Quality Signaling through Certification

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Abstract: This paper analyzes the problem raised by quality provision in globalizing economies. When quality is a credence attribute, there is a signaling problem and quality drops to its minimum level. A way out of this under-provision equilibrium consists to rely on certification. However certification of goods involves costs, most of which are fixed, because to credibly signal quality, the certification process has to be carry out by an independent authority above all suspicion. The certification costs, which might justify a centralized intervention, become a major force in deciding market structure. Then in a given population the rate of certification depends on the consumers' wealth and size. If the population is too poor the market for certification collapses unless it is publicly funded. This analysis implies that at a national level certification should be an increasing function of GDP/capita and population size under laissez-faire. It should be higher under voluntary public certification. We evaluate the empirical relevance of the theory based on a statistical preview made on the economics of seed certification.

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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 and/or preserve the environment. In the process, problems are arising linked to the possibility for consumer deception and, more generally, to the efficient signaling of the quality attributes of goods and services. This signaling problem is a consequence of globalization. Confronted to the worldwide labor division and specialization, individuals and firms can no longer trace the origin or control the composition of their consumption goods or inputs. Permanent flows of innovations and of new products introduction exacerbate the problem. It is then difficult for them to assess the impact of their consumption, especially when individuals' health or the environment are involved. This is obviously true for complex goods like electricity generated from nuclear power, but is also true for more simple commodities like beef.

These problems can be better understood once different categories of goods are acknowledged with respect to quality signaling. Nelson (1970, 1974) 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. *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. Finally, *credence attributes* are those for which consumers can assess the quality attributes neither before nor after purchase and use. Typical cases refer to environmental impact at the production stage but also at the consumption stage. In particular it applies to health and safety related attributes such as food nutritional composition, chemical formula of a drug, or safety of an airplane. 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. Accordingly, 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 a given level of quality of some product *a priori* unobservable is made known to the consumer or the user of the product through the guarantee issued usually 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. 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 expensive personnel. Moreover such assessment procedures take time, often several years.

It is natural to assume that the costlier the certification process, the fewer will be the firms able to afford a certification process. 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 certification cost be a major factor in deciding market structure, with very high costs leading to a monopoly for certification? These questions have not, to date, been studied in great depth. The present paper aims at contributing to their study. It analyzes, with a simple model, the problem of quality provision when the quality is costly to produce and unobservable by the consumer. This creates a problem of quality signaling. A way out of the under-supply problem is to rely on the costly process of quality certification. We show that the private incentives to certify quality is sub-optimal. We next study the optimal regulation of certification. Finally we propose to examine the empirical relevance of the theory on the economics of seed certification based on an international comparative approach.

The paper is organized as follows. A first part presents a simple model that attempts at describing the relationship between demand for certified goods and services, wealth of the population, certification costs, and market structure. A second part examines the example of agricultural seed certification in the light of the results of the model.

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, and by $a \geq 0$ which corresponds to a wealth index (a larger a correspond 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 term. The larger a is, the less the consumer behavior is affected by price increase. On the other hand, the price elasticity is independent of β_i which reflects heterogeneous need and size in the consumers population.

Quality is a vertical differentiation variable. The consumers have unanimous preference over the quality set. They all prefer high quality to low one. Then the elasticity of demand with respect to quality is constant no matter the consumer wealth, measured by a, or his/her taste or need for the commodity, measured by β_i, in the total population. That is, $\epsilon_{v,d_i} = 1$ for all (a, β_i) positive.

Consumers maximize their surplus. Let $P_i(q, v) = a - \frac{q}{\beta_i v}$ be the inverse demand function, when he/she 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 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 (**??**) that confronted to 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 β_i, whereas the quantity purchased by each individual increases with β_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 $D_a(p, v) = v(a-p)b$.

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 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:[1]

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

where $q_j \geq 0$ is the quantity produced by firm j at quality $v_j \geq \underline{v}$.

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

[1] The second part of the paper deal with an application to agricultural seed certification. Agricultural production is consistent with the constant return to scale assumption.

no quality signaling problem so that 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 consumers a point of view, denoted v_a, is solution to the following equation:

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

The optimal quality level is increasing with a (i.e., $\frac{dv_a}{da} \geq 0$). The wealthier the population is the larger the level of quality it seeks.[2] Then, on segment a of the market either a firm sells quality v_a defined equation (**??**) at marginal cost $p_a = c(v_a)$, or else it disappears. At equilibrium $q_{a,b} = D_a(v_a, c(v_a))$ 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 of trade.

