Quality Choice in a Product Market

by

John Spriggs*

Contributed paper

American Agricultural Economics Association Meetings

Pullman, Washington

July, 1979

* Assistant Professor, Purdue University, W. Lafayette, Indiana

Quality Choice in a Product Market

The benefits and costs of grading agricultural commodities have been frequently addressed (e.g., Mehren, 1961). Grading facilitates transactions between buyers and sellers. Substantial savings from grading may be realized because buyer inspection of individual lots is unnecessary. Further, standardization reduces uncertainty between buyers and sellers and this helps reduce marketing costs. If the important quality attributes can be identified and the product standardized on these attributes, then there is a meaningful basis for grading. Of course, grading is not costless and there is the question of whether the gains from grading justify the added cost. But, suppose for a given commodity that grading is economically justified, there is still the question of optimal grading. When the commodity's grade bounds are not optimal there is a welfare loss to society. The purpose of this note is to develop a simple method for measuring the welfare loss from sub-optimal grading with respect to a single quality characteristic.

One of the earlier theoretical contributions on optimal grading was by Dorfman and Steiner (1954). They used marginal analysis to determine the optimal level of product quality for a firm selling a differentiated product. More recent theoretical contributions have analyzed optimal quality levels or grade bounds for a standardized product at the market level. Zusman (1967) was concerned to find the optimal grade-bounds for a given stock of commodity containing various quality levels. Rosen (1974) extended Zusman's work, finding the optimal levels of quality characteristics in a product where the stock of commodity is <u>not</u> assumed given. That is, price-quality tradeoffs were permitted to feedback to the supply side. He used a partial equilibrium model of quality choice to study a single commodity market.

The approach taken in this note is based on Rosen's theoretical model of quality choice and uses the familiar concepts of producer and consumer surplus. For illustration, this approach is applied to the U.S. corn export market.

The Method

Rosen's model applies to a class of products which can be described by a vector of n objectively measured characteristics, $z = (z_1, \ldots, z_n)$. Products in the class are completely described by numerical values of z.

For simplicity, assume only a single characteristic, z_1, is variable. Therefore, z_1 represents an unambiguous measure of quality. In order to measure the welfare effects of quality choice it is necessary to develop the market demand and supply curves incorporating the quality variable.

On the supply side each producer is assumed to maximize profit $\pi = q_S \cdot P(z) - C(q_S, z)$ by choosing q_S (quantity supplied) and z_1 optimally. P represents product price while C represents cost of production. The cost function is assumed to be of the form

$$C(q_S, z) = s(q_S | \bar{z}_1) + c(z_1) \cdot q_S$$

where $c(z_1) = \int_{\bar{z}_1}^{z_1} c'(z_1)dz$, and $\bar{z}_1$ is any given level of z_1. The first-order conditions for optimality are

$$P(z_1) = s'(q_S | \bar{z}_1) + c(z_1) \qquad \ldots. (1)$$

and,

$$c'(z_1) = {}^{\partial P}/\partial z_1 \qquad \ldots. (2)$$

Equation (1) is the individual producer's supply curve where $c(z_1)$ is a supply shifter. As a result, P may be replaced by P_S to denote supply price. Equation (2) requires that the producer's marginal cost of z_1 equal the marginal change in product price at the optimum. Assume that all producers have identical $c'(z_1)$ functions. Then, aggregating over producers

$$P_S = S(Q|\bar{z}_1) + c(z_1) \qquad \text{....(3)}$$

where Q denotes market quantity.

On the demand side, each consumer is assumed to maximize utility $u = u(X, q_D, z)$ subject to the income constraint $y = x + q_D \cdot P(z)$. The term q_D refers to the units of product consumed while x refers to all other goods consumed with price set equal to unity. The utility function is assumed to be of the form

$$u(x, q_D, z) = x + w \cdot (q_D|\bar{z}_1) + v(z_1) \cdot q_D$$

where $v(z_1) = \int_{\bar{z}_1}^{z_1} v'(z_1) \cdot dz_1$. The first-order conditions for optimality are

$$P = w'(q_D|\bar{z}_1) + v(z_1) \qquad \text{....(4)}$$

and

$$v'(z_1) = {}^{\partial P}/\partial z_1. \qquad \text{....(5)}$$

In equation (4), $w'(q_D)$ represents the marginal value of q_D. This equation is the individual consumer's demand curve where $v(z_1)$ is a demand shifter. As a result, P may be replaced by P_D to denote demand price. Equation (5) requires that the consumer's marginal value of z_1 [$v'(z_1)$] equal the marginal change in price at the optimum. Assume all consumers have identical $v'(z_1)$ functions. Then, aggregating over consumers

