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Optimal Quality Assurance Systems for Agricultural Outputs

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Abstract
New quality assurance systems (QASs) are being put in place to facilitate the flow of information about agricultural and food products. But what constitutes a proper mix of public and private efforts in setting up QASs is an unsettled question. A better understanding of private sector incentives for setting up such systems will help clarify what role the public sector might have in establishing standards. We contribute to this understanding by modeling the optimal degree of "stringency" or assurance in a processor's quality control system over procurement of agricultural output when there exists uncertainty about quality.

Our model addresses two questions: (1) Should a buyer of agricultural outputs implement a QAS as a way to gain and provide information about product quality to its potential customers? and (2) Given that it is profitable to adopt a QAS, what is the profit-maximizing degree of assurance in the system? We study a particular case in which the input buyer requires its suppliers to implement a given QAS.

Increased stringency through the QAS reduces the probability of type I errors of falsely declaring that a product is of high quality and of type II errors of rejecting high-quality output. The optimal degree of assurance balances the marginal cost of increased assurance with the value of reduced type I and type II errors. The model predicts that the optimal degree of assurance depends on (1) the likelihood that the sought-after attribute is discoverable by consumers, (2) the price premium paid for the attribute, (3) the cost of quality control, and (4) the damage caused by false certification.

A number of privately developed U.S. QASs are examined to see how well the model predictions are supported.

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OPTIMAL QUALITY ASSURANCE SYSTEMS FOR AGRICULTURAL OUTPUTS

New quality assurance systems (QASs) are being put in place to facilitate the flow of information about agricultural and food products. Incentives for growers and food manufacturers to adopt QASs include (*a*) increased consumer demand for knowledge about where their food came from and how it was produced; (*b*) opportunities for producer groups to capture a greater share of the consumer dollar by differentiating their products; and (*c*) greater protection for food manufacturers and retailers against food safety liability.

Various QASs have been developed in the United States to facilitate the flow of information about products. Some have been developed purely by the private sector. Others have relied on the U.S. Department of Agriculture (USDA) to set standards. But what constitutes a proper mix of public and private efforts in setting up QASs is an unsettled question. A better understanding of private sector incentives for setting up such systems will help clarify what role the public sector might have in establishing standards. We contribute to this understanding by modeling the optimal degree of "stringency" or assurance in a processor's quality control system over procurement of agricultural output when there exists uncertainty about quality.

We include both process control, where verification of certain production methods are to be followed, as well as control over a physical attribute of the input. The model predicts that the degree of stringency depends on (*a*) whether the sought-after attribute is discoverable by consumers, (*b*) the price premium paid for the attribute, (*c*) the cost of quality control, and (*d*) the damage caused by false certification. We conclude with a discussion of a number of products and associated quality control systems to see how well these real-world examples match the model predictions.

The Model

The decision modeled is whether a buyer of an input should implement a QAS as a way to gain and provide information about product quality to its potential customers, and, if so, what level of insurance is profit maximizing.[1] We study a particular case that is becoming pervasive in the food industry (Caswell, Bredahl, and Hooker 1998; Reardon and Farina 2001; Northen 2001; Fearne, Hornibrook, and Dedman 2001), in which an input buyer requires its suppliers to implement a given system of assurance. This would be the case of a quasi-voluntary system (Caswell, Bredahl, and Hooker 1998; Noellke and Caswell 2000). To keep the framework general, we are not specifying the “type” of quality assurance strategy that an input processor will follow. For example, assurance potentially can come from a system run by the buyer, from reliance on certification by a private or public third party, or both. The information obtained through the implementation of the system allows the processing firm to better sort the input it buys, to gain a better idea of the actual quality of the inputs, and to be able to convey assurance to its customers about the quality of its product.

The topic of this paper is especially relevant in an environment where it is difficult to assert the quality of a particular product (both before and after the input is processed and consumed). That is, there is imperfect information about quality.[2] Many food attributes can be thus classified (see, e.g., Caswell and Mojduszka 1996; Antle 1996; and Unnevehr and Jensen 1996). Clearly, if quality is readily observable, there is no need for a QAS in the procurement process.

Quality characteristics of agricultural products have an inherently high degree of heterogeneity (Ligon 2002). This variability stems mainly from the randomness of the production environment (e.g., weather and biological uncertainty) and/or the heterogeneity of the practices employed by farmers. We aim to capture this variability and the fact that quality can be only imperfectly assessed by assuming that the processor believes it can be represented by a random vector Q. Specifically, let Q denote the vector of the imperfectly observable array of quality attributes, and let $\mathbb{Q}$ denote the set of possible quality attributes of an input. In general, $\mathbb{Q}$ could be a set in many dimensions. However, for the sake of tractability, we will assume that only one quality attribute is of interest, is imperfectly observable, or differs across goods. In this case, the sample space of interest is one-dimensional (i.e., $\mathbb{Q} \subseteq \Re^1$). Further, we assume that the unconditional cumulative distribution function of Q[3] is $F_Q(q) = \mathrm{P}_Q(Q \leq q)$ for all q. This distribution of quality would prevail in the absence of a QAS or in the open market.