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

Now if quality is an experienced 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, this problem can be solved by a guarantee system, assuming it exists a credible way to enforce the contract. That is, the product is sell with a guarantee specifying the quality level v_a and a penalty rule in case of consumers deception. The credibility of the guarantee contract depends upon the cost of deviating for the producer.

[2]For instance if $C(v) = c + v$ with $c \geq 0$ being a marginal cost of production common to all firms, we get $v_a = \frac{a-c}{3}$. If $C(v) = cv$ then $v_a = \frac{a}{3c}$.

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 consumers associations, dedicated to the defense of consumers interest. 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. The signaling quality problem does not change the market structure.

Proposition 1 *When quality is observable, either before or after the purchase, there is no signaling problem. Quality v_a, solution of equation (**??**), is sell 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.*

Since we assume constant returns to scale, when there is no signaling problem the production technology is compatible with perfect competition. The market allocation is Pareto-efficient. 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 the level of quality of the product they purchase is never observable to consumers. They are not able to discriminate between different quality levels when they are faced with them, neither prior nor after purchase. There are many attributes in 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 or work condition of the labor force... Then poor quality producers can pretend to be high quality ones; from the consumer perspective, they are not discernable. For instance, whether a shirt has been made by a child or by an adult, it is the same shirt in the end. Yet many people disapprove with children being put at work and would rather pay a premium to avoid that. This is the same with an environment friendly versus a polluting technology. They cannot be tell apart based on the final product. In this context a firm that would think of producing quality $v > \underline{v}$ anticipates that it will not be able to recover its cost, since consumers cannot discriminate among low or high quality producers (neither prior purchasing nor after). It then supplies the minimal level. On the other hand, consumers anticipate that since firms' profit is decreasing with 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 to the cheapest producers. At equilibrium there is a unique quality level offered which is the minimum one. It is competitively supplied at price $\underline{p} = c(\underline{v})$ as the production function involves constant returns to scale. A firm that would deviate from this low quality/marginal cost pricing strategy would go bankrupt. The net surplus falls to the minimum 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 fall 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. Consumers anticipating this refuse to pay a premium for quality. When quality is a credence attribute, the quality supplied falls to its minimum level. 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 the population is composed of different groups of wealth a, for instance rich and poor ($\overline{a} > \underline{a}$), in the absence of signaling problems there would be as much quality levels offered as group of wealth a. Proposition 2 implies that, in addition to a decrease in the absolute level of the quality, there is also a decrease in the variety offered.

2.3 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. As explained earlier for the experience goods, the most common one consists to supply a guarantee contract with the commodity. Unfortunately, with credence attribute such contracts are inefficient. Consumers cannot send back the product based on a poor quality since they do not experience it. They are then unwilling to pay a premium based on the fact that the product they purchase comes with a guarantee. Who would like to take an unchecked medicine on the ground that it comes with a guarantee?

With credence attributes, the solution is *certification*. As explained in the introduction certification is a process whereby a given level of quality of some product a priori unobservable is made known to the consumer or the user of the product through the labeling issued usually by a third independent party. In other words, certification is a process to transform 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.[3] 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 natural environment throughout their life cycle (their production, their consumption,

[3] This is the case of traditional drinks, such as French wines from Bordeaux, Burgundy and other areas. They are signaled through a system of *Appellation d'Origine Contrôlée*, which refer to both the origin, and to the wine-making processes.

and their disposal), are typically credence attributes, especially as far as production is concerned. In this case, a way of signaling environmental quality are ecolabels which to be credible to potential consumers have to be granted by some independent authority or body. 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 norm system. Finally whenever safety issues are at stake, the certification process is usually put under the government supervision. Mandatory certification processes may then be imposed by regulation as it is for instance the case for pharmaceutical drugs. The Food and Drug Administration in the US is an example of governmental organizations involved in mandatory certification.

In all these cases, the cost of quality signaling is the cost to certify the goods or the processes which 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 firm perspective it is basically a fixed cost, potentially a very high one. For instance the assessment of biophysical, biochemical, and microbiological attributes of food and drug 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 follow we study the incentive an individual firm might have to set up its own certification process. We will next turn to the study of certification as a coordinated activity under regulation.

