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Quality certification standards in competitive markets: When consumers and producers (dis)agree

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ABSTRACT

A quality certification standard in a competitive setting can improve welfare but may affect consumers and producers differently. In a competitive model with quality preferences of the vertical product differentiation type, we find that producers prefer a higher (lower) quality standard than consumers if individual demand functions are log-convex (log-concave).

1. Introduction

The introduction of quality standards, in a setting with asymmetric information about quality, can improve welfare by addressing the market failure discussed by Akerlof (1970), but may affect consumers and producers differently. An interesting way to look at the question, considered in Leland (1979) in the context of minimum quality standards (MQS), asks whether producers would choose a different standard than that set by a benevolent (and informed) government. In that model, producers actually would prefer a higher quality standard than the one that maximizes welfare, a result attributed to the producers' desire to exploit the possibility of increasing profit by lowering aggregate supply (i.e., a monopoly effect). But this setup is special in ways that do not always reflect the attributes of many real-world markets. Specifically, the assumed production "technology" is such that, if the MQS is increased, the aggregate output of goods that conform to this standard must decline.

To disentangle the separate impacts of higher quality standards from a mandatory reduction in output, in this article we analyze quality certification, as opposed to MQSs. The usual interpretation of an MQS is that qualities below the given level are not allowed on the market. Quality certification, on the other hand, is typically understood as allowing all quality levels on the market, provided they are properly labeled. Work on MQSs has primarily focused on imperfectly competitive industries (e.g., Ronnen, 1991). Here, by contrast, we study a quality certification standard in the somewhat neglected competitive setting, which is arguably relevant for a number of industries. In the agricultural and food sector, for instance, there is a long history of quality standards set by the government. Recent examples include the introduction of new organic food standards by the U.S. Department of Agriculture (USDA) in October 2002, and the new regulation for labeling genetically modified (GM) foods in the European Union in April 2004 (Lapan and Moschini, 2007).[1]

2. The model

We consider a partial equilibrium setting where the good of interest is supplied by a competitive industry and could conceivably be produced to have any set of quality levels $q \in [0,1]$. Consumers are heterogeneous with respect to their preference for quality, and the equilibrium is influenced by a quality standard exogenously set by a public authority.

2.1. Production

The aggregate (industry) cost of production is assumed to depend upon total industry output, X, as well as the amount produced of each

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[1] Note that, in both of these cases, producers can elect to comply or not comply with the standard, but products that do not meet the standard can still be sold as a lower quality good that competes directly with the higher-quality good to satisfy consumer demand.

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quality type. Thus, if X_i denotes the output of quality level q_i ($i=1,\ldots,n$), then total industry cost is represented as

$$\mathrm{TC} = \psi(X) + \sum_i c(q_i)X_i \tag{1}$$

where $X \equiv \sum_i X_i$. The quality-independent portion $\psi(X)$ of industry costs is assumed to be strictly increasing and strictly convex in total output X, that is, $\psi'(X)>0$ and $\psi''(X)>0$. Such increasing production costs may arise because a specific input used by the industry (e.g., land) has a rising supply curve. Given this specification, the supply price for any quality type is $p_s(q_i;X)=\psi'(X)+c(q_i)$, where the unit cost of quality $c(q)$ satisfies $c(0)=0$ and $c'(q)>0$, $\forall q\in(0,1]$. Hence, $(\psi')^{-1}(p)\equiv S(p)$ has the standard interpretation of an industry supply function and, given the assumed convexity of the industry cost function, $S'(p)>0$.

Because producing quality is costly, under the presumption that competitive firms cannot credibly signal higher quality, there is a pooling equilibrium with $q=0$. A quality certification standard in this setting is interpreted as a government-set quality limit $Q\in[0,1]$ so that only product with $q\geq Q$ can be sold as a "high-quality" good, and product with $q<Q$ can be sold as a "low-quality" good. Because the unit cost of quality $c(q)$ is strictly increasing in q, given a standard Q, firms that supply the high-quality good produce exactly $q=Q$, and firms that supply the low-quality good produce $q=0$.

2.2. Demand

Demand for the product of interest is generated by a population of heterogeneous consumers whose preference for quality is captured by an individual parameter $\theta\in[0,1]$, the distribution of which follows the continuous distribution function $G(\theta)$. We abstract from income effects by assuming that preferences are quasilinear, and write the utility function of the θ-type consumer as

$$U = y + u\left(\sum\nolimits_i x_i\right) + \sum\nolimits_i a\theta q_i x_i \tag{2}$$

where y is a composite (numeraire) good; x_i is the individual's consumption of the good of interest with quality $q_i\in[0,1]$; $u(\cdot)$ is a strictly increasing and strictly concave function; and $a>0$ is a parameter indexing the strength of consumers' preference for quality.

