Measurement of Grading Error Costs

In the Beef Industry

Peyton Ferrier
Department of Economics
North Carolina State University
Raleigh, NC 27695
peyton.ferrier@ncsu.edu

2002 Annual Meeting of the American Agricultural Economics Association
Long Beach, CA, July 28-31, 2002

May, 8th 2002

I. Introduction

Industry observers[1] assert that the quality of beef products has declined in relative terms to non-beef meat products, such as chicken or pork, over the last 30 years and that this decline has caused the steady erosion of beef demand since the late 1970's. Over this period beef's share of the overall meat market fell from 48% of the total meat market in 1976 to 32% of the meat market in 1998. Similarly, beef inventories fell from 45 million head to below 33 million head. Tables 1 and 2 depict the relative decline of beef in absolute terms and as a percentage of total meat production over this period.

Industry observers assert that the current pricing and generic market structure of beef products does not adequately convey important product quality information to consumers. Boland and Schroeder (July 2000) write "at the present time, there is no value-based marketing program that provides economic incentives for producers and processors to market more tender beef primal cuts to consumers. Rapid and accurate measurement of tenderness is needed to implement a value-based marketing program." Evidence has accumulated that the USDA grading standards poorly measure palatability and tenderness characteristics of beef. Several branded beef programs have emerged that may fill the void of the perceived inadequacies of the USDA beef grading program. The beef industry then faces both supply side and demand side problems. The supply side problem involves creating institutional arrangements that ensure that specified quality levels are produced in the parameters of the brand. The demand side problem involves creating a creating a product sufficiently matched to consumer preferences to raise prices.

This paper presents a model for bounding the effect of grading errors on price. Unlike previous studies of grading errors in agricultural markets, this method utilizes the fact that consumers purchasing higher quality types have revealed themselves as having higher marginal valuation of quality. The Spence model of market separation with vertically differentiated products informs us that market separation occurs if the single-crossing property is satisfied. When market separation occurs, the value of two identical is different between consumers who have chosen separate products. For this reason, methods that measure the effect grading errors on price are incorrect if they treat price as merely a linear combination of utility values from a single utility function.

As programs of testing and grading which reduce grading error in the beef industry, this method may be used to estimate the relative benefits of these programs.

II. Overview of the Beef Industry

II.A. Production Process

Production of beef involves distinct links in the supply chain--ranching, feeding and packing. Ranchers regulate optimal herd size, feed the cattle and select the genetic makeup of the herd. Feedlots then purchase the cattle from the ranchers at auction at around the age of 18 months and prepare the cattle for slaughter by altering the animal's diet to have them add weight. The feeder decides when and to which meatpackers the cattle are sold. The meatpacker slaughters the animal and sells it as boxed beef to either a supermarket or a restaurant.

Beef production has been a very diffuse industry at the ranching stage, more concentrated at the feedlot stage, and very concentrated at the packing and slaughtering stage. For example, in 2001, there were approximately 840,000 ranching operations with a total inventory of approximately 33,400,000. Moreover, approximately 60% of all

[1] Purcell (1999), Schroeder, Ward, Minnert and Peel (1998), and Lamb and Breshear (1998)

beef cattle are raised on ranches of less than 500 head. Alternatively, feedlots have been concentrating steadily since the 1970's. In 1995, there were 41,400 feedlots in the 12 major cattle feeding state with 65% of fed lots having capacities exceeding 16,000 head. Beef packing firms are very concentrated with the top four firms servicing about 80 percent of the market.

Economies of scale are limited at the ranch level due to the unique features of cattle production. Whereas swine and poultry can be fed corn and grain mixes throughout their lives in high-density feeding areas, cows are distinguished by their ability to feed on otherwise unproductive grassland through rumination. For this reason, cattle production is land intensive at the ranch stage so that the number of cattle that can be managed on any single ranch is small relative to the market. Once cattle are moved to the feedlots, cattle are concentrated in smaller areas as food sources are imported for the fattening process. Finally beef packing exhibits large economies of scale as modern slaughter facilities are large-scale operations with high fixed costs. As a result most beef packing facilities contract with feedlots and ranchers for future delivery to ensure that the plant operates near peak capacity.

II.B History

In 1927, the first concerted effort at improved beef quality assurance began with the introduction of the USDA beef-grading program as a one-year experimental program. It has continued on a voluntary basis ever since. In 1946, the Agricultural Marketing Service Act required that the USDA provide grading services to any group upon request and despite adjustments in terminology and individual grade requirements, the program has remained basically unchanged from its original format.