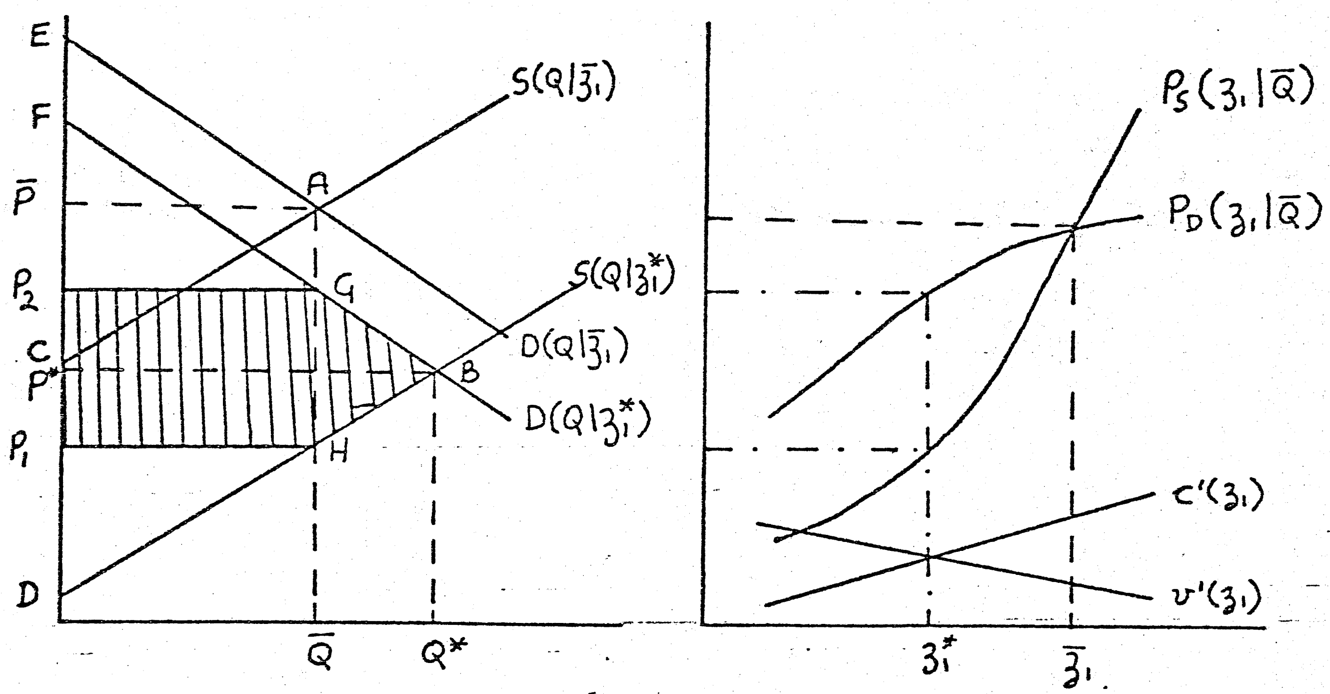
$$P_D = D\ (Q|\bar{z}_1) + v(z_1) \qquad \text{....(6)}$$

Equilibrium in the quantity market may be obtained for any given level of z_1 by invoking the condition $P_S = P_D$ and solving equations (3) and (4) simultaneously.

The equilibrium can be described graphically as in Figure 1. In panel (a), $S(Q|\bar{z}_1)$ and $D(Q|\bar{z}_1)$ are respectively the supply and demand curves when $z_1 = \bar{z}_1$. The equilibrium price and quantity are respectively $\bar{P}$ and $\bar{Q}$. In panel (b) curves $P_S(z_1)$ and $P_D(z_1)$ show the supply price and demand price,respectively for various levels of z_1, given $Q = \bar{Q}$. The slopes of $P_S(z_1)$ and $P_D(z_1)$ at any given level of z_1 equal $c'(z_1)$ and $v'(z_1)$, respectively.

The optimal level of z_1 is obtained when $c'(z_1) = v'(z_1)$, that is, when $z_1 = z_1*$. The equilibrium at price $\bar{P}$ and quantity $\bar{Q}$ is not optimal since $z_1 = \bar{z}_1 \neq z_1*$.

