AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

378.752
D34
W-90-26

MINIMUM QUALITY STANDARDS AND ASYMMETRIC INFORMATION

by

Robert G. Chambers

and

Michael D. Weiss

Department of Agricultural and Resource Economics
University of Maryland
College Park, Maryland 20742

Working Paper No. 90-26

September 1990

WAITE MEMORIAL BOOK COLLECTION
DEPT. OF AG. AND APPLIED ECONOMICS
1994 BUFORD AVE. - 232 COB
UNIVERSITY OF MINNESOTA
ST. PAUL, MN 55108 U.S.A.

378.752
D34
W-90-26

Minimum Quality Standards and Asymmetric Information

Gresham's Law has taught generations of economists the importance of symmetric information about product quality. The observation that "the bad drives out the good" implicitly assumes that individuals cannot perceive the good from the bad at the time of exchange. The literature on exchange under asymmetric information has forcefully highlighted Gresham's observation. In a classic paper, Akerlof showed that asymmetric information about product quality can lead to market collapse.

Product-quality arguments are frequently used by marketing-order proponents to justify the existence of minimum-quality standards. A typical argument runs something like this: minimum-quality standards improve the average quality of the product marketed; this higher average quality translates into a higher price; and, consequently, both producers and consumers gain (Jesse and Johnson). Bockstael has demonstrated that with symmetric information between producers and consumers about product quality this argument is false. To the contrary, minimum-quality standards make both producers and consumers worse off. An intuitive appreciation for this result might be grasped by recognizing that if information about product quality is symmetric then, absent other market failures, minimum-quality standards serve only to circumscribe the range of choices of both producers and consumers. Because the range of choices has gotten smaller welfare can also be expected to diminish.

This paper examines whether the Bockstael result is robust to the introduction of asymmetric information between sellers and consumers about product quality. Leland has shown that minimum-quality standards can improve upon competitive allocations under these circumstances. We show, however, that minimum-quality standards are <u>never</u> components of the constrained Pareto-optimal (i.e., the best feasible) policy if marginal cost varies positively with product quality (i.e., if quality is costly to produce). This result applies even when the efficient outcome under symmetric information dictates exclusion of certain ranges of product quality from the market.

The Model

Consider the market for an agricultural commodity, say, oranges where at the time of exchange asymmetric information exists between sellers and buyers about product quality. Sellers know product quality, consumers do not. Oranges, in effect, are an experience good. The logical difficulties associated with assuming that asymmetric information about a nondurable, repeatedly consumed product can persist for any extended period of time are put to the side. The reason for doing so is not a belief that consumers are irrational and cannot isolate the "bad" producers by repeat buying and avoid them. Instead the assumption is made because it is implicit in the typical arguments made to support minimum-quality standards by proponents of marketing orders. Because that argument presumes that one price prevails despite quality differences, either consumers observe quality but are irrational and pay a single price regardless of quality, or information is asymmetric at the time of purchase and consumers cannot directly observe quality. (Bockstael, in fact, makes the realization that symmetric information implies different prices for differing qualities the point of departure for her theoretical model.) To judge the argument for minimum-quality standards in its strongest possible logical fortification we, therefore, assume that information is asymmetric. Moreover, we also assume that because oranges must be consumed to determine product quality, quality is not verifiable to any third party (the government or the courts) responsible for enforcing contracts.

Sellers

Quality is indexed by the continuous variable q, as q increases so does quality. Each producer is only capable of producing a single quality of orange. A single producer cannot produce, for example, both good and bad oranges. The distribution of producer types is given by the strictly increasing, twice differentiable function H(q) which has support $Q = [q_a, q_b] \subset \mathbb{R}_+$. Assume without loss of generality that $H(q_a) = 0$ and $H(q_b) = 1$. h(q) represents the derivative of H(q).

The production of oranges of quality q is governed by the thrice-differentiable cost function c(y(q),q) where y(q) denotes the quantity of fruit of quality q produced. The cost function satisfies

(1)
$$c_1(y,q) > 0$$
$$c_2(y,q) > 0$$
$$c_{12}(y,q) \geq 0$$
$$c_{11}(y,q) > 0$$

Subscript i denotes partial derivative with respect to the ith argument of c. Hence, cost is strictly increasing and convex in quantity. Cost and marginal cost are both increasing in quality.