Noellke and Caswell (2000) propose a model of quality management for credence attributes in a supply chain. Based on a literature review, the authors discuss benefits and costs of a voluntary, quasi-voluntary, and mandatory quality management system (QMS) for a firm within a supply chain. They then provide some comparative static results on how the behavior of the firm (given by the choice of a QMS) changes when other firms upstream or downstream modify their QMS under different tort laws. In our model, the firm under consideration is the one that has influence on the behavior of firms upstream in the supply chain. We also make the probability that a firm is punished dependent on the ability of consumers to discern when quality is substandard. Hence, our model accommodates both credence and experience goods.

We define quality as meeting an agreed-upon standard. Every unit of the product meeting or surpassing this minimum standard will be considered of high quality. Caswell, Noellke, and Mojduszka (2002) also define quality in a supply chain as consistently delivering a product that meets or exceeds “defined sets of standards for extrinsic indicators and cues.” The task of the processors is to decide which QAS to implement (if any) to better infer the nature of the product being certified. In particular, the QAS will inform the processor about the proportion of the input that is likely to deliver a product that meets the minimum standard. Note however that the processor will not be able to discern the difference in quality of any given unit it actually buys. We assume that the quality of the processed output has a direct relationship to its input counterpart, an assumption that is equivalent to claiming that the processing technology cannot be used as a substitute for input quality, or that it does so only at prohibitively high costs.

The proposed approach accommodates both the case where the quality attribute or trait is the production method itself and the case where the process alters the probability distribution of quality (i.e., the costlier process increases the probability of obtaining a high-quality product). The former has an analog to a discrete attribute (the good was produced using a desired process or it was not), whereas quality in the latter case is a continuous random variable whose distribution is altered by the process followed. The interpretation of the continuous case is straightforward. Let q^M be the minimum acceptable quality to be considered good quality (or with desirable properties for a good performance at the processing stage, or to deliver a good eating experience). In this case q^M divides the range of the random variable Q into two subsets in $\Re^1$, namely, $q^L = \{q \in \mathbb{Q} : q \leq q^M\}$ and $q^H = \{q \in \mathbb{Q} : q \geq q^M\}$. Hence, $F(q^M) = P_Q(Q \in q^L)$ would be the unconditional probability that the product is inferior or unacceptable. A product that is deemed inferior receives a lower price than that certified as being high quality. This interpretation is akin to attributes such as the tenderness of a steak, where q^M would be some acceptable degree of tenderness, or to food safety, where q^M would be interpreted as the count of pathogens[4] that makes a particular food item unsafe.[5]

The discrete case can be analyzed in a similar way. Strictly speaking, here the input has or fails to have a particular attribute or was or was not produced following a value-adding (cost-increasing) production process. For example, milk used by some companies was produced with or without treating milking cows with genetically engineered hormones such as rbST (recombinant bovine somatotropin). Also, eggs can be produced using animal welfare[6] enhancing techniques (e.g., free-range production) or by conventional means. Poultry is or is not fed with animal protein. Crops can be grown conventionally or using environmentally friendly practices (e.g., minimum tillage).

However, to unify the analysis, we will differentiate by class of production practice. For example, in the case of animal welfare, we will consider a product to be of high quality if the production facilities meet a minimum set of amenities or if certain practices, such as forced molting of egg-laying hens, are avoided. Another example would be the intensity of the soil conservation practices employed. A different interpretation of Q is needed to tackle this type of attribute. Let $\mathbb{Q}$ be the set of all production practices "bought" by the input-processing firm. The natural variability here would come from the heterogeneity of farmers. Implicit here is the idea that the firms will buy from producers and certify the product if they believe the input was produced following a process that meets or surpasses some minimum standard (more on this to follow). Hence $\mathbb{Q}$ would represent the set of all input procured from producers that have the capabilities needed to produce, and are believed to produce, following the desired processes. The clarification is important because having the capabilities does not necessarily mean that the process will be strictly followed under conditions of imperfect information.[7] A problem of moral hazard arises here. Because production of the high-quality input is costlier than production for a commodity market, and there is a strictly positive probability that deviant behavior will not be discovered and penalized, suppliers will find it rational to deviate from perfect compliance.[8, 9] Hence, there is a strictly positive fraction of the output that will not be produced under the desired cost-increasing conditions. This fraction is again represented by $F_Q(q^M)$.

The preceding discussion suggests that there are two different types of uncertainties associated with the attribute under consideration. In the discrete case, the uncertainty is mainly about the opportunism of the suppliers, whereas the continuous case also entails the uncertainty derived from the randomness associated with agricultural processes that generate a distribution of qualities for any given set of production practices. Hence, both symmetric and asymmetric informational imperfections may be present in this setting (see Antle 2001).