(Figure 1)



E
F
P̄
P2
C
P*
P1
D
A
G
B
H
S(Q|z̄1)
S(Q|z1*)
D(Q|z̄1)
D(Q|z1*)
Q̄
Q*
PS(z1|Q̄)
PD(z1|Q̄)
c'(z1)
v'(z1)
z1*
z̄1

Figure 1

Figure 1 may be used to trace through the effects on market equilibrium of moving from quality level $\bar{z}_1$ to z_1*. Curve $P_S(z_1|\bar{Q})$ indicates that producers are prepared to supply quantity $\bar{Q}$ at $z_1 = z_1$* for a price P_1. Hence, in panel (a) the supply curve $S(Q|z_1^*)$ will pass through the point $P_1\bar{Q}$. Since the quality cost function $[c(z_1)]$ only enters the intercept of the supply function (equation (3)) the new supply function $S(Q|z_1^*)$ will be vertically parallel to $S(Q|\bar{z}_1)$. Similarly, curve $P_D(z_1|\bar{Q})$ indicates that consumers are prepared to pay P_2 for quantity $\bar{Q}$ at $z_1 = z_1$* level of quality. Hence, in panel (a) the demand curve $D(Q|z_1^*)$ will pass through the point $P_2\bar{Q}$. Since the quality value function, $v(z_1)$ only enters the intercept of the demand function (equation (6)), $D(Q|z_1^*)$ will be vertically parallel to $D(Q|\bar{z}_1)$. The new equilibrium is obtained at the intersection of $S(Q|z_1^*)$ and $D(Q|z_1^*)$, that is point P*Q*.

There is a welfare gain in moving from the sub-optimal level of quality, $\bar{z}_1$, to the optimal level. Using the concepts of producer and consumer surplus the welfare gain is measured by the shaded area in Figure 1. This is readily seen in the following. At the initial price-quantity equilibrium $(\bar{P}, \bar{Q})$, producer plus consumer surplus,

$$SW = \text{area } EA\bar{P} + \text{area } \bar{P}AC$$

$$= \text{area } FGP_2 + \text{area } P_1HD$$

At the new price-quantity equilibrium (P*Q*),

$$SW = \text{area } P^*BF + \text{area } P^*BD$$

$$\text{The change in } SW = (\text{area } P^*BF - \text{area } FGP_2) + (\text{area } P^*BD - \text{area } P_1HD)$$

$$= \text{area } P^*BGP_2 + \text{area } P^*BHP_1$$

An Illustrative Example

To show how the graphical model may be used to analyze the welfare effects of sub-optimal quality choice consider the export market for U.S. corn. Grading is particularly important in this market. The large orders typical of this market make buyer inspection of individual lots quite unattractive. Substantial savings are realized in transportation and handling costs through bulk shipment of a standardized product. A particular benefit is not having to preserve the identity of shipments. The seller gains through the ability to commingle various lots and to interchange shipments.

Corn exported from this country is subject to federal inspection and grading. Corn is graded according to five physical characteristics: test weight, broken corn, and foreign material (BCFM), moisture content, heat damage to kernels and total damage to kernels. Of these the most easily adjusted is BCFM. It involves a very low cost to change the level of BCFM provided this is accomplished during loading or unloading (Schrader and Lang, p. 10). Exports are almost all 3 yellow corn which stipulates a maximum of 4 percent BCFM.[1/] Unlike the domestic market, discounts typically do not apply to export corn. It is sold at the base grade. About 85 percent of all exports is used for livestock feed. The remainder is used in industry by starchers and distillers.

Before analyzing the welfare effects of sub-optimal grading one should first address the question of why the market does not automatically adjust to the optimal quality level. The reason is that any change in quality

---

[1/] Export grade differs from 3 yellow corn with respect to moisture content. The export grade has a maximum 15.5 percent moisture, while no. 3 grade has a maximum 17.5 percent moisture.

by an individual seller from the base grade would involve significant added costs in the need to preserve the identity of shipments. These costs would very likely exceed any gains to the buyer and seller making movements away from the base grade unattractive on an individual basis.[2/] If, however, the whole market moved to a new (optimal) quality level, the base grade would change and again shipments would not need to be identity-preserved.

An attempt is made to generate data for this problem which roughly approximate the real-world situation. However, no claim can be made for the empirical accuracy of the data. They are only to illustrate the method developed and to indicate the type of data required. The data required include estimates of the excess supply (ES) and export demand (ED) curves and estimates of the marginal cost and marginal value of quality curves [$c'(z_1)$ and $v'(z_1)$].

The estimated ES and ED curves for corn facing the U.S. are

$$ES = -.835 + .931P$$

$$ED = 5.024 - 1.247P$$

where ES and ED are measured in billion bushels and P is measured in dollars per bushel. These curves assume the elasticities of ES and ED are respectively 1.5 and -2 and equilibrium price and quantity are respectively \$2.69 and 1.67 billion bushels (average export value and export volume for 1976/77). Presently the export market consists of corn with a maximum BCFM content of 4 percent. Since there is no economic advantage to be had from exporting corn with less than 4 percent BCFM, the ES and ED curves assume $z_1 = 4$.