Preference for quality is thus assumed to be of the vertical product differentiation (VPD) form: all consumers agree on the ranking of qualities (and they would all buy the same quality if all qualities were offered at the same price). As in Mussa and Rosen (1978), utility is linear in θq. This implies, *inter alia*, that the marginal utility of quality is increasing in θ, that is, $\partial^2U/\partial\theta\partial q>0$ for all $(\theta,q)\in(0,1)\times(0,1)$ (this is the monotonicity assumption of Champsaur and Rochet (1989)). The specification in Eq. (2) also relaxes the common assumption of VPD preferences that the consumer purchases at most one unit of the product. Whereas such an assumption may be appropriate to capture the indivisibilities of demand for durables that are often the object of product differentiation studies, it is clearly unsuited for a host of other situations. Also, with the unit-demand specification of VPD preferences, some results critically depend on whether in equilibrium one has the case of a covered market (i.e., all consumers buy one unit of the product) or that of an uncovered market. Our specification allows us to eschew the awkwardness of keeping track of both such possibilities and instead captures the demand responsiveness of each individual with a continuous function.[2]

Because the quality certification standard induces exactly two qualities in this competitive market, the θ-type consumer in effect maximizes

$$u(x_H + x_L) - (p_H - a\theta q_H)x_H - (p_L - a\theta q_L)x_L \tag{3}$$

where x_H is the quantity of the high-quality good consumed, x_L is the quantity of the low-quality good consumed, q_H and q_L are the corresponding qualities of the two goods, and p_H and p_L are the consumer prices of the two qualities. Given this preference structure, the consumer of type θ will consume only x_H if $(p_H - a\theta q_H)<(p_L - a\theta q_L)$, consume only x_L if $(p_H - a\theta q_H)>(p_L - a\theta q_L)$, and be indifferent if $(p_H - a\theta q_H)=(p_L - a\theta q_L)$. For the structure of production articulated earlier, however, $q_H=Q$ and $q_L=0$. Furthermore, if p is the production (supply) price of the good with the lowest quality level, consumer prices p_L and p_H satisfy the competitive production and arbitrage conditions:

$$p_L = p \tag{4}$$

$$p_H = p + c(Q) \tag{5}$$

Hence, the consumers with type θ will consume only x_H if $\theta>\hat\theta$, will consume only x_L if $\theta<\hat\theta$, and will be indifferent if $\theta=\hat\theta$, where

$$\hat\theta \equiv \min\left\{\frac{c(Q)}{aQ}, 1\right\} \tag{6}$$

Recalling that $G(\theta)$ denotes the distribution function of consumer types, aggregate demand functions for the two qualities are

$$D_L(p,Q) = \int_0^{\hat\theta} x(p)\,\mathrm{d}G(\theta) \tag{7}$$

$$D_H(p,Q) = \int_{\hat\theta}^{1} x(\rho(\theta;p,Q))\,\mathrm{d}G(\theta) \tag{8}$$

where the individual demand function $x(\cdot)$ satisfies $x^{-1}(\cdot)=u'(\cdot)$, and

$$\rho(\theta;p,Q) \equiv p + c(Q) - a\theta Q \tag{9}$$

Thus $\rho(\theta;p,Q)$ can be thought of as a "personalized price," that is, the effective price (in terms of the numeraire good) born by the θ-type consumer for the good of quality Q. Note that the structure of the model is such that this personalized price decreases in θ.[3]

3. Equilibrium and welfare

The competitive equilibrium price p^* satisfies the market clearing condition

$$J \equiv S(p^*) - \int_0^{\hat\theta} x(p^*)\,\mathrm{d}G(\theta) - \int_{\hat\theta}^{1} x(\rho(\theta;p^*,Q))\,\mathrm{d}G(\theta) = 0 \tag{10}$$

Welfare in this partial equilibrium setting is given by the sum of producer surplus and consumer surplus. Let $\Pi(p)$ denote the aggregate profit (producer surplus) function so that, by Hotelling's lemma, $\Pi'(p)=S(p)$. Similarly, let $\phi(\cdot)$ denote the indirect utility function that

[2] We also note that our framework does not restrict the distribution $G(\theta)$ of consumer types (unlike many applications that rely on the unit-demand representation of VPD preferences, which typically assume that the distribution of consumers is uniform).