The choice of the firm is on the QAS and the associated stringency of controls. Suppose there is a set of alternative systems denoted by $S = \{s \in \Re : 0 \le s \le s^U\}$, where $s = 0$ represents the absence of quality verification (reliance on claims made by suppliers), and $s = s^U$ is a situation in which the quality of the product is perfectly revealed (e.g., perfect monitoring, vertical integration, or a good system of incentives). In the absence of a QAS, the processor rationally expects to obtain an input of "average" quality from the market for raw materials. When $s = s^U$ is chosen, note that the actual quality of a given unit of input will be perfectly revealed only on the discrete case; in the continuous case, even the most stringent system available still leaves the uncertainty derived from the randomness of the production environment and attributable to scientific ignorance over biological processes. However, in the continuous case, a more stringent system potentially has the double effect of increasing the proportion of compliers and the probability of being in the set q^H.

In short, a processor procuring raw materials from certified suppliers (using the QAS indexed by s) expects to buy a fraction of good-quality input, denoted by

$\lambda(s) = 1 - F(q^M|s)$. Also, a fraction $1 - \lambda(s) = F_Q(q^M|s)$ of the inferior input is expected because of the informational imperfections noted earlier. Here, we consider the QAS as aiding in the selection of which input to buy. All inputs bought (and hence certified) will be subjected to the production activity and sold to downstream customers as possessing the desired trait.[10] The case where $s = 0$ (absent an assurance effort) will result in the processor buying an input that is expected to have average market quality. To put it concisely, $\lambda(0) = 1 - F(q^M|0) = 1 - F(q^M)$. Alternatively, if the input were going to be bought anyway, the QAS would be functioning as a sorting device that allocates the input either to the commodity or to the high-quality market (or production process). In this case, the QAS tells the processor how much a unit of the input is worth to him, just as an imperfect test does (Hennessy 1996).

With this in place, we can focus on how to model the effects of a more stringent QAS on the overall quality of the product traded by the processor. For this purpose, we will use the concept of first-order stochastic dominance. Implementation of different levels of stringency switches the relevant distributions for quality as follows. For any $s^i, s^j \in S$ there is an associated conditional distribution for quality, namely, $F_Q(q|s^i)$ and $F_Q(q|s^j)$. In this context, increasing the level of stringency of the QAS, for example by moving from s^i to s^j where $s^i \leq s^j$, leads to a first-order stochastically dominating shift on the distribution of quality. Therefore, we have that $F_Q(q|s^i) \geq F_Q(q|s^j)$ for all $q \in Q$. In particular, this implies that $\lambda(s^j) = 1 - F(q^M|s^j) \geq 1 - F(q^M|s^i) = \lambda(s^i)$. This can be interpreted as reducing the probability of incurring type I (rejecting an input that is of good quality[11]) and type II (certifying a product that is of low quality) errors. In short, systems that are more stringent increase the precision with which the actual quality of the input is asserted by processors. If we are willing to assume that $F_Q(q|s)$ is differentiable with respect to *s*, the above implies that $\partial\lambda(s)/\partial s \geq 0$

However, the implementation of a QAS does not come without a cost. The use of cost-increasing technologies has to be compensated for by processors. Complications arise, however, because the incentives of farmers and processors are not aligned, and the production practices used at the farm level are only imperfectly observed. Hence, processors may have to give up some information rent if they want to elicit production of high-quality inputs (or in the language of agency theory, a high level of effort from the principal's suppliers or agents). In other words, there are costs for monitoring and/or providing the incentives (e.g., premiums or discounts) to discourage dishonest performance on the part of input suppliers. We seek to capture those costs[12] through a cost function $C(s)$, which satisfies $\partial C(s)/\partial s > 0$.

Consumers value both types of goods but like the high-quality good better and are willing to pay a premium for it. Because consumers can only assert the quality of a given product imperfectly, they must rely on the signals sent by the processors, in the form of quality certification.[13] Hence, we assume that consumers are willing to pay a price premium p^A for a good that comes from a quality-assured process.

Putting all this together, the processor chooses whether to participate in the market for quality-certified goods and what level of certainty to obtain from the QAS or to direct its product toward the market for commodities. Clearly, the processor will implement a QAS as long as the benefits outweigh the costs of doing so.

Participation in the market for high-quality goods, using the QAS indexed by s yields a per unit benefit (net of processing cost) of $\pi^A\left(s \middle| w, p^A\right) = \lambda(s) p^A$ $+\left(1-\lambda(s)\right)\left(p^A - w\delta\left(p^A\right)\right) - C(s)$, or, equivalently,

$$\pi^A\left(s \middle| w, p^A\right) = p^A - \left(1-\lambda(s)\right) w\delta\left(p^A\right) - C(s). \tag{1}$$

Here, $\delta(p^A)$ represents the economic loss due to certifying a product that is of low quality. Several potential interpretations are possible for this loss. It could be the result of obtaining a bad reputation through some form of information dissemination or could occur just because the consumer will make future purchases from other processors.[14] It also could be the result of legal action under the current tort law, applying mainly in the case of a food safety interpretation of the model. However, Caswell and Henson (1997) argue that this last effect is likely to be less important than the loss of reputation or market share. Therefore, the latter is the interpretation to which we adhere for most of the analysis. As stated by equation (1), we assume that the economic loss is a function of the price premium consumers are willing to pay for high-quality goods.[15] Naturally enough, we assume that the economic loss is an increasing function of the price premium.