Consumers

For simplicity, assume that consumers are capable of being aggregated and that their valuation (in money terms) of oranges is additively separable in quality. (This assumption is made solely to simplify the calculations necessary for analysis. All of the qualitative results and, in particular, the results on the nonoptimality of minimum-quality standards extend to more general nonseparable cases.)[1] Consumer valuation of Y units of q-quality oranges is depicted by the twice-differentiable function v(Y,q). The valuation function is strictly increasing and concave in Y. In other words, marginal willingness to pay for quantity is positive but decreasing for each quality. Further, marginal willingness to pay for quantity is increasing in quality in the sense that v_{12} is nonnegative.

Net Social Benefits and Rotten Fruit

Net social benefits associated with producing the trajectory (schedule) {y(q)} is the difference between the consumer valuation of {y(q)} and the cost of production. Mathematically, net social benefits are measured by

$$(2) \qquad \int_Q v(h(q)y(q),q) - c(y(q),q)h(q)dq$$

The maximizing trajectory $\{\hat{y}(q)\}$ (2) can be obtained by pointwise maximization of (2). In what follows, we shall refer to $\{\hat{y}(q)\}$ as the *efficient outcome.* The efficient outcome can only be implemented if consumers can perceive product quality at the time of purchase. Hence, *under our assumptions the efficient outcome is not achievable.*

We assume that there exists a subinterval of Q, $Q_r = [q_a, q_r]$ for which fruit is of such low quality that $\hat{y}(q) = 0$, $q \in Q_r$. We refer to this assumption as the *rotten fruit* (RF) assumption and justify it formally by

$$(\text{RF}) \qquad v_1(0,q) - c_1(0,q) < 0 \qquad q \in Q_r.$$

In what follows, we shall show that even in spite of the presence of rotten-fruit, minimum-quality standards do not form a part of the constrained Paretian policy unless the constrained Paretian policy dictates that no fruit be consumed.

The Utility-Possibility (Constrained Paretian) Frontier

In formulating the mathematical program defining the utility-possibility frontier, i.e., the locus of constrained Pareto-optimal allocations, we rely on the *revelation principle* (Myerson). The revelation principle ensures that any equilibrium associated with the model can be implemented by a *truthful direct revelation mechanism.* In simpler terms, any solution to the constrained Paretian problem can be achieved by a mechanism which involves producers truthfully reporting their quality type to the government and then being assigned a payment and a quantity to be produced. Thus, without loss of generality the constrained Paretian problem can always be depicted as involving the specification of a menu of consumer payments to producers, which we represent as {t(q)}, and producer quantity levels, {y(q)}, both indexed by truthful revelation of q. Thus, the constrained Paretian (best feasible) outcome can be written:

$$(3) \qquad \max_{\{y(q)\}} \int_Q v(h(q)y(q),q) - t(q)h(q)dq$$

s.t.

$$\pi(q) \equiv \pi(q/q) \geq \pi(\hat{q}/q) \qquad \forall \quad q,\hat{q} \in Q$$

$$\pi(q) \geq r(q)$$

where $\pi(\hat{q}/q) \equiv t(\hat{q}) - c(y(\hat{q}),q).$

Here r(q) is the reservation value for a producer of type q. The second constraint in (3), therefore, represents the Paretian requirement that all producers be guaranteed their reservation value. With little loss of generality, in what follows assume that r(q) is identically equal to zero for all quality types. The first constraint in (3), which reflects the presence of asymmetric information, requires that the optimal policy corresponds to truthful revelation of quality types by producers in accordance with the revelation principle. Simply put it says that a producer's return from revealing his true q must dominate his return from reporting any other feasible $\hat{q}$ given the structure of the payment schedule, $\{t(q)\}$, to producers.

Model Analysis

Problem (3) is a mechanism-design problem of the type considered by Guesnerie and Laffont. Therefore, the results of Guesnerie and Laffont can be applied to problem (3). Following Guesnerie and Laffont and many others, our first result, which is a special case of Guesnerie and Laffont's Theorem 1, places restrictions on the trajectory, $\{y(q)\}$, which are required by truthtelling:

Result 1: If $\pi(q)$ and $y(q)$ are almost everywhere differentiable in the solution to (3), necessary and sufficient conditions for the first constraint in (3) to be satisfied are that $\pi'(q) = -c_2(y(q),q)$ and $y'(q) \leq 0$.