2.3.1 Private self-certification

The certification cost is modeled as a fixed cost. We assume that the quality level (chemical composition of a drug, environmental quality of a production process, germination rate of seeds...) can be publicly assessed at cost $K \geq 0$. The fixed cost K is called a *certification* cost. A firm can decide to invest K in order to make its quality credible to the consumers.[4] The important point

[4]To keep things simple we assume that the certification process is perfect. In reality the certification process is imperfect such that the quality is in probability and could be

here, is that no matter the 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 credibility of the quality 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. 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 demand size b) the market structure that is going to emerge varies widely. We model competition among firms as a generalized Cournot competition (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 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 (**??**).*

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 (**??**) and that $p_M = \frac{1}{2}(a + c(v_a))$. Now if several firms enter the market for certified good, the individual profit depends on the competitors quality/price strategy. We solve it backward. 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 it 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 α_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 Π_j with respect to v_j yields $v_j = v_a$ with v_a solution to equation (**??**). 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

made dependent on an unobservable effort.

perfect substitute. There remains to consider the firms choice in quantity. The relevant equilibrium concept is Nash. Let $Q_{-j} = \sum_{h\neq j} q_h$ denote the total quantity out of the production of firm j and $Q = \sum_{j=1}^{N} q_j$ the total quantity. 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 is increasing 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 consumer 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 (**??**) 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 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 (**??**). 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 with no certification. Moreover, for a given number of firms, N, in the industry, certification will be preferred more often by rich population than by poor one. That is, from the definition of v_a defined equation (**??**) 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, richer population prefers more often certified commodity than poor one, an intuitive result.

We compute next the per capita profit assuming that the 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,

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

The next proposition provides 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 $N(K)$ defined equation (**??**) producers. Otherwise, the low quality/low price equilibrium prevails.*

Proof: The certification equilibrium prevails if and only if it exists $N \geq 1$ 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 it 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) holds 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 (**??**).QED

[5] If this difference is smaller than 1, it is easy to find examples where there is no integer that meets the two inequality.

We deduce from (**??**) a necessary condition for voluntary certification to hold, which implies $N(K) \geq 1$, by putting $\underline{S} = 0$.

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

The market structure that is going to emerge at the equilibrium depends on the certification cost K, on the demand size b and on consumers wealth a. By virtue of proposition 3 the larger is a or b the easier it is for the condition (**??**) to hold. Figure 1 illustrates these results. It represents the $N(K)$ function for two different level of wealth $a' > a$ (or alternatively two demand size $b' > b$). We deduce that the certification equilibrium appears less often for poorer population. It appears also less often for smaller population. That is, the critical level of fixed cost such that the certification equilibrium is no longer sustainable increases with a and b. It implies that if the fixed certification cost, K, is such that $\hat{K} < K < \hat{K}'$ a rich population purchases high quality/certified commodity and a poor one low quality/uncertified commodity (and similarly for a large and a small population).

[**Figure 1**]

Proposition 3 then helps to understand that in a given population there might be a market segmentation. The rich choose to purchase certified commodity while the poor buy low quality, uncertified commodity. More importantly it helps to understand the difference in certification level *across* countries. Indeed developed countries tend to 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.

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

The welfare loss involved in the self-certification equilibrium are potentially high. The problems surrounding pharmaceutical practice in developing countries illustrate this phenomenon. The people who are too poor to buy official medicines in drugstores, have to rely on those available on the streets. The problem with the street market drugs is that they are uncertified. For instance a study in Nigeria concluded that up to 60% of medicines on the street market were counterfeit. Counterfeit drugs are unchecked and thus very dangerous. It is simply safer not to consume them. This leaves the population with traditional remedies. In developing economies the market for modern medicines collapses. The social cost of this equilibrium is very high. A centralized intervention, such as regulation, can be a valuable alternative to the market failure. We study next the optimal certification policy.

2.3.2 Optimal certification policy

Laissez-faire can lead to inefficient outcome. In particular when the population is not rich enough (i.e. when a is small), or when its demand is not large enough (i.e. when b is small), the market for certification collapses, and the quality provided drops to its minimum level. This low quality/uncertified equilibrium might have a dramatic impact on growth and social welfare if the product at stake is an essential input or commodity. Moreover since certification involves large fixed costs, there are increasing returns to scale in this activity. Self-certification might lead to a wasteful duplication of the certification cost among the downstream firms. To overcome the under provision problem and strengthen the credibility of the certification process, the government can encourage the creation of an independent certification firm or firms depending on the market size, and regulate it to avoid consumers deception or monopoly power abuse. 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.