The parameter w is a measure of the degree to which consumers can ascertain the actual quality of the good. For example, we could interpret $w \in [0,1]$ as the exogenous probability that a consumer discovers the true quality of the product ($w = 1$ implies that quality is perfectly observable after consumption). Equation (1) asserts that the economic loss is weighted by w, the probability that the consumer will notice that the good is actually of low quality. Note however that the processor obtains the price for the certified commodity no matter what the actual quality might be, because customers cannot assert a priori whether the claims made by the processor are false. In other words, processors will be trusted until proven wrong.

On the other hand, participation in the market for commodities yields a quasi-rent of $\pi^C = p^C = 0$. Because the market for the commodity is perfectly competitive, profits are zero. Note that profits in this case do not depend on w or $\delta\left(p^A\right)$. Here the processor is not asserting that his or her product is of high quality.

Factors Affecting Adoption of Quality Assurance Systems

In this section, we examine how fundamental characteristics of the economic environment influence decisions about the implementation of a QAS and the relative profitability of the competing markets or options. Clearly, a QAS will be observed if $\pi^A\left(s \middle| w, p^A\right) \geq \pi^C$ for some $s \in S$, that is, if

$$p^A - \left(1 - \lambda(s)\right) w \delta\left(p^A\right) - C(s) \geq 0 \text{ for some } s \in S. \tag{2}$$

Rearranging this equation, it is easy to see that effort in quality provision and assurance will be worthwhile only if $p^A - C(s) \geq \left(1 - \lambda(s)\right) w \delta\left(p^A\right)$. This inequality readily asserts that the easier it is for a processor to acquire information about quality (i.e., the cheaper it is to implement a QAS that yields a given level of certainty about quality), the more likely it is that a QAS will be implemented. A rising price premium also would increase the likelihood that there exists a profitable QAS, as long as the expected punishment for errors in certification does not grow too fast.[16]

Note also that $p^A - (1-\lambda(s))\delta w - C(s)$ is decreasing in both the function $\delta(p^A)$, and the parameter w. As the economic loss from incurring a type II error and/or being discovered increases, processors will be more reticent about assuring product quality to their customers (i.e., the premium needed will be higher, but see endnote 20), for any given imperfect certification system. This point can be easily demonstrated by partially differentiating equation (1) with respect to the parameter w and the function $\delta(p)$ as follows:

$$\frac{\partial\left\{p^A - (1-\lambda(s))w\delta(p^A) - C(s)\right\}}{\partial\delta(p^A)} = -(1-\lambda(s))w \le 0;$$

$$\frac{\partial\left\{p^A - (1-\lambda(s))w\delta(p^A) - C(s)\right\}}{\partial w} = -(1-\lambda(s))\delta(p^A) \le 0.$$

The preceding derivatives show that as long as the certifications system is imperfect $\left(\lambda(s) = 1 - F\left(q^M \middle| s\right) < 1\right)$, the profitability of participation in the market for quality-assured products is hindered by increased consumer awareness and the potential punishments for noncompliance.

Note that the price premium p^A is exogenous in this model. We are not making any statement about how the premium is maintained. In the long run, we presume that if the markets for assured high-quality products are profitable, entry would eventually occur until the premiums are dissipated. Hence, the current analysis would be valid only in the short run or if certifying firms have some way to prevent entry and/or control the quantity supplied. Although this limits the scope of the model, several agricultural and food industries for which the framework applies enjoy market power and/or real cost advantages.[17]

Optimal Choice of Quality Assurance System

As previously noted, the choice of the input processor is about the stringency of the QAS to implement (if any). We are assuming for mathematical convenience that there is a continuum of stringency levels from which to choose. The convexity of the set S frees us from worrying about problems of non-existence of solutions related to discontinuities. It also allows us to use the tools of calculus to analyze the problem. Conditional on the existence of some QAS for which (2) holds, the processor's profit-maximizing level of stringency is given by

$$s^*\left(w, p^A\right) = \arg\max_{s \in S} \left\{ p^A - \left(1 - \lambda(s)\right) w \delta\left(p^A\right) - C(s) \right\}.$$

Therefore, the profit-maximization problem faced by processors can be rewritten as

$$\pi^A\left(s \middle| w, p^A\right) = \underset{s \in S}{Max} \left\{ p^A - \left(1 - \lambda(s)\right) w \delta\left(p^A\right) - C(s) \right\},$$

which has first-order conditions given by

$$\frac{\partial \pi\left(s \middle| w, p^A\right)}{\partial s} = \frac{\partial \lambda(s^*)}{\partial s} w \delta\left(p^A\right) - \frac{\partial C(s^*)}{\partial s} \leq 0, \tag{3}$$

with equality if $s^* > 0$, assuming that the second-order conditions hold.[18] Equation (3) has the usual interpretation. It states that the level of stringency should be increased until the marginal benefits of increased stringency equal the marginal costs. The marginal benefit of an increase in s equals the change in the proportion of purchases that are of high quality multiplied by the expected loss from false certification. If the expected loss is low, either because the probability of being discovered is low or because of a low price premium, then the marginal benefit will be low. The marginal benefit of increased assurance rises as the quality of the good is more readily observable by the processor's customers, and as the potential punishments for false certification become more severe. The marginal cost of an increase in s is simply the increase in costs that must be incurred from implementing a more stringent QAS.