[3] Lapan and Moschini (2007) model preference for food as decreasing in the level of GM impurity. In that setting, the personalized price of the high-quality (i.e., non-GM) product is increasing in the consumer heterogeneity parameter.

is dual to the function $u(\cdot)$ of Eq. (2). Then the welfare function can be written as

$$W(Q;p) = \Pi(p) + \int_0^{\hat\theta} \phi(p)\mathrm{d}G(\theta) + \int_{\hat\theta}^1 \phi(\rho(\theta;p,Q))\mathrm{d}G(\theta) \tag{11}$$

If the quality certification standard is chosen to maximize this welfare function, the optimality condition for an interior solution $Q^*\in(0,1)$, given that the market equilibrium condition (10) holds,[4] is

$$\frac{\partial W}{\partial Q} = -\int_{\hat\theta^*}^1 x(\rho(\theta;p^*,Q^*))(c'(Q^*) - a\theta)\mathrm{d}G(\theta) = 0 \tag{12}$$

where $\hat\theta^* = c(Q^*)/aQ^*$, and where we have applied the fact that, by Roy's identity, $x(p) = -\phi'(p)$. Because $x(\cdot)>0$, to have an interior solution it is necessary that $(c'(Q^*) - a\theta)$ change sign in the interval $[\hat\theta,1]$, and that will depend on the properties of the cost function $c(q)$. As noted earlier, we assume that the cost of quality $c(q)$ is increasing in the quality level q. We also assume that it is convex. More specifically

Assumption 1. $c(0)=0$; $c'(0)\geq 0$; $c'(q)>0$ and $c''(q)>0, \forall q\in(0,1]$.

Given Assumption 1, $c'(q)>c(q)/q$ for all $q\in(0,1]$. For any $\hat\theta$ such that $\hat\theta\in(0,1)$ we have $\hat\theta \equiv c(Q)/aQ$, and thus for any $\hat\theta\in(0,1)$ it must be that $c'(Q)>a\hat\theta$. But if a is large enough,then $c'(Q)<a\theta$ in some part of the domain. More specifically

Assumption 2. $a>c'(1)$.

Under Assumptions 1 and 2, for any $q\in(0,1)$ we have $c(q)/aq< c'(q)/a<c'(1)/a<1$. Thus, for any quality standard $Q\in(0,1]$, we have $\hat\theta = c(Q)/(aQ)<1$. Also, let $\bar\theta = c'(Q)/a$. Then $\hat\theta<\bar\theta<1$ and $c'(Q)<a\theta$, $\forall\theta>\bar\theta$. Also, recalling the structure of the personalized price in Eq. (9), then $c'(Q) - a\theta = \partial\rho(\theta;p,Q)/\partial Q$, and thus the foregoing assumptions imply that as one increases the quality standard, the personalized price increases for $\hat\theta<\theta<\bar\theta$ (the comparatively lower value consumers) and the personalized price decreases for $\bar\theta<\theta\leq 1$ (the comparatively higher value consumers).

4. Comparative statics of equilibrium

How a marginal change in the standard Q impacts producer surplus depends directly on how it impacts the producer price (because producer surplus $\Pi(p)$ is monotonically increasing in price). From Eq. (10) we have $\partial p^*/\partial Q = -(\partial J/\partial Q)/(\partial J/\partial p)$. Because $\partial J/\partial p>0$ by the usual stability conditions (which here are satisfied because supply and demand functions have the usual slopes), the comparative statics of interest hinge on the sign of $\partial J/\partial Q$.

Differentiating the equilibrium condition yields

$$\frac{\partial J}{\partial Q} = -\int_{\hat\theta}^1 x'(\rho(\theta;p,Q))(c'(Q) - a\theta)\mathrm{d}G(\theta) \tag{13}$$

Evaluating $\partial J/\partial Q$ at Q^*, and using the optimality conditions for welfare maximization in Eq. (12), obtains

$$\left.\frac{\partial J}{\partial Q}\right|_{Q^*} = -\int_{\hat\theta^*}^1 x(\rho(\theta;p,Q^*))\left[\upsilon(\rho(\theta;p,Q^*)) + k\right](c'(Q^*) - a\theta)\mathrm{d}G(\theta) \tag{14}$$

[4] For a given Q, the competitive equilibrium price p^* minimizes the sum of producer and consumer surplus, so that, in particular, $(\partial W/\partial p)|_{p^*} = J = 0$.

where k is any scalar and where

$$\upsilon(\rho(\theta;p,Q)) \equiv \frac{x'(\rho(\theta;p,Q))}{x(\rho(\theta;p,Q))} \tag{15}$$

Note that, if $\upsilon(\rho(\theta;p,Q))$ is monotonic in its argument, then for an appropriate choice of the constant k we can sign unambiguously the integrand in Eq. (14). From Eq. (15) it is clear that $\upsilon(\rho(\theta;p,Q))$ is monotonically increasing (decreasing) in $\rho(\theta;p,Q)$ i.f.f. the demand function $x(\rho(\theta;p,Q))$ is log-convex (log-concave).