The USDA grading service assigns two grades to beef, a yield grade and a quality grade. Assigning a quality grade consists of assessing two characteristics of the cattle carcass---maturity, by evaluating the shape and ossification of bones and cartilage and the color and texture of the flesh, and marbling, by examining the amount of fat dispersed through the meat itself. Based on these assessments, the USDA assigns the meat to one of eight quality grades (Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner) but only the Choice and Select grades are typically transacted in consumer markets. Prime graded meat typically goes to upscale restaurants whereas lower graded meat is processed into soups, sausage or, at the lowest level, pet food. Sorting tends to be relatively consistent as the USDA reports a 95% agreement rate between independent evaluations.

In the post WWII era, transportation and refrigeration improvement allowed supermarkets to supplant traditional meat markets. As supermarkets had organized themselves primarily as resale outlets for finished food goods, they sought to minimize their roles as meat processors. Starting with Iowa Beef Packers (IBP) in the 1960's, meat packers began shipping "boxed beef" where the carcass is divided and packed into boxes before it is shipped. Furthermore, reductions in transportation and refrigeration costs allowed meatpacking plants to move closer to feedlots to avoid the costs of shipping live cattle to slaughter facilities. In 1971, the Union Stockyards, the most visible symbol of the era of distant packing, closed after 106 years of operation.

The post-war trends in agricultural market of expanding demand, deepening market integration, and standardization of products were also readily apparent in the beef industry. The availability of cheap fossil fuels and surplus grain allowed producers to use feedlots more extensively to increase weights and yields of cattle in the finishing process.

Corn feeding also raised the amount of marbling in beef and substantially improved the chances of an animal earning a higher USDA grade.

Significant developments in animal husbandry would increase yields but, also possibly, influence the quality of consumer meat on the market. In 1952, the first successful breeding occurred using frozen semen and by 1960 artificial insemination was being emphasize by AI studs.[2] In this time period, new herd associations arose and several new breeds were being introduced into the United States from abroad (see Table 5.) Mixed breeds became more common as breeders were able increase yields and feed conversion ratios by combining the traits of several breeds. Through the mid-1970's cattle breeding, a relatively market, soared through the mid-1970's.

The emergence of hybrid breeds (*Beefmaster*, *Brangus*) that mixed characteristics of European (*Bos Taurus)* and exotic (*Bos Indicus,* zebu-type) animals, however, may have been responsible for the decline in beef tenderness on average across the industry. While hybrid breeds may perform adequately within a USDA grading system that is primarily based on the amount of marbling in beef, evidence shows that these breeds are less tender than the European breeds[3] and that less than 10% of the variation in tenderness is explained by marbling.[4] As Holmstrom and Milgrom (1991) document, if two desirable traits (tenderness and yield) are negatively correlated but only one trait (yield) has a market incentive, then the trait with the incentive crowds out the trait with no incentive.

By the end of the 1970's, the 30-year trend of increasing beef demand had ended. Real beef prices began falling steadily along with cattle inventories through the late

---

[2] Taylor and Field, Beef Production, page 610
[3] Crouse et al., 1987 and 1989; Wheeler et al, 1994.
[4] Pearson,1966; Parrish, 1974; Jeremiah, 1978; Wheeler et al, 1994. Look up later.

1990's. Since 1976, both the pork and the beef industry have lost market share relative to a booming poultry industry (See Tables 1 and 2). This fall has been explained in several ways including the relative decline in price of chicken compared with beef and other meat products, changes in consumer tastes, and health concerns. Separate authors have emphasized that the beef industry has essentially remained a unprocessed commodity good in a market of increasingly differentiated, processed, consumer-oriented goods. The industry as a whole has not created new, more convenient products or substantially improved beef quality and consistency to reflect these demands.

Certification programs have grown dramatically in an attempt by producers to separate out the consumer market for high-end consumers. When in 1976 the USDA widened grading for prime and choice cuts, some producers believed that the grading system was weakening as a method of differentiating beef quality types. In response, the American Angus Association established the Certified Angus Beef™ (CAB) program in 1978 in conjunction with the USDA. Although this program was not widely adopted until 1994, it marked the first of 25 quality certification programs now administered by the USDA.