Equation (3) can be used to determine how the observability of quality and the size of the damage from noncompliance affect the optimal degree of assurance. Intuition suggests that both factors would lead to the implementation of more stringent assurance systems. The product of *w* and $\delta\left(p^{A}\right)$ is the expected loss from a type II error. As this expected loss increases, the optimal amount of quality assurance increases, as shown by the following comparative statics results:

$$\frac{\partial s^*\left(w,p^{A}\right)}{\partial w}=-\frac{\left[\dfrac{\partial\lambda\left(s^*\right)}{\partial s}\delta\left(p^{A}\right)\right]}{\left[\dfrac{\partial^{2}\lambda\left(s^*\right)}{\partial s^{2}}w\delta\left(p^{A}\right)-\dfrac{\partial^{2}C\left(s^*\right)}{\partial s^{2}}\right]}\geq 0 \tag{4}$$

$$\frac{\partial s^*\left(w,p^{A}\right)}{\partial\delta\left(p^{A}\right)}=-\frac{\left[\dfrac{\partial\lambda\left(s^*\right)}{\partial s}w\right]}{\left[\dfrac{\partial^{2}\lambda\left(s^*\right)}{\partial s^{2}}w\delta\left(p^{A}\right)-\dfrac{\partial^{2}C\left(s^*\right)}{\partial s^{2}}\right]}\geq 0\,. \tag{5}$$

The previous derivatives are signed assuming that second-order conditions hold. It is easy to see from equation (5) and the assumption $\partial\delta\left(p^{A}\right)/\partial p^{A}>0$ that changes in the price premium affects s in the same direction as does $\delta\left(p^{A}\right)$.

Equation (4) is similar in a sense to one of the results of Darby and Karni (1973). These authors argued that it is very likely (albeit not necessarily true) that as consumers become more knowledgeable, the optimal amount of fraud is reduced.[19] In our paper, firms would have incentives to reduce the number of mistakes they make as consumers become increasingly able to discern qualities (or become more informed).

There exists a key trade-off between the benefits and costs of information acquisition on the part of processors. Having a more precise QAS, though costly, decreases the probability that firms will lose consumers trust. On the other hand, as the expected losses derived from consumer distrust increase, it is more important for a processor to become better informed about actual quality. Since the size of the price premium is not dependent on the QAS in place in this model, all the benefits are driven by a reduction in the frequency of certification mistakes.

We have seen that both w and $\delta(p^A)$ have a negative impact on the profitability of production for the high-quality market for any imperfect QAS in place. Consider the case in which a public agency (if we give $\delta(p^A)$ a product liability interpretation) or the customers of the processor overestimate the real damage of noncompliance and punish accordingly. This reduces the incentives for processors to participate in the market for value-added goods, and in the extreme, it is possible that the market would disappear altogether. The point is valid only if the market functions for the correct determination of $\delta(p^A)$. Of course, underestimation of $\delta(p^A)$ also would have implications in this context: it would create incentives to underinvest in quality assurance, which would increase the amount of false certifications. Therefore, caution is warranted when determining the actual damage caused by a firm that wrongly certifies the quality of a good.

Albeit conceptually different, w and $\delta(p^A)$ have been shown to have identical effects on the profitability of processors and on their incentives to "learn" about the actual quality of the products they are certifying. Increases in w indicate that the processor's customers can more easily detect mistakes in certification. Therefore, processors expect to be punished more frequently for any given system in place, which reduces expected profits. Of course, if it is not possible for customers to detect incorrect certification $(w = 0)$, it is optimal for processors to certify their products without running any QAS.[20] We could argue that is hard to envision a situation in which w is exactly zero. Although not modeled here, several organizations (activists, for example [Feddersen and Gilligan 2001]) exist that act as important sources of information for consumers, pushing w away from the lower bound of its domain.

Case Studies

rbST-Free Milk

Recombinant bovine somatotropin (rbST) (also referred to as rbGH—recombinant bovine growth hormone) was introduced in the market in 1993 following its approval by the Food and Drug Administration (FDA). Manufactured by the Monsanto Company, rbST is a genetically engineered copy of a naturally occurring hormone produced by cows. Farmers use rbST to increase the productivity of their dairy herds.

Opposition to rbST arose from a number of perspectives. Some natural food companies opposed rbST because it was an artificial additive. In addition, some farm advocacy groups opposed rbST because they felt that a supply-increasing technology that perhaps could best be utilized by large dairy operations was the last thing that small dairy farmers needed. And some opposed rbST because it purportedly increased the incidence of mastitis.