The best feasible solution thus must be characterized by the lowest quality producers producing the most fruit. Because low-quality producers have distinct cost advantages over higher quality producers, a mechanism which successfully segregates high from low-quality producers must have low-quality producers communicating their quality levels by producing quantities which a high-quality producer could not profitably achieve. In other words, scarcity signals quality.

Minimum-Quality Standards

Result 1, which must apply for any solution to (3), is central to establishing that the constrained Paretian solution cannot involve minimum-quality standards. Minimum-quality standards involve excluding a range of low-quality fruit from the market. In present terms, minimum-quality standards imply a subinterval of Q, $Q_m = [q_a, q_m]$ must exist for which $y(q) = 0$ if $q \in Q_m$. But Result 1 implies that the best achievable policy must obey $y'(q) \leq 0$. So if $y(q) = 0$ for $q \in Q_m$ then it follows immediately that

Corollary R1: If $\pi(q)$ and $y(q)$ are almost everywhere differentiable in the solution to (3), then the constrained Paretian solution involves, minimum-quality standards if and only if all qualities are excluded from the market.

It must be emphasized that Corollary R1 emerges *solely from the requirements for truthful revelation by producers*, i.e., from the presence of a symmetric information. As such it assumes nothing about consumer behavior, and in particular consumer valuation of oranges. Thus *the result is completely robust to different assumptions on consumer valuations.* The truthtelling requirements in (3) are a necessary consequence of designing feasible alternatives to accomodate the presence of asymmetric information (Myerson; Guesnerie and Laffont). Hence, the really critical assumption here is that marginal cost is increasing in quality. But this only presumes that quality is costly to provide. As long as this plausible requirement is met, minimum quality standards are not the best feasible approach.

More specifically, even given the presence of rotten fruit, minimum-quality standards are never constrained Pareto dominant. Even though the efficient outcome involves, in effect, minimum-quality standards the best achievable policy under asymmetric information cannot involve minimum-quality standards. This apparently paradoxical result emerges from the limitations that asymmetric information places on equilibrium outcomes. Because quality is both costly to produce and nonverifiable, a producer's quality must be reflected in the amount he or she chooses to produce. The only way for high-quality producers to be screened from low-quality producers is for them to signal their higher quality by lower production levels. This communicates to consumers that, because of their *higher quality*, these producers can make an acceptable return on a *lower quantity*. Invoking minimum-quality standards, therefore, removes the most effective signalling mechanism for the very highest quality producers. By producing a nonzero amount in the presence of minimum quality standards they effectively signal to the consumers that they are lower quality producers not deserving of the highest quality compensation. Therefore, even though RF requires deleting some qualities for efficiency, the best *achievable* outcome is only possible if some inefficient production on the part of producers in the interval Q_r is allowed.

Other Characteristics of the constrained Paretian policy

Following Guesnerie and Laffont, we can establish (see the Appendix for a proof):

Result 2: If $\pi(q)$ and $y(q)$ are almost everywhere differentiable in the solution to (3), then the following problem is equivalent to (3)

$$\max_{y(q)} \int_Q W(y(q),h(q),q)dq$$

$$\text{s.t.} \qquad y'(q) \leq 0$$

$$\pi(q_b) = 0$$

where

$$W(y(q),h(q),q) \equiv v(h(q)y(q),q) - c(y(q),q)h(q) - c_2(y(q),q)H(q)$$

As originally recognized by Mirrlees and later by Guesnerie and Laffont, the constrained Paretian problem in Result 2 is an autonomous control problem. (The main reason for assuming that consumer valuations are separable in qualities is to insure that the constrained Paretian problem could be treated as an autonomous control problem permitting the use of simple Hamiltonian methods. Under weaker assumptions more complicated variational methods could be used to analyze the constrained Paretian problem. However, similar qualitative results would emerge.)[2] Therefore, identifying $u \equiv y'(q)$ as the control and $y(q)$ as the state variable we can solve for the constrained

Paretian policy, which we denote by $\{y^*(q)\}$, by maximizing the Hamiltonian expression

(4) $$H(y(q),u,q) = W(y(q),h(q),q) + \lambda(q)u$$

subject to the constraint that u be nonpositive where $\lambda(q)$ is a co-state variable.