2/ Waxy maize is a notable exception. Small amounts of this special quality corn are exported in identity-preserved shipments.

The marginal cost of a percent change in BCFM is estimated as follows. The supply price of corn at different levels of BCFM content is assumed to be given by

$$P_S(z_1|Q) = \frac{(100-z_1)p}{100} + \frac{z_1 \cdot m \cdot p}{100}$$

where

z_1 = quality index (percent BCFM in the corn),

p = theoretical price of corn containing zero BCFM,[3/]

m = market value of screenings as a proportion of p.

The cost of blending or cleaning is assumed to be negligible over the relevant range and so is omitted from this cost function. The marginal cost of a percent decrease in BCFM is given by $c'(z_1) = p(1-m)$. The value for m is assumed to be .7. This compares with a figure of .75 in a recent study which expresses the market value of screenings as a proportion of the market value of 2 yellow corn (Schrader and Lang, 1978).

The value of p is estimated from the equation for $P_S(z_1|Q)$ where $z_1 = 4$ and P_S = \$2.69. (This is the current market situation.) Thus, p = \$2.723 and $c'(z_1)$ = \$.008/bu.

The marginal value of a percent change in BCFM is somewhat more difficult to estimate because users are clearly not homogeneous with respect to their attitude to BCFM. In particular, starchers and distillers are much more sensitive to the level of BCFM in the corn than are livestock feeders. However, livestock feed is by far the most important export market for U.S. corn (taking 85 percent of all exports). Hence, a single $v'(z_1)$ function is estimated with the idea of incorporating the collective attitude of livestock feeders toward BCFM.

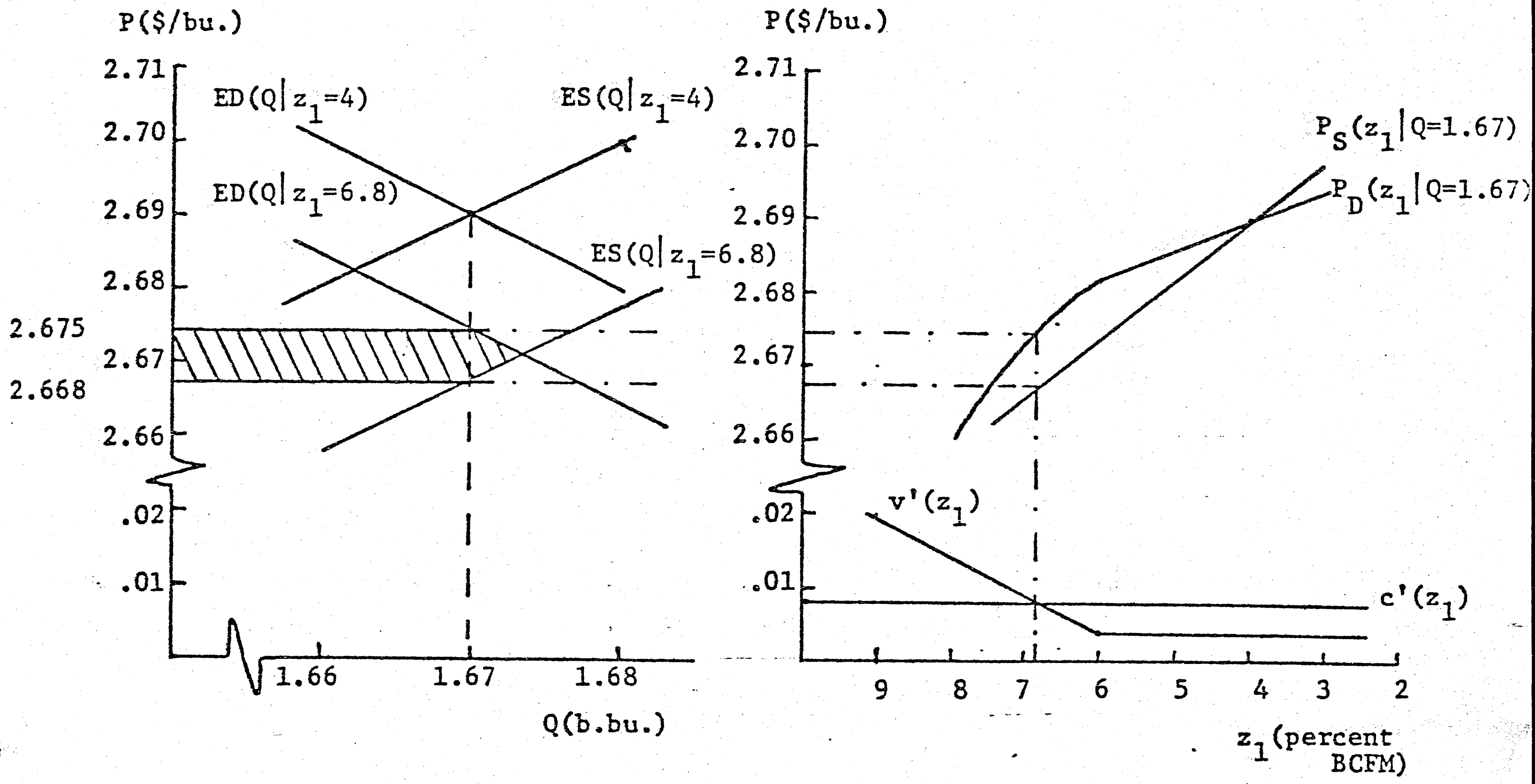
In general, livestock feeders are insensitive to levels of BCFM provided they are not so high as to risk molding. This is because the