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 increases the taxation burden which is already quite heavy. Moreover it yields the issue of cross-subsidies when the general taxpayers are not the direct beneficiary of the certification process. Rich countries favor a self-finance certification system with a fee levied on output.

We first consider the case of a public funded certification. We assume that the regulator is utilitarian. She maximizes the sum of consumers surplus, $S(p,v) = \frac{bv}{2}(a-p)^2$, plus the firms' profit, $\Pi(p,v) = (p - c(v))bv(a-p)$, minus the cost of funding the certification fixed cost, $-(1+\lambda)K$. Term $\lambda \geq 0$ denotes the shadow cost of the public fund. It is greater than 0 because it is distorting to raise taxes. It can be think of as the multiplier of the state budget constraint which measures the social opportunity cost of the public funds. 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:

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

Solution to program (**??**), is the first-best level quality v_a defined equation (**??**). The quantity produced is that of the first best level $q_{a,b}$ defined proposition 1. We deduce the value of the net social surplus of public funded certification S^λ.

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

When λ is close to 0, this solution is close to the first best. On the other hand when λ is large, the net surplus decreases and might even become negative. In rich countries λ is quite high (it is often assessed to be around 0.3). It seems then difficult to increase the taxation burden for the sake of the users of the certified commodity. For the certification of the private goods, wealthy nations prefer to rely on the final users. We next consider the case of a self-finance regime.

The certification process is finance 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 carry out by a public or by a private body.[6] 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

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

being either regulated or contestable. The optimal tax rate, chosen to 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 (**??**) 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 certified, and $c(\underline{v})$ otherwise. Therefore the cost function, $C(q) = (c(v) + \tau(v))q$, is linear in quantity. It remains compatible with perfect competition. Under the competitive pressure (see section 2.1) the firms set their price at $p = c(v) + \tau(v)$ and they choose quality to maximizes the net consumers' surplus $S(p, v)$. They solve:

$$\operatorname*{Max}_{v} \frac{bv}{2}\Big(a - [c(v) + \tau(v)]\Big)^2. \tag{15}$$

Using equation (**??**), one can check that the level of quality solution to (**??**) is the first best level v_a defined equation (**??**). Then at the equilibrium the optimal tax rate, chosen to cover the certification cost, satisfies $\tau bv_a\Big(a - [c(v_a) + \tau]\Big) = K$. 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 viable 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-regulation being viable (see equation (**??**)). 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 dead weigh loss of the tax $\tau_{a,b}$. We deduce the net social surplus when relying on self-finance regime.

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

Comparing this regime with *laissez-faire*, yields the following result.

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

Proof: Comparing S^τ defined equation (**??**) with S^N defined equation(**??**) 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. Centralization dominates self-certification because in the centralized framework the fixed cost of certification is not duplicated (the two regimes are equivalent when $N = 1$). The existence of an independent body to carry out the certification process is preferable to the anarchy of individual firms trying 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 conflict of interest in the certification process. It is the cheapest way to generate consumers confidence. Accordingly in free-market economies voluntary certification is carried out by independent firms or organizations.

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 later case the publicly finance regime is preferable to the self-finance regime if and only if*

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

Proof: 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 finance 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 finance certification through a linear tax is better than no certification if and only if $\frac{S^*}{K} \geq 2$. Finally a publicly finance regime is preferable to a self-finance regulation regime if and only if $S^\tau \leq S^\lambda$ as defined equations (**??**) and (**??**). This is equivalent to: $\lambda \leq \frac{S^*}{4K}\left(1-(1-\frac{2k}{S^*})^{0.5}\right)^2$. Developing the right hand side yields (**??**). 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 the public funds. For the low value of λ, public funding is less distorting than a linear tax levied on final output. On the other hand, when λ 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. We now turn to the problem of evaluating the empirical relevance of these results on the market of agricultural seed certification.

3 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.

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). In every case, it provides 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. Thus, only seed of a certain quality is certified. Certification reflects and signals high quality, measured as productive performance.