In the meantime, as beef demand fell and cattle yields increased through the 1980's, the meatpacking industry consolidated in the midst of packing plant closures. Four firms, IBP, ConAgra (Excel), Cargill (Montfort), and National Beef, came to control 80% of the market share of beef packing. But, where the meat-packers of the earlier era have been viewed historically rent-seeking cartel, some economists today have speculated that the concentration of meat-packing may be beneficial to downstream suppliers as packer concentration facilitates coordination across supply links with regard to product innovation.

II.C Quality and Grading Overview

Like most agricultural products, beef has been marketed as a commodity for most of its modern history and supermarket beef is typically neither branded nor traceable to its origin. Information about the production process used to raise cattle is not easily recoverable. Price variation across beef products is typically reducible to variation in cuts, grade and, with sometimes with regard to ground meat, fat content.

Several authors in the meat science field have shown that the USDA grading standards do not identify significant variation in several valuable beef traits including, most notably, tenderness[5]. Savell et al (year) also find that USDA grade standards are ineffective at identifying meat tenderness. Wheeler, Cundiff and Koch (1999) find that only 5% of the variation in palatability traits are explained by the degree of marbling in beef, the dominant USDA grading criterion. Brooks et al (2000) corroborates Wheeler's results in finding that the USDA grade had no effect on the Warner Bratzler Shear[6] (WBS) force values of top loin steaks. Shackelford et al find that 89% of consumers would definitely or probably buy certified "tender select" beef if it were available at their local store. Boleman et al found that approximately 95% of consumers are willing to purchase the highest tenderness level as offered as certified by the WBS method when offered to select from three products of increasing tenderness and price differentials of $1.10/ kg. It is worth noting that while all of these studies support the underlying finding that consumers are will to pay more for more tender cuts of beef, all of the studies were

---

[5] Dikeman (1987) and Miller et al (1995) showed that tenderness is the most important palatabilty attribute of beef.

[6] The Warner Bratzler Shear (WBS) Force test is method used to evaluate meat tenderness. It involves measuring the force necessary to cut a cooked steak. Obviously, this test is destructive of the final product and expensive to administer.

conducted in non-market settings and are therefore open to long-running criticism of contingent valuation studies.

Several authors within agricultural economics have shown that consumers exhibit a significant willingness to pay for beef that is certified to be higher quality. Lusk et al found that 20% of consumers were willing to pay more than $2.67 over the cost of a comparable steak if it was certified as tender using the WBS method. Overall, 51 percent were willing to pay a premium for steaks labeled “guaranteed tender" using this method. Similarly, Fuez and Umberger found that 29% of consumers were willing to pay $1.30 more for an USDA Choice steak over an USDA Select steak.[7]

With such a clear market incentive for reasonable assured higher quality, producers have stepped in to fill the void. “Branded” beef products have expanded through the creation of several USDA beef certification programs and process verification (PV) programs. Both types of programs are voluntary, producer-regulated and producer-financed. The USDA’s role is to act as an independent intermediary who can credibly commit to impartiality in product evaluation according to the standards established by the program's members.

USDA beef certification programs consist of USDA graders evaluating visible live animal and post-mortem carcass characteristics at a packing plant. In the Certified Angus Beef (CAB) program, for example, graders first check to see if cattle meet the live requirement that the hide be 51% black, and that the cow be traceable back to registered Angus cattle, and that the hump be less than a specified size[8]. After slaughter graders then evaluate the carcass on several characteristics including hot carcass weight, ribeye area, and marbling. The USDA requires that the cattle by presort at a packing plant at

[7] There is more to this study but has not yet been published.

the suggestion that 90% of presorted cattle eventually pass the certification process. As separating cattle is costly to meat-packers, this target is generally adhered too.

The USDA will certify cattle on any set of criterion provided to it. Ownership of the brand name attached to the certification process, however, belongs to the developer of the certification program. In the case of the CAB programs, only packers, fabricators, distributors, restaurants and retail stores licensed by the American Angus Association may use the CAB trademark. Revenue from licensing is then used to promote the brand. Currently, 25 programs are actively used while 41 certification program standards are on record. Most of active programs have been developed very recently (see Table 1.)

The USDA Process Verification programs involve the USDA auditing the entire production process. As there are only two active PV programs for the beef industry, patterns for successful programs are difficult to establish. PV programs begin with the USDA getting a manual of operations detailing the criterion for the production process at each stage. USDA auditors then audits the ranches, feedlot, or packing plant to ensure the criterion is met. Each audit typically takes one week annually. The one-time process of adopting a new manual also takes about a week. For example, the brand Your Own Beef™ is verified under the PM Beef Group program. In this program, three separate weeklong audits are conducted annually, in the feedlot, packing plant and cutting facilities respectively.