Before formally examining (4), however, it is useful to digress for a moment and to consider the $\{y(q)\}$ which maximizes W without constraint. To do so, first assume that W is strictly concave so that it will have an unique maximizer which we denote $\{\tilde{y}(q)\}$. It is then easy to establish (see Appendix):

Result 3: $\tilde{y}(q) \le \hat{y}(q)$ for all $q \in Q$. If RF applies a subinterval of Q, Q_W, must exist for which $\tilde{y}(q) = 0$ $q \in Q_w$, where $Q_r \le Q_w$.

Result 3 is yet another manifestation of the "rat-race" phenomenon. Because information is asymmetric the maximization problem defining the constrained Paretian solution has to incorporate informational constraints that are not present in the efficient-outcome maximization problem. By Result 1, these informational constraints can be reduced to an equality, $\pi'(q) = -c_2(y(q),q)$ (this emerges from the first-order condition for truthtelling), and an inequality, $y'(q) \le 0$ (this emerges from the second-order conditions). Integrating the equality gives

(5) $$\pi(q) = \pi(q_b) + \int_q^{q_b} c_2(y(\tilde{q}),\tilde{q})d\tilde{q}$$

Because quality is costly to provide in the sense that $c_2 > 0$, it follows immediately that $\pi(q) > \pi(q_b)$ if this constraint is to be satisfied. The reason this happens is that, absent symmetric information about product quality, all firms with qualities lower than q_b have the incentive to represent their oranges as quality-q_b oranges. Accordingly, they can generate economic rent from their superior information about quality. If they are to be induced to reveal this information they must be compensated (bribed) to do so. Their marginal rent from misrepresenting quality is measured by $\pi'(q)$. The least that they can be bribed (the least-cost or constrained Paretian solution to the information problem) to reveal this information is, therefore, given by the integral on the right of (5).

Because each additional unit of y(q) produced raises the marginal rent generated from the asymmetric information (recall marginal cost is increasing in quality), the constrained-solution must end with less (strictly no more) of all quality types of oranges produced than under the efficient outcome. This loss in fruit produced, in effect, is a quantity measure of the losses generated by the asymmetric information.

To incorporate the second constraint required to deal with the presence of asymmetric quality information in designing the constrained-Paretian solution, return to the Hamiltonian in (4). Applying the Pontryagin principle reveals that necessary and sufficient conditions are

(6) $$\lambda'(q) = -W_1(y(q),h(q),q)$$

$$u(q) = y'(q)$$

$$\lambda(q_a) = \lambda(q_b) = 0 \qquad \text{(transversality conditions)}$$

$$\lambda(q) \geq 0$$

$$\lambda(q)u(q) = 0$$

One can easily deduce from (6) (see Guesnerie and Laffont for a general discussion) that either $y^*(q) = \tilde{y}(q)$ or that $y^*(q)$ is a constant. A sufficient condition for $y^*(q) = \tilde{y}(q)$ in all cases is that the latter be nonincreasing in q for all $q \in Q$. Therefore, we can readily state the following Corollary

Corollary R3: If $\tilde{y}(q)$ is nonincreasing in q for all $q \in Q$, then $y^*(q) \le \hat{y}(q)$ for all $q \in Q$.

However,

$$\text{(7)} \qquad \tilde{y}'(q) = -\frac{(v_{11}\tilde{y}(q) + v_1 - c_1)h'(q) + [v_{12} - 2c_{12}]h(q) - c_{212}H(q)}{W_{11}(\tilde{y}(q),h(q),q)}$$

Because consumer valuation is strictly increasing in quantity, consumer marginal willingness to pay for quantity is increasing in quality, and no assumptions have been made about third-order partial derivatives of c and second derivatives of H, expression (7) is generally ambiguous. So, in the present context one should expect cases to emerge where the conditions of Corollary R3 are not met.

An easy way, to see why Corollary R3 will not generally hold is to impose RF. Then Corollary R3 can only apply if no fruit is supplied to the market. So if the efficient outcome dictates that certain low quality types be eliminated from the market, $y^*(q) = \tilde{y}(q)$ for all $q \in Q$ only if $\tilde{y}(q)$ is always zero. For if RF applies $\tilde{y}(q) = 0$ for all $q \in Q_r$. If there is to exist a q for which $\tilde{y}(q) > 0$ then $\tilde{y}'(q) > 0$ over some range. But this violates Result 1 so that $\tilde{y}(q)$ cannot be optimal.