Such is the value of certified seed. To farmers, it can provide higher and more stable yields and income. To the agricultural sector as a whole, it can increase productivity, however measured: land, labor or capital. Quality seed embodies the outcome of scientific investments and genetic improvements. It leads to substituting new genetic material and knowledge to land, labor and capital. 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 material.

At the national level, countries with a growing population and a predominantly rural economy can reap net benefits from widespread adoption of certified seed. As highlighted in the model, however, given the needs in expertise and sophisticated equipment, poor farmers find certification beyond their reach. As a result, non-certified, low quality seed is used, leading to low and unreliable yields, which for a rural economy means low incomes. This negative result can be offset by a public intervention. The state, possibly with the help of foreign aid, might take in charge the certification process. The level of certification should then be close to its first best level. This is, at least, the picture the model would have us believe.

If the logic is correct, under laissez-faire richer countries should see a widespread use of certified seed, sell at a linear price which varies with the quality of the seed, whereas poorer countries should see scant use of certified seed. On the other hand, under a voluntary certification policy, the level of certification in a given country should be close to the first best level. Thus, there seem to be at least two hypotheses generated by the model when applied to national scale seed certification.

Hypothesis 1 : In the absence of a public funded program, there is a high correlation between a nation's wealth, its population size 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 that would have occurred under laissez-faire. Such program occurs when the funds used to finance it come at a low cost (e.g., foreign aid).

Finally there is an additional hypothesis that we would like to consider. It is not a direct implication of the formal analysis of section 2, 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 the hypothesis 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 the hypotheses 2 and 3 turn out to be true, a corollary is that under a public funded certification, poor countries should also be able to achieve high-performance levels.

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.[7] 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.[8] Only 40 files contained exploitable information, generating a total of 40 data

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

[8] 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.

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 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 staple crop and overall certification seems to be good.

Auxiliary data included national populations (a measure for b), 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.

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. If the theoretical model described above is correct, we should observe a positive relationship between the two variables in the absence of a voluntary certification program. In countries where a public funded certification program exists, the certification ratio should be much higher than the level we might predict otherwise. 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. We dubbed this latter set 'Group A countries' and those clustered around the upper left-hand corner 'Group B countries'.[9] On inspection of the individual identity of group B countries, it appeared they all represent so-called less developed countries (LDCs). The original FAO information files were re-examined, only to find out that 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. Rather than leaving it to the market to decide, central provision by the state is preferred. In this case, high certification ratios are correlative with low GDP/head as predicted by the model. In checking hypothesis 3, we shall have to see whether such policies indeed achieve their purpose, higher agricultural productivity.

Secondly, a distinction was made between the wealthier and the poorer end of the spectrum in group A countries.[10] Table 1 shows that 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.

Thirdly, simple linear regressions were run to investigate the influence of GDP/head and population size on certification. An initial model was run without the use of a dummy variable representing a country's belonging to group A or B. Table 2 shows that such a model performs very poorly. By adding a dummy identifying group A and B, things change dramatically. There is therefore a discontinuity between groups A and B. Table 3 reveals,

[9] 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.

[10] 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.

as expected, that GDP is a poor predictor for group B countries, but a good predictor for group A countries. According to the model, state certification occurs in countries that have received foreign aid to implement a certification program. In theory poor group A countries can be discriminated from group B countries, based on the existence of such a foreign program dedicated to certification and on the size of their population. Figure 2 indicates that for a given level of GDP/head (i.e, wealth a), a larger population (i.e., size b) will lead to a higher ratio $\frac{S^*}{K}$, and thus to the optimality of a certification program. The foregoing results, as preliminary and incomplete they are, seem, nevertheless, to corroborate hypothesis 1 and 2. We now turn to the testing of hypothesis 3.

Hypothesis 3

The next question was to examine, particularly for group B countries, whether their certification effort yielded any results. Because certification entails 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.