The FDA does not require food products to be labeled when they contain milk produced by treated cows. However, in February 1994, the agency issued guidelines on voluntary labeling. Most states followed those guidelines, but other states, including Illinois, refused to permit any anti-rbST labeling. Given this prohibition, Ben & Jerry's Homemade, Organic Valley, Stonyfield Farm, and Whole Foods Market sued the State of Illinois and the City of Chicago. The 1997 legal settlement gave manufacturers of ice cream, yogurt, and other dairy products that use milk and cream produced without rbST the right to advertise that fact on their labels.

All organic dairy products are rbST-free because USDA national organic standards prohibit the use of rbST. Examples of organic companies that claim to sell rbST-free products are Good Heart Organics, Straus Family Creamery, and the organic line of products of Clover Stornetta. All dairy products made from sheep's milk or goat's milk are also rbST-free since the drug is not used with these animals. Dairy products from Canada, the European Union, New Zealand, and Australia are rbST-free, as these countries have not approved the use of this drug, although products have not used the rbST-free labels.

No test can distinguish rbST-free milk from milk obtained from rbST treated cows. Thus, companies that want to buy rbST-free milk must rely on information from suppliers about how their milk was produced. Ben & Jerry's ice cream company publishes a statement telling their consumers that they oppose the use of rbST. The company offers a premium to farmers who pledge that they do not use rbST. Stonyfield Farm offers cash premiums and contracts to self-certified suppliers of rbST-free milk, and its labels state "we oppose r-BGH." Green Mountain Blue Cheese uses its own milk to make its cheese, which it states is rbST-free. Promised Land Dairy and Smith Brothers Farm also use their own milk and state that they do not use the growth hormone. Wallaby Yogurt Company uses high-quality milk produced in the Sonoma and Marin counties of California, which, according to the milk's producers, does not contain the growth hormone. Westby Cooperative Creamery goes a step further and uses farmer-certified rbST-free milk. The certification consists of affidavits signed by the farmers stating that the growth hormone was not used. Once a year, a Wisconsin state inspector checks that the affidavits are in the folders of companies claiming certification. Joseph Farms was granted governmental approval to label its cheese "No Artificial Hormones." Another example of a company with certified rbST hormone-free products is Berkeley Farms. Clover Stornetta Farms has two lines of products, organic and non-organic. The non-organic product labels state "Our Philosophy on rbST: NO," and the company insists that dairies awarded the North Coast Excellence Certified designation do not use rbST. In response to pressure from several activist groups, including the Organic Consumer Association (OCA), in 2000, Starbucks Coffee Company started offering rbST-free organic milk as an option upon request. Starbucks stated that they would consider converting to these sources as long as it is financially feasible.

Thus, for rbST-free milk, the main purpose of the QAS seems to be to provide a means for companies to be able to proclaim that they are against rbST and that they would prefer to support farmers who do not use it. There does not seem to be a large consumer demand for a high degree of assurance that they are consuming rbST-free milk, perhaps because there is no discernable difference in the milk.

T.G.I. Friday's and Angus Beef

On July 16, 2001, T.G.I. Friday's began featuring source-verified all-natural Angus beef burgers in their U.S. casual dining restaurants. T.G.I. Friday's selected Meyer Natural Angus to supply its beef. Meyer Natural Angus chooses producers with herds that meet its criteria for genetic composition (≥ 50 percent Angus heritage) and whose management protocol is compatible with Meyer's program. These producers raise their animals in accordance with welfare standards for cattle set by the American Humane Association (AHA). Under Meyer's program, animals cannot receive subtherapeutic antibiotics, synthetic hormones, or synthetic growth promotants.

Producers who supply Meyer must sign a "Contract of Purchase of Livestock and Affidavit," which guarantees that the producer has met all the conditions that Meyer Natural Angus requires. Meyer personnel make site visits to inspect and test cattle and feed for chemical residues. In addition to their internal controls, AHA, USDA, and FDA monitor this source-verification system. All of the beef is processed at Meyer Foods, a custom food processing facility in Lincoln, Nebraska.

The site visits and legal contracts make T.G.I. Friday's Angus quality assurance program more stringent than the rbST programs. One justification for a greater degree of stringency may be that T.G.I. Friday's wants to enhance the dining experience of its customers by making sure that they eat only Angus hamburgers. Of course, this justification is valid only to the extent that there is a discernable difference between ground beef obtained from a steer with more than 50 percent Angus heritage and beef obtained from other sources.

Laura's Lean Beef

Laura's Lean Beef is a company that produces extra lean beef from cattle raised without the use of antibiotics or added growth hormones. The company's label states "Cattle raised without antibiotics. No growth hormones added." Only companies that raise their animals under a strict protocol regulated by the USDA are allowed to use this statement on their labels. Producers must sign a legal affidavit verifying that none of the cattle has ever received antibiotics or growth hormones. Cattle that must be treated with antibiotics for illness are removed from the program.