Rotten Fruit and Constrained Paretian Solutions

From now on suppose that RF applies. In what follows, we shall consider several different profiles for $\tilde{y}(q)$ to illustrate some interesting exceptions to Corollary R3. (We make no claim of generality here. Other cases are certainly possible and plausible.) Figure 1 illustrates the case where $\tilde{y}(q)$ is strictly increasing for all $q \notin Q_W$. (For example suppose H(q) is uniform, $v_{12} > 2c_{12}$, and $c_{212} = 0$.) Because the constrained Paretian solution cannot correspond to $\tilde{y}(q)$ in this case, the constrained Paretian solution, if one exists, must have all producers produce the same quantity, call it y', regardless of quality. (Put in other terms all producers are *pooled.*) Using the Pontryagin conditions in (6) one obtains

$$\lambda(q) = -\int_{q_a}^{q} W_1(y(\xi),h(\xi),\xi)d\xi \geq 0 \tag{8}$$

with $\qquad y'(q)\,\lambda(q) = 0 \qquad$ for all $q \in Q$.

If y' is to be strictly positive, then from (8) and the transversality conditions

$$\int_Q W_1(y',h(q),q)dq = \int_Q [v_1(y',q) - c_1(y',q)]h(q) - c_{12}(y',q)H(q)dq = 0 \tag{9}$$

To understand the economic implications of (9), integrate the last term on the right after the first equality by parts to get (recall y' is constant)

$$-\int_Q c_{12}(y',q)H(q)dq = -c_1(y',q_b) + \int_Q c_1(y',q)dH(q)$$

whence (9) reduces to

$$\int_Q v_1(y',q)dH(q) = c_1(y',q_b)$$

In words, average marginal willingness to pay is equated to the marginal cost of producing y' by the highest cost (highest quality) producer. Because marginal cost is increasing in quality this ensures that all producers have the marginal incentive to produce at least y'. Moreover, orange producers of less than the highest quality generate profit equalling (recall $\pi(q_b) = 0$) their total cost advantage in producing the amount y', i.e., $c(y',q_b) - c(y',q)$.

Comparing this outcome with the efficient outcome reveals that the constrained Paretian solution, with the same quantity for all quality types, involves over production of the lower quality type of oranges relative to the efficient outcome and underproduction of the highest quality type of oranges relative to the efficient outcome.

Now suppose that $\tilde{y}(q)$ assumes the shape illustrated in Figure 2 where no oranges with quality $q \in Q_w$ are produced, production of oranges is increasing with quality over some range of Q, and then production of oranges falls with quality over the remainder of Q. The constrained Paretian solution then is given by production of a constant amount y″ for all quality levels in the interval $[q_a, q_c]$ where $y'' = \tilde{y}(q_c)$ and q_c is determined as the solution to

$$\int_{q_a}^{q_c} (v_1(y''h(q),q) - c_1(y'',q))h(q)dq = \int_{q_a}^{q_c} c_{21}(y'',q)H(q)dq.$$

Proceeding as before and integrating by parts reveals that q_c is chosen so that the marginal cost of producing $\tilde{y}(q_c)$ for a firm of type q_c equals the average marginal willingness to pay over the interval $[q_a, q]_c$.

After q_c the constrained Paretian solution corresponds to $\tilde{y}(q)$ for the remainder of quality types. As with the case where $\tilde{y}(q)$ was nondecreasing in q, the constrained Paretian solution involves overproduction of the lowest quality oranges and under production of the highest quality oranges relative to the efficient outcome. Again the intuitive reason for the inefficiently large production of the lowest quality types is the requirement for inducing truthful revelation of qualities. When RF applies this involves pooling the lowest quality producers with some producers not belonging to Q_W in order to ensure that the very lowest quality producers do not have the incentive to claim that they are higher quality producers when the fruit is exchanged.

