwise. Conditional to the fact that a public funded certification program exists the quantity-based certification ratio increases by 68%. Government certification occurs in countries that have low shadow cost of public fund. That is, in countries that received foreign aid to implement a certification program. The foregoing results are very preliminary and incomplete. They seem, nevertheless, to corroborate hypotheses 1 and 2. In checking hypothesis 3, we shall next see whether such policies indeed achieve their purpose: higher agricultural productivity.

Hypothesis 3

The next question was to examine, particularly for group B countries,

[13]Making the most of a gap between \$7,000 and \$10,000 in the data, "poor" countries were identified in the less than \$7,000 GDP/head category (with most in the less than \$3,000), and "rich" countries in the more than \$10,000 GDP/head.

[14]Non-linear specifications including a squared GDP term did not improve the model.

whether their certification effort yielded any results. Because certification programs entail a certain time lag for production results to be felt, the three-year average around the 1995 data set was used with the 1990 certification data. In terms of the output variable, there was a choice amongst several options in the FAO database: actual cereal yields, crop production indices relative to a base year, and increases in production indices over a period of time. Only the cereal output data yielded any significant results. Thus, these were used for testing hypothesis 3. The following linear regression model was used:

$$CERYLD = f(CERT, FERT, TRACT, LAB, IRRIG, DUM)$$

where:
$CERYLD$ = cereal yields, in tons per hectare
$CERT$ = certification ratio (%), as explained earlier
$FERT$ = kg of fertilizers per ha of arable land area
$TRACT$ = number of tractors per ha of arable land area
$LAB$ = active population in agriculture per ha of arable land area
$IRRIG$ = percentage of arable land irrigated
$DUM$ = dummy variable for each group (A=1, B=2), only for aggregate model

In the aggregate model (whole sample), certification appears not to be a significant explanatory factor. Instead, fertilizers and labor are the most important variable. Excluding the non-significant regressors: Adj $R2 = 0.70$.

$$CERYLD = 1918 + 9.4FERT - 0.3LAB$$

(8.3) (8.7) (- 2.9) (t values)

When the sample was split between the two groups A and B, a new picture emerged. Certification appeared as the most significant factor. In group A, excluding the non significant regressors: Adj $R2 = 0.77$

$$CERYLD = 795 + 21CERT + 11FERT + 21IRRIG - 15TRACT$$

(1.4) (1.0) (3.7) (2.1) (-2.0) (t values).

For group B, however, its significance worked the other way around. Its regression coefficient was negative, implying a negative impact of certification on cereal productivity: Adj $R2 = 0.73$.

$$CERYLD = 4255 - 28CERT + 13FERT + 21IRRIG - 0.5LAB$$

(4.3) (-2.6) (4.6) (-1.1) (- 0.5) (t values)

This result proved robust under various model specifications. Interpreting it is not obvious. In fact, the available data has not allowed us to come up with a satisfactory explanation.

One possibility is that the relationship works indeed the other way around. That is, in countries with very low productivity, efforts are made to improve the situation. Voluntary certification in poor countries is then the signal of very low productivity. A regression was run by inverting $CERYLD$ and $CERT$ as dependant and explanatory variables, in the form $CERT = f(CERYLD, \text{other variables})$. The resulting model is of lesser quality (R-square of 0.48 instead of 0.73), which suggests the answer lies elsewhere.

Another possibility lay in the dimensions of the variables, defined per hectare of land. Accordingly, another model was constructed with the original data, using total rather than per hectare values, and the area of arable land itself was entered as an extra variable. There were no major changes in the results (certification retains its negative coefficient for group B), and this model was not as good as the original.

It may also simply be that our data are too aggregated and of too poor quality. For instance, labor input also appeared with a negative coefficient with respect to cereal yields, which might seem preposterous. However, at the aggregate level, higher labor inputs are correlated with lower technology and therefore with lower yields. Other, hidden, variables are at play. This is likely to also be the case for certification.

In conclusion, hypotheses 1 and 3 appear to be corroborated, in the light of these preliminary findings. It is true, given the above evidence for the countries where there is no voluntary state-planned certification program, that certification is a function of national income or wealth, reflecting the weight of the underlying costs of certification. It is also true that certification does contribute, in an important way, to the agricultural performance of these countries, at least as measured by cereal production.[15] Where certification appears as a significant factor in explaining cereal productivity, equally significant values of other explanatory variables: fertilizers, tractors, irrigation suggest colinearity. Certification obviously does not lead by itself to higher productivity; rather, it is an element of a composite technological and institutional package. This suggestion was tested by creating composite variables representing various such packages. However, none of these played a significant role in explaining cereal productivity. Although one would think that certification is part of a larger technical-institutional package, the data

[15] This is not as restrictive as it may seem, because, including wheat, rice and maize, by far the world's three major staples, it covers the greater part of crop production in most countries. On the other hand, pasture and forage products linked to animal production are not captured by this measure.

have not permitted a positive test of this idea.

In the case of countries that have initiated a government based certification program, generally with the help of international aid,[16] hypothesis 2 seems to be vindicated. In these countries, as predicted by our theoretical model, the level of certification should otherwise be zero. On the other hand hypothesis 3 seems to be wrong. Certification does not appear to contribute towards agricultural (cereal) productivity. In fact, certification seems to be related to it negatively. This unexpected result might reflect the fact that the certified seeds which perform very well when properly used, are very sensitive to seeding condition and climatic variations. Then these seeds might simply be unfitted for many developing countries, especially those where rainfall is rare and unpredictable (e.g. sub-Sahara area). More importantly this unexpected result might reflect our initial assumption of perfect certification, where credibility is taken to be 100%. In many developing countries, this is a strong assumption and does not appear to be warranted (the case of Ghana appears illustrative). Future work is needed to investigate in similar model a probabilistic formulation of certification, where the confidence of farmers in certified seed is less than perfect.

# 5 Conclusion

This paper has studied the problem of quality certification when quality is a credence attribute and certification is perfect. It has shown that the costlier the certification process, the fewer will be the firms able to afford certification. In this sense certification cost is a major factor in deciding market structure, with high costs leading to a monopoly for certification, and ultimately to no certification at all. In this case the market for quality collapses. The certification equilibrium is also influenced by the wealth level of the population. For a rich population a certification equilibrium might prevail, whereas with a poor one it might not. We have shown that certification through an independent certification body always dominates self-certification. Whether it should be funded by a fee on the certified product or by public funds, depends on the shadow cost of public funding. In developing countries where there are external organizations eager to fund the certification program, the shadow cost of funding is close to 0 (at least in theory). These countries should rely on public funding. On the other hand, in rich countries the shadow cost of public funding is high because the tax burden is already very high. It is better to rely on a fee to finance the certification process.

[16] Funding through certified product fees is not possible in countries whose problem is precisely that farmers lack enough money to generate an effective demand for certification.

These ideas were confronted with the issue of agricultural seed certification. Although the available data was limited in both quantity and quality, the relationship between levels of average income and levels of certification is verified for countries with market-based certification (that is, provided through the private sector). In countries with government provision, GDP per head, as expected, is not a good predictor of certification levels, especially where international aid is relied on. Finally a difficulty appeared regarding the efficiency of government-funded seed certification. One would have expected that these often voluntary certification programs would have had some positive (though lagged) impact on agricultural productivity. Instead, the data revealed a negative impact. We were not able to explain away what appears as an anomaly, and it is not obvious whether the data is at stake. For government-based certification schemes, it is likely that there is more at stake than what is accounted for in our model.

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