Laura's Lean Beef makes on-site visits and tests feed for antibiotics and pesticides as an additional quality control measure. Some of Laura's Lean Beef company's ground beef and ground round have the following statement on their labels: "Affidavit verified for at least 20 months before finishing." This is a USDA-approved statement verifying that no growth hormones have been administered for at least 20 months.

The QAS used by Laura's Lean Beef adds another layer of assurance to the system used by T.G.I. Friday's in that USDA-regulated protocols are followed to justify use of the phrases "Cattle raised without antibiotics" and "No growth hormones added."

Niman Ranch Pork

Niman Ranch attempts to offer its customers a superior eating experience by selling meat with superior taste, produced without antibiotics or hormones. In addition, animals must be raised following a strict code of husbandry standards set by the Animal Welfare Institute.

Niman Ranch controls taste by taste-testing pork from potential suppliers. Pork is tested for tenderness, flavor, color, and marbling. Those farmers who consistently supply pork with the characteristics Niman Ranch is looking for become qualified suppliers. Niman Ranch claims a complementarity between the taste of its pork and the fact that its suppliers must follow husbandry standards prescribed by the Animal Welfare Institute. Niman Ranch values pork with more back fat. Animals with more back fat are also better able to withstand the rigors of outdoor living on farms such as those in Iowa.

Farmers must sign a Quality Standard Affidavit guaranteeing that no antibiotics were used, no growth-promoting hormones have been given, animals were raised on pasture or deeply bedded pens, and no meat or meat by-products were used as feed. Verification of a farmer’s action is accomplished by unannounced visits by Niman Ranch inspectors who examine the production facilities of the farmer and obtain feed samples.

Niman Ranch has also begun a trace-back system that allows its loins to be traced back to each producing farmer. This is accomplished by placing an identification tag on each loin. The tag has a number that corresponds to the certified farmer who supplies Niman ranch.

The rudimentary trace-back system put into place by Niman Ranch is one step closer to a complete QAS. The trace-back system enhances Niman Ranch’s ability to control the taste of its pork. Farmers who supply loins that fail to meet certain taste standards are easy to identify, meaning Niman Ranch can determine both average quality and quality variability for each of its suppliers, thus allowing identification of the best suppliers.

Fast-Food Chains

Animal welfare activists have convinced McDonald's Corporation, Wendy's International, and Burger King Corporation to buy meat only from producers and packinghouses that follow certain animal welfare guidelines. These companies typically do not own, raise, or transport animals, but they are now committed to the humane treatment of animals. All three are large enough buyers of meat to force change in the meat production industry.

The three have adopted animal handling guidelines and have required suppliers to adhere to their strict standards. These guidelines are based on the animal welfare guidelines of the American Meat Institute (AMI) for pork and beef. To monitor, evaluate, and verify the proper animal handling among suppliers, these companies are using a comprehensive auditing program. This program consists of a minimum of two audits per year to the suppliers' establishments, both announced and unannounced. The inspections generally include review of housing, transportation, holding facilities, and humane slaughter procedures. The companies that fail to meet these strict guidelines are terminated as suppliers.

McDonald's, Burger King, and Wendy's also adopted recommendations issued by the Scientific Advisory Committee on Animal Welfare of the United Egg Producers (UEP). These guidelines are to ensure the proper treatment of laying hens used for egg production and include specifications for cage space per bird, forced molting, air quality, and beak trimming. An auditing program enforces the guidelines. The companies that do not comply with the recommendations are terminated as suppliers of Burger King and Wendy's (effective March 2002 and the third quarter of 2002, respectively). McDonald's implemented a purchasing preference policy to buy shell eggs from those suppliers that are able to meet the requirements, effective in late 2001.

By using their economic advantage to force change on their suppliers, the fast food industry is determining, de facto, the types of animal production systems that will exist in the United States. The industry benefits from the reduction in pressure put on them by animal welfare groups through organized boycotts and other campaigns. The cost of the changes may be borne mainly by the industry's suppliers and, ultimately, by all meat consumers. Avoiding adverse publicity seemingly is enough of an incentive for the industry to adopt the more stringent inspection system. In addition, McDonald's is beginning to enter into firmer vertical relationships with its suppliers to reduce the cost of verification.

Concluding Remarks

The examination of existing QASs reveals a great disparity in the "stringency" (and associated costs) of the systems employed. Producers of rbST-free milk products proclaim that they are using rbST-free milk based on assurances from their suppliers. T.G.I. Friday's buys Angus beef from a supplier who requires its producers to sign a contract that verifies heritage and husbandry practices. Laura's Lean Beef uses USDA protocols to define how it wants the cattle that it purchases raised. Niman Ranch has begun a trace-back system that allows it to better control the quality of its meat. And the fast food industry is using its financial influence to assure that its animal welfare requirements are being met.