III. Literature Review

Many agricultural products are sorted by quality before reaching the market. Cherries, prunes, shrimp, mussels, and olives are sorted by size. Meats, including beef,

[8] Large humps are characteristics of cattle crossed with *Bos Indicus* bloodlines.

are graded by quality and priced accordingly. Oranges, grapefruit, bananas, almonds, and onions may be branded so as to distinguish them as high quality from their commodity counterparts.

Rosenman and Wilson (1991) empirically exam sorting under asymmetric information in their study of the cherry industry. They find that when cherries are divided into three categories-- sorted high quality, sorted low quality and unsorted-- the price of unsorted cherries resides between the high quality and low quality prices reflecting the expectation that the average quality of the unsorted cherries is likely to be between the average qualities of the two sorted categories. In Rosenman and Wilson 's model, firms are more likely to sort as the cost of sorting decreases, their proportion of high quality cherries increases, the difference between sorted high quality and low quality prices increases, and the difference between the unsorted price and the low quality price decreases.

Hennessey (1996) argues that the information asymmetries over quality provide a reason for vertical integration between suppliers and retailers. In his model, producers under-invest in quality-improving technology because retailers can not differentiate between good and bad quality products with certainty. Non-vertically integrated retailers must test products to determine whether they are high or low quality. Producers who have invested in quality improving technology have a higher proportion of output being of high quality than the non-invested producers do. Non-integrated buyers test the product without knowing whether the producer from which they are buying have invested in quality improving technology. Since testing is not completely accurate, the return to investing versus non-investing diminishes and fewer firms invest. Alternatively, in a vertically integrated firm, testing is not required to determine the proportion of high quality. Instead, the true change in proportion of high quality products is used to construct the incentive to invest, rather than the proportion that test as high quality. Henessey extends the model to the case where testing is costly but the results are essentially identical.

Chalfant, James, Lavovie, and Sexton (CJLS) (1999) consider the price of effects of grading errors in the California prune industry. In their model, prunes graded by size are subject to grading error, as undersized prunes are not always sorted out from large prunes in the sieving process. Containers of large prunes may contain some small prunes but not vice versa. The authors model market prices for graded products as a linear combination of the underlying true values of a correctly graded product based on the probability of misgrading. The paper then extrapolates the effect of asymmetric grading errors on the returns to producers by calculating the difference between the true value of a graded product and its price.

(CJLS) specify that the price of a good is a probability-weighted average of the true market value of that each type of product. If there are four quality types, then the value of a grade two good equals the probability of getting a type 1 good times the true market value of a type 1 good plus the probability of getting a type 2 good times the true market value of a type 2 good and so on. If s_1^2 represents the probability of a type one good being graded type two, V_1 represents the true market value of type one, w_1 equals the proportion of final output that is actually type 1, and $m_1$equals the proportion of output that is graded type 1, the price of a type 2 good is

$$P_2 = \frac{V_1 s_1^2 w_1 + V_2(1 - s_2^1 - s_2^3 - s_2^4)w_2 + V_3 s_3^2 w_3 + V_4 s_4^2 w_4}{m_2}$$

A depiction of a utility function that could match this is depicted in Figure 3.

This paper focuses on some potential inadequacies of the (CJLS) model in estimating the effects of grading error on prices from a consumer standpoint. Whereas the CJLS paper is concerned mainly with the estimating effect of grading error on prices that producers receive, it is inadequate to address the potential effect on prices from a reduction in the likelihood of grading error since it treats the true market value of a graded good as constant. In vertically differentiated product markets, consumers separate themselves based on the tastes for quality. Market separation implies that consumers do not value identical products equally. Different consumers will not treat the costs of grading errors the same. For this reason, higher value consumers suffer higher costs in being forced to take a low quality product than lower value consumers do. Importantly, as the probability of grading errors decrease neither the market shares nor the underlying market values will remain constant.

The demand model presented below offers a way in to estimate the effect on prices from a reduction in grading error. By estimating distribution of consumer taste preferences, one may specify the changes to prices that occur from a reduction in the frequency of grading errors.

IV Demand Models under Vertical Differentiation

IV. A Demand when Quality is Certain.

A simple model for consumer demand under vertical differentiation is taken from Tirole (1995). In this model, all consumers rank quality over identically over several products and quality is know with certainty but consumers differ in their willingness to pay for quality. Consumers may select a product from a menu of several products with different prices and qualities. Naturally, higher quality products have higher prices.