Let $k\equiv -\upsilon(p + c(Q^*) - a\bar\theta Q^*)>0$. Then, if $\upsilon(\rho(\theta;p,Q))$ is monotonically decreasing in the personalized price (and so monotonically increasing in θ), it follows that

$$\upsilon(\rho(\theta;p,Q^*)) + k \ \lesseqqgtr\ 0 \quad \text{as} \quad \theta \ \lesseqqgtr\ \bar\theta \tag{16}$$

whereas if $\upsilon(\rho(\theta;p,Q))$ is monotonically increasing in the personalized price (and so monotonically decreasing in θ), then

$$\upsilon(\rho(\theta;p,Q^*)) + k \ \gtreqqless\ 0 \quad \text{as} \quad \theta \ \lesseqqgtr\ \bar\theta \tag{17}$$

As noted earlier,

$$c'(Q^*) - a\theta \ \lesseqqgtr\ 0 \quad \text{as} \quad \theta \ \gtreqqless\ \bar\theta \tag{18}$$

Hence, if the consumer demand function $x(\rho(\theta;p,Q))$ is log-concave, then

$$\left.\frac{\partial J}{\partial Q}\right|_{Q^*} > 0 \Rightarrow \frac{\partial p^*}{\partial Q} < 0$$

whereas the opposite holds if the demand function is log-convex. The foregoing has therefore established our main result, which we summarize as follows.

Result 1. The quality standard that maximizes producer surplus is higher (lower) than the quality standard that maximizes aggregate consumer surplus if the demand function $x(\rho(\theta;p,Q))$ is log-convex (log-concave).

The choice of Q to maximize welfare in our setting reduces to maximizing consumer surplus for any given price p (and thus also for the competitive equilibrium price p^*). As Eq. (12) illustrates, the optimality condition for welfare maximization entails an optimal trade-off across consumers of the impact of a marginal change in Q on the personalized price. Specifically, the impact of the quality standard on individual prices is weighted by the individual demand levels $x(\rho(\theta;p,Q))$. By contrast, maximizing producer surplus is equivalent to maximizing total demand for any given price p, and a standard Q^0 that achieves that would require

$$\int_{\hat\theta^0}^1 x'\left(\rho\left(\theta;p^*,Q^0\right)\right)\left(c'\left(Q^0\right) - a\theta\right)\mathrm{d}G(\theta) = 0 \tag{19}$$

Thus, to maximize producer surplus the impact of a marginal change in Q on the individual price, $(c'(Q) - a\theta)$, is weighted by the responsiveness of demand (rather than quantity demanded). How the two weighting schemes differ, then, hinges upon how both demand and demand responsiveness change when the (individual) price changes, which is neatly summarized by the log-concavity (log-convexity) property of demand functions.

Of course, in the heterogeneous-preferences setting of our model, the aggregate consumer surplus measure is not sufficient for understanding the individual effects on different consumers that arise with the choice of a quality standard. Given the measure of the aggregate consumer surplus articulated by the welfare function in Eq. (11), we can summarize the individual impacts on consumers as follows.

Result 2. Around the level that maximizes welfare, an increase in the quality standard benefits high θ-type consumers and harms lower θ-type consumers who consume the high-quality good. The welfare impact on consumers of the low-quality good, on the other hand, depends solely on price (and thus it is qualitatively opposite to the producers' impact).

5. Conclusion

Quality standards, and associated labeling, are increasingly used in what are typically considered competitive markets. Food products perhaps provide the best example, including government standards for "organically" produced or "GM-free" goods. Even abstracting from asymmetric information issues (that have been the object of many studies), in this paper we have shown that consumers and producers are likely affected differently by the choice of a single standard. This result, of course, is not surprising. What our analysis adds to that generic recognition is a specific articulation of the conditions that determine whether producers prefer a stricter or looser standard than consumers. In particular, we have shown that a common presumption in applied settings—that competitive producers prefer laxer quality standards than consumers—need not hold. The condition that we have derived emphasizes the nature of demand, in particular the log-concavity (or log-convexity) of the individual demand functions. We note, in closing, that the log-concavity of demand has also been linked to comparative statics results in other problems, such as the monopolist pricing response to a demand expansion (Baldenius and Reichelstein, 2000) or the related problem of taxation pass-through for a monopoly firm (Amir et al., 2004).

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