Table 4 shows results for the following linear regression model:

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

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
$IRRIG$ = % of arable land irrigated
POP = total population of country
DUM = dummy variable for each group (A=1, B=2), only for aggregate model

The variable POP was added to include a scale effect, reflecting the size of the market for certification. Although it did improve the model, it did so marginally. In the aggregate model (denoted "All"), certification appears, somewhat surprisingly, as being a non-significant explanatory variable. Instead, fertilizers are by far the most important variable, which, of course, is not surprising. When the sample was split between the two groups A and B, a new picture emerged. Certification appeared as a significant factor for cereal yields for group A. For group B, however, its significance worked the other way around. Its regression coefficient was negative, implying an inverse relationship between certification and cereal production performance. Interpreting this result is not obvious. One possibility is that the relationship works indeed the other way around. That is, in countries with a very low productivity efforts are made to improve the situation. Voluntary certification in very poor countries is then the signal of a very low productivity. A regression was run by inverting CERYLD and CERT as dependant and explanatory variables, in the form CERT = f (CERYLD, constant). Table 5 shows results for the two groups. The resulting model is of lesser quality (lower R-squares), which suggests the answer lies elsewhere. Another possibility lay in the dimensionless nature of the model so far, where variables were defined per hectare of land. Accordingly, another model was constructed with the original data, using total values, and the area of arable land itself was entered as an extra variable. Table 6 shows the results with different (linear) regression techniques. There are no major changes for group B, which retains its previous characteristics: fertilizers as the main production factor and a negative link between production and certification. Explaining the impact of certification on production remains unachieved for group B.

The surprise comes with group A, where certification now appears as the relatively most significant factor in explaining cereal productivity. On closer inspection, however, strong collinearity is suggested by the close values of other explanatory variables: fertilizers, tractors, and the size of the population, all equally significant. Although certification obviously does not lead by itself to higher productivity, it is suggested that it is an important element of a global package, where technological, market and institutional aspects work together. Hypothesis 3 can be accepted as a valid statement for group A countries, but not for group B.

In conclusion hypotheses 1 and 3 appear to be corroborated, in the light of these preliminary findings. It is true for the countries where there are no voluntary state-planned certification program, given the above evidence, that certification is a function of national income or wealth, pointing to 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.[11] Although it appears that certification is part of a larger technico-institutional package, it may be hypothesized that it adds value to the technological components of the package. This is a statement that can be tested in future studies.

In the case of countries that have initiated a government-based certification program, whether funded by general tax revenues or international aid,[12] the hypothesis 2 seems to be vindicated. For it is the case that in these countries, as predicted by our theoretical model, the level of certification will otherwise be zero and the quality of the seed provided by the market will be minimal, both in terms of expected performance and in terms of sensitivity to random factors. Without government or external intervention, farmers will be locked into a triple productivity, poverty and development trap, holding back the whole rural-based economy. This view however is not confirmed by the data. In countries that have initiated a government-based certification program, 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 puzzle shows that more work is needed to understand the role of certification in agricultural production in developing countries.

4 Conclusion

This paper has studied the problem of quality certification when quality is a credence attribute. It shown that the costlier the certification process, the fewer will be the firms able to afford a certification process. In this sense

[11] 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.

[12] The third option, 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.

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 totally collapses which is very inefficient. The paper also shown that the certification equilibrium is influenced by the wealth level of the population. In rich population a certification equilibrium might prevail whether with poor one it might not. Since laissez-faire leads to inefficient outcome, there is room for a centralized intervention. An independent centralized certification agency always dominates self-certification. Whether it should be finance by a fee on the certified product or by public funds, depends on the shadow cost to the public funds. In developing countries where there are organizations eager to fund the certification program, the shadow cost to the funds is equal to 0 (at least in theory). These countries should rely on public funding. On the othe hand in rich countries, the shadow to the public fund is high because the taxation burden is already very high. It is better to rely on a fee to finance the certification process.

We believe the problem of quality signaling of credence attribute is an important problem of the modern economy. Quality has clearly broadened in today's firms, usually embodying a bundle of different characteristics, including many credence attributes. Credible quality signaling for these characteristics may be achieved in several ways, all of which are more or less costly to the firm : reputation, as entertained through informative publicity, company reports, and other information; conformation to quality norms, resulting in quality labeling, or certification of the goods; registered trade marks, which are enforced in order protecting firms' commercial and quality efforts against free riders. Various certification or labeling systems do occur as government-certified. In these cases, the greater part of what we call the cost of quality signaling is merely the cost of enforcing such denominations and brands by some public authority. Therefore, the actual certification costs that do apply to individual firms is likely to be small. Public bodies enforcing these labeling systems appear to create some kind of a public good which is ascertaining to consumers the quality.

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