Let Q equal a positive number that represents the quality of good and θ equal a positive number that represents a consumer specific taste parameter for quality. Across all consumers, θ is distributed according to some distribution F(θ) that has a positive support and consumers with larger θ's have a stronger preference for quality. The consumer surplus function can be represented as a discrete choice between multiple products as:

$$CS = \begin{cases} \theta Q_i^{\alpha} - P_i & \text{if a consumer purchases a product with quality } Q_i \text{ at price } P_i \\ 0 & \text{if the consumer does not purchase a good.} \end{cases}$$

Here, consumers simple pick the good that yields them the highest consumer surplus. Importantly, consumers who purchase a product reveal through their product selection that their individual θ levels are constrained to fall with certain bounds where θ_i is the minimum level of θ that ensures a consumer still purchases that good (See Figure 4 for an illustration.) The distribution of consumers with specific θ boundaries are defined by F(θ). Through this cumulative density function, demand for each product can be defined.

The consumer surplus function is likely to be concave in quality. Consumption of agricultural products in general and beef in particular is usually accompanied by a great deal of secondary process in the home after purchase. A higher quality cut of meat will be used as a steak whereas a lower cut may be stewed or heavily seasoned. Uncertainty in quality results in sub-optimal uses of the meat at home. For this reason, the expected utility from consumption under uncertain quality is less than the utility under certain quality. Moreover, several studies[9] report that inconsistency in quality is a key consumer complaint. For these reasons, I restrict α to be between 0 and 1.

Solving for demand in the two good case yields:

$$D_1(P_1, P_2) = Z[1 - F((P_1 - P_2)/(Q_1^{\alpha} - Q_2^{\alpha}))]$$

$$D_2(P_1, P_2) = Z[F((P_1 - P_2)/(Q_1^{\alpha} - Q_2^{\alpha})) - (P_1 / Q_2^{\alpha})]$$

where Z represents the total number of consumers in the market.

In the *n* good case where good 1 is the highest quality good,

$$D_1(P) = Z[1 - F((P_1 - P_2)/(Q_1^{\alpha} - Q_2^{\alpha})]$$
$$D_i(P) = Z[F((P_i - P_{i+1})/(Q_i^{\alpha} - Q_{i+1}^{\alpha}) - F(P_{i-1} - P_i / Q_{i-1}^{\alpha} - Q_i^{\alpha})]\forall i < n-1$$
$$D_n(P) = Z[F((P_{n-1} - P_n)/(Q_{n-1}^{\alpha} - Q_n^{\alpha}) - F(P_n / Q_n^{\alpha})]\forall i < n-1$$

Note that in the *n*-good case, a proportion of consumers, those with θ less than P_n / Q_n, do not purchase any product. This occurrence can be resolved for purposes of estimation by constraining θ to be greater than P_n / Q_n^{α}. The restriction assures that the consumers who purchase a good have a positive consumer surplus.

Contract theory informs us that stability in purchasing decisions requires that two properties be satisfied. First, the individual rationality constraint requires that consumers only purchase a product if it yield them a surplus in excess of their reservation surplus which is assumed to be zero in this model. Second, the incentive compatibility constraint specifies that consumers only pick the product that yields him the highest possible consumer surplus. If the either of these constraints are not satisfied the consumer will unilaterally deviate from their product choice. Contract theory informs us that a mechanism (a price-quality offer) satisfies these constraints if and only if being

[9] Lusk et al. (2001),

truthful (with regard to the agent's true θ) provides every agent at least as much utility as any misrepresentation of it.

The individual rationality constraint is satisfied through the definition of demand. In the case of the n^{th} good, the consumer surplus is zero for the marginal consumer. For all consumers with higher marginal valuations of quality the consumer surplus must be greater than zero. Since any consumer with a higher marginal valuation of quality than the marginal consumer of the n^{th} good can always pretend to have a lower valuation of quality than they actually do have and pick the n^{th} good, all consumers who purchase must receive a non-negative surplus.

It can be shown that the first and second order conditions for incentive compatibility are:

$$\forall \theta \in \Theta \begin{cases} \dfrac{dP}{d\theta}(\theta) = \dfrac{\partial u}{\partial q}(q(\theta),\theta)\dfrac{dq}{d\theta}(\theta) \\ \dfrac{\partial^2 u}{\partial q \partial \theta}(q(\