Perhaps not surprisingly, the cost of the QAS, and its associated reliability, seems to be correlated with the expected losses that would result from false certification, as predicted by our model. Low costs (and low reliability) of assuring rbST milk makes sense when there really is nothing to lose because one cannot test for milk that comes from cows treated with rbST. More costs and reliability are borne when the taste of the product may depend on the product having the advertised traits, such as with the Angus beef in T.G.I. Friday's hamburgers. And even higher costs seem to be justified when a company exists solely to provide consumers with a product with particular attributes, such as Laura's Lean Beef being free of hormones and antibiotics. Finally, the QAS put in place by Niman Ranch is even costlier because it is meant to assure customers (mainly chefs in high-quality restaurants) that Niman Ranch products have consistently superior taste. The correlation between cost and benefits of QASs may illustrate that the private sector is flexible enough to put into place appropriate QASs, with just the right amount of assurance to meet consumer demand.

However, the motivation for the fast food companies to put in place QASs seems to be somewhat different than those of the other companies. Rather than using the QAS to differentiate their product, these companies seem to be trying to make sure that their products are not treated differently than that of their competition. That is, when one company decided to require that its suppliers use animal-friendly practices (in response to political pressure from People for the Ethical Treatment of Animals), then there existed an incentive for other companies to follow suit to avoid similar pressure.

Endnotes

1. Caswell, Bredahl, and Hooker (1998) provide an overview of the functions and effects of quality management systems (or metasystems as they call them) on the food industry. See also Henson and Hooker 2001.

2. These are the types of quality attributes that Nelson (1970) and Darby and Karni (1973) labeled as "experience" and "credence," respectively. The authors introduced the terms *search*, *experience*, and *credence* to refer to the moment in which consumers can gain information about product quality.

3. The quantity of Q is assumed to increase with the quality of the underlying input.

4. For this interpretation, we would need to reverse the claim that a larger Q represents a higher quality. Pathogen counts above q^M represent an unacceptable good.

5. Antle (2001) provides a literature review of the economics of food safety. Segerson (1999) discusses whether reliance on voluntary approaches to food safety will provide adequate levels of safety in a competitive framework that allows for consumers and firms to be imperfectly informed about potential damages. Marette, Bureau, and Gozlan (2000) explore the provision of product safety and possible public regulation for search, experience, and credence attributes when the supply sector competes imperfectly, and hence can use prices as signals.

6. See Blandford et al. 2002 for a classification of science-based definitions and measures of animal welfare.

7. Hayes and Lence (2002) provide the example of Parma Ham. They discuss that only ham produced within a certain region can be marketed as Parma Ham. The rationale for the restriction is that the weather in this region during the dry-curing process is what gives the ham its unique attributes. Nowadays, however, the dry-curing process is mainly carried on in modern, climate-controlled facilities.

8. There is a large literature showing that when certification is imperfect, some producers of low quality will apply and obtain certification. See De and Nabar 1991 and Mason and Sterbenz 1994.

9. Hennessy (1996) and Chalfant et al. (1999) showed that imperfect testing and grading lead to under-investment in quality-enhancing techniques by farmers. This is because producers of low quality impose an externality on producers of high quality.

10. Firms would be participating in only one market.

11. Type I errors may be due to imperfections on the QAS (for example, due to incorrect monitoring.). This would increase the costs of procuring the input the processor needs.

12. Note that we are being vague about what is being represented by this cost function. It could be modeling search costs, monitoring costs, or compensation given to farmers to induce high levels of effort.

13. This does not mean that their message to customers has to coincide with the assurance they get from the suppliers. For example, a restaurant that sources beef that is assured to be from a certain breed (e.g., Angus) may want to claim that the steaks they serve are tender. Another example would be a branded product. A customer of a well-known upscale restaurant expects to get a tender steak, and the restaurant will try to buy only beef it can certify to have been fed in a certain way or again from a certain breed.

14. Both views would lead us to believe that the $\delta\left(p^{A}\right)$ factor is related to such things as the price premium, frequency of purchases, and dissemination of information among consumers. These are some of the factors identified by Klein and Leffler (1981) as vital to ensuring contractual performance.

15. We could interpret the function $\delta\left(p^{A}\right)$, as the present value of the stream of premiums that the firm would obtain if it keeps its reputation, discounted by the relevant interest rate.

16. To see this, we take derivatives on both sides of the inequality, and after some rearranging we get $\frac{1}{\left(1-\lambda(s)\right)w} \geq \frac{\partial\delta\left(p^{A}\right)}{\partial\left(p^{A}\right)}$. Therefore, if the loss derived from mistakes in certification does not grow too fast, it is more likely that a profitable QAS exists. Note however, that this condition is neither necessary nor sufficient.

17. For example, production may require specific resources, skills, or technologies not widely available. Marketing orders may help to control quantities supplied (Babcock 2002). Hayes and Lence (2002) also discuss several forms in which supply control can be exercised without breaking price-fixing rules. For firms with real cost advantages, the QAS may be viewed as a device to deter entrance.

18. A sufficient condition for this to hold is that $\frac{\partial^2\lambda(s^*)}{\partial s^2} w\delta\left(p^{A}\right) \leq \frac{\partial^2 C(s^*)}{\partial s^2}$.

19. Note that in Darby and Karni's (1973) paper, supplying firms knew the actual quality of the product (repair services) they were offering.

20. Note that if $w = 0$, the profit function is strictly decreasing in s.

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