Our final example illustrated in Figure 3 considers the case where $\{\tilde{y}(q)\}$ is multi-peaked. For the lower quality types the discussion surrounding Figure 2 continues to apply, the lowest quality types are pooled with some producers whose quality exceeds that of Q_w. But we also recognize that for the very highest quality types $\tilde{y}(q)$ does not satisfy the conditions imposed by truthful revelation. Therefore, the constrained Paretian solution will also involve pooling of the highest quality types with some lower quality types with all these producers producing y^o where $y^o = \tilde{y}(q_o)$ and q_o is determined by the solution to

$$(13) \qquad \int_{q_o}^{q_b} (v_1(y^0 h(q),q) - c_1(y^0,q))h(q)dq = \int_{q_o}^{q_b} c_{21}(y_0,q)H(q)dq.$$

Putting these results together we see that for Figure 3, the constrained Paretian solution involves pooling of the lowest quality types up to orange-type q_c at quantity $\tilde{y}(q_c)$, individuals in the intermediate range produce $\tilde{y}(q)$, and pooling of orange producers of quality higher than q_o at $\tilde{y}(q_o)$. Comparing these results with the efficient outcome, it follows that the constrained Paretian solution again exhibits over production of the lowest quality types, under production of intermediate to higher quality types, and potentially (this is the case illustrated) over production of the very highest quality types.

Each of these case studies has revealed that a central implication of RF is

Result 4: Suppose RF: the constrained Paretian solution always involves pooling of all producers $q \in Q_w$ with producers of higher quality at a level of production which involves over production, relative to the efficient outcome, for some subset (not necessarily restricted to Q_w) of the pooled producers.

Concluding Remarks

This paper has examined the relative efficiency of minimum-quality standards in markets where asymmetric information about product quality exists. The main result is that if marginal cost of producing output is increasing in quality minimum-quality standards are only components of the constrained Paretian policy if the constrained Paretian policy dictates that no fruit be provided to the market. This result even applies in the case where the economically efficient outcome under symmetric information would require that fruit of the lowest quality not be exchanged. Moreover, the result is very robust and applies for any assumption about consumer valuations because it arises out of the requirements for implementability of the constrained Paretian policy. The paper also characterizes the constrained Paretian policy under a range of assumptions about producers and consumers. If RF applies, then the lowest quality producers will always be pooled with higher quality producers and the lowest quality producers will overproduce relative to the efficient (but not achievable) outcome.

Footnotes

[1] Both Akerlof and Leland presume that consumer valuation depends on the average quality marketed. In the present context this would imply the existence of a valuation function, call it v*, such that

$$v^* = v^*\left(\int_Q w(q)\ q\ dq\right)$$

where $w(q) = y(q)\ h(q)/\int_Q y(q)\ d\ H(q)$.

[2] In the case where consumer valuation depends only on average quality marketed the appropriate problem is

$$\max_{y(q)} v^*\left(\int_Q w(q)\ q\ dq\right) - \int_Q c(y(q),q)\ h(q) + c_2(y(q),q)\ H(q)\ dq$$

subject to the same constraints as in Result 2. This problem is a variational problem which can be handled by variational methods. However, the nonseparability of v* makes it illegitimate to apply Pontryagin's condition here.

Appendix

Proof of Result 2: From Result 1 $\pi'(q) = -c_2(y(q),q)$ so that integrating gives

$$\pi(q_b) - \pi(q) = -\int_q^{q_b} c_2(y(\tilde{q}),\tilde{q})d\tilde{q}.$$

Now by assumption and Result 1 $\pi'(q) < 0$ so that $\pi(q_b) < \pi(q)$ for $q < q_b$. Using the definition of $\pi(q)$ in (3) gives

$$t(q) = \pi(q) + c(y(q),q)$$

which with the above implies

$$t(q) = \pi(q_b) + \int_q^{q_b} c_2(y(\tilde{q}),\tilde{q})d\tilde{q} + c(y(q),q)$$

Substitute this into the objective function in (3)

$$\int_Q v(h(q)y(q),q) - c(y(q),q)h(q)dq - \int_Q \int_q^{q_b} c_2(y(\tilde{q}),\tilde{q})d\tilde{q}\ dH(q).$$

$$- \pi(q_b).$$

By Fubini's theorem the last integral can be rewritten

$$\int_Q c_2(y(q),q)H(q)dq.$$

Because the objective function is strictly decreasing in $\pi(q_b)$ set $\pi(q_b)$ equal to its lower bound which is zero which with the second part of Result 1 establishes the result.

Proof of Result 3: $\tilde{y}(q)$ is the solution to the first-order condition

$$[v_1(h(q)y(q),q) - c_1(y(q),q)]h(q) = c_{21}(y(q),q)H(q)$$

while $\hat{y}(q)$ solves

$$v_1(h(q)y(q),q) - c_1(y(q),q) = 0.$$

Because $c_{21} \geq 0$ we have

$$v_1(h(q)\tilde{y}(q),q) - c_1(\tilde{y}(q),q) \geq v_1(h(q)\hat{y}(q),q) - c_1(\hat{y}(q),q).$$

The strict concavity of v - c then implies the result.

References

Akerlof, G. "The Market for Lemons: Qualitative Uncertainty and the Market Mechanism," Quarterly Journal of Economics 84(1970):488-500.

Bockstael, N. "The Welfare Implications of Minimum Quality Standards," American Journal of Agricultural Economics 66(1984):466-471.

Guesnerie, R. and J.-J. Laffont. "A Complete Solution to a Class of Principal Agent Problems with an Application to the Control of a Self Managed Firm," Journal of Public Economics 25(1984):329-70.

Jesse, E.V. and A.C. Johnson. "Effectiveness of Federal Marketing Orders for Fruits and Vegetables," Washington, D.C.: U.S. Department of Agriculture, ESCS Technical Bulletin No. 1608, July 1979.

Leland, H.E. "Quacks, Lemons and Licensing: A Theory of Minimum Quality Standards," Journal of Political Economy 87(1979):1328-46.

Myerson, R.B. "Optimal Auction Design," Mathematics of Operation Research 6(1) (1981):58-73.

Washington D.C. U.S. Department of Agriculture, ESS Agr. Econ. Rep. #471, June 1981.

minqual.chi/dw/11-16-90

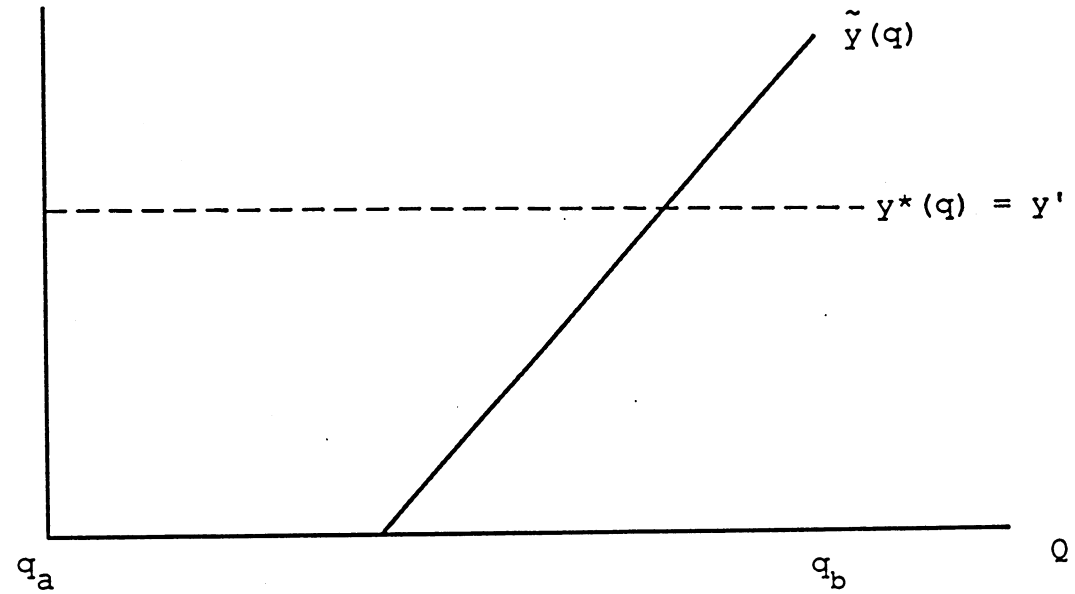

Figure 1

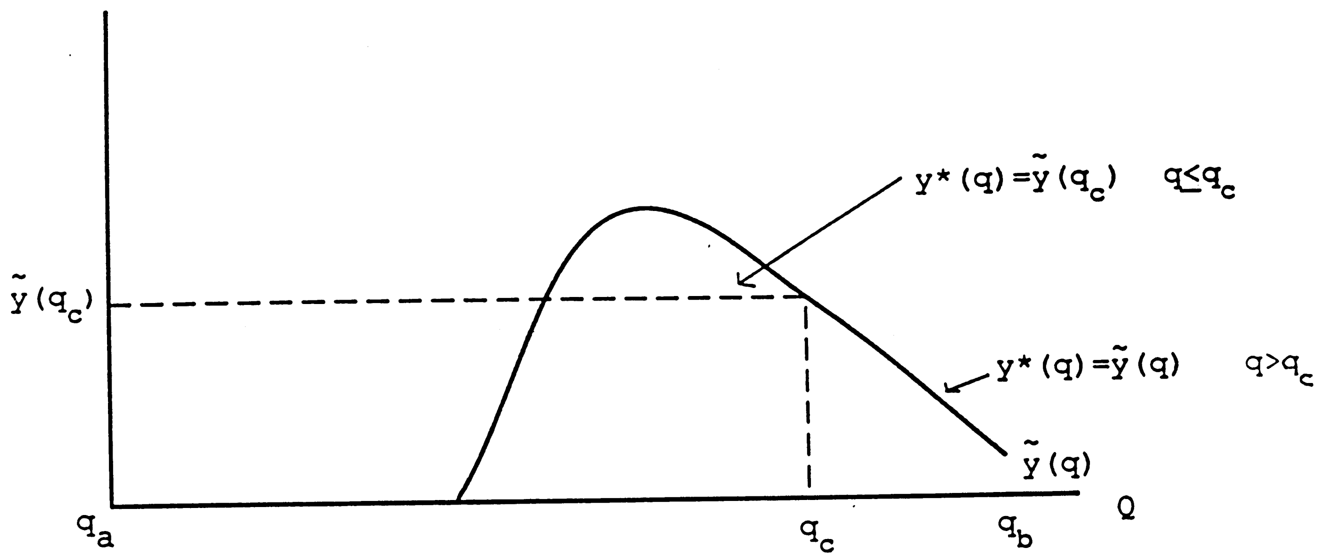
$y^*(q) = \tilde{y}(q_c) \quad q \le q_c$
$\tilde{y}(q_c)$
$y^*(q) = \tilde{y}(q) \quad q > q_c$
$\tilde{y}(q)$
Q
q_a
q_c
q_b

Figure 2

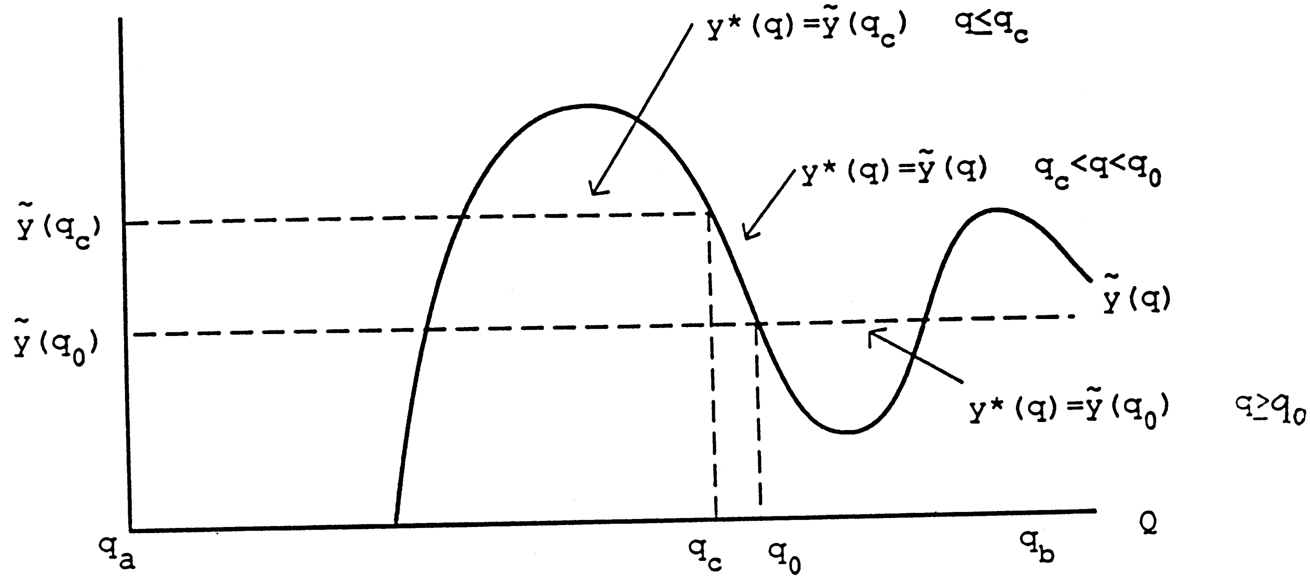

Figure 3