3/ There is no market for corn with zero BCFM. The theoretical price is estimated below.

feeding value of broken corn is not much lower than whole kernels. The corn is usually milled anyway along with other feedstuffs so that the corn looses its separate identity.[4/] To reflect the insensitivity of livestock feeders over a range of BCFM levels $v'(z_1)$ is given a low value of $.004 per bushel over that range. Corn containing higher levels of BCFM are more susceptible to storage fungi which lower the feeding value of corn (Anderson, p. 155). To offset this higher risk at higher levels of BCFM a price discount would be required. For purposes of the example, assume the segment of the $v'(z_1)$ curve reflecting this discount is given by a linear curve with slope -.005. Finally, the critical level of BCFM at which the price discount begins to be effective is assumed to be 6 percent.

Figure 2 shows the model as developed for the corn export market. In panel (a) the ES and ED curves are drawn for $z_1 = 4$, the current level of BCFM in export corn. Panel (b) shows the $c'(z_1)$ and $v'(z_1)$ curves. Given the market price of $2.69 per bushel for corn with $z_1 = 4$ the corresponding $P_S(z_1)$ and $P_D(z_1)$ curves are drawn. Since $c'(z_1) \neq v'(z_1)$ when $z_1 = 4$, the optimal level of z_1 is not 4. Rather, the optimal level of BCFM is 6.8 percent. At this quality level the supply price is found to be $2.668 (from $P_S(z_1)$) and the demand price is found to be $2.675 (from $P_{D1}(z_1)$). In accordance with the assumed utility and cost functions the ED curve in panel (a) shifts down in a parallel fashion to $ED(Q|z_1 = 6.8)$ which passes through the point (P = 2.668, Q = 1.67). Similarly, the ES curve shifts down in a parallel fashion to ES $(Q|z_1 =$

4/ In countries like Italy where whole grain feeding is still carried out on a large scale, corn buyers tend to be more sensitive to the level of BCFM.



P($/bu.)
2.71
2.70
2.69
2.68
2.675
2.67
2.668
2.66
.02
.01
ED(Q|z1=4)
ES(Q|z1=4)
ED(Q|z1=6.8)
ES(Q|z1=6.8)
1.66
1.67
1.68
Q(b.bu.)
P($/bu.)
2.71
2.70
2.69
2.68
2.67
2.66
.02
.01
PS(z1|Q=1.67)
PD(z1|Q=1.67)
v'(z1)
c'(z1)
9
8
7
6
5
4
3
2
z1(percent BCFM)

Figure 2

6.8) which passes through the point (P = 2.675, Q = 1.67). The new equilibrium is found at (P = 2.672, Q = 1.673). The increase in social welfare as measured by the change in consumer plus producer surplus is shown in Figure 2 (a) as the cross-hatched area. It amounts to $11.7 million.

Conclusion

This note has developed a simple practical approach to measuring the effects on social welfare of sub-optimal grading. The method may be useful in markets where a single quality characteristic is open to variation, and where market forces are inadequate to ensure optimal quality levels. The method was applied to such a market: the U.S. corn export market. In this market the level of broken corn and foreign material is open to variation. In addition, the market is characterized by forces tending to favor the status quo in the choice of quality levels to be offered. Since the market cannot be relied upon to ensure an optimal quality choice some non-market method is required. For such markets the approach detailed in this note may be of help. The approach generates a measure of the change in social welfare from adjusting quality levels. This would help to determine whether moving to an optimal quality level was economically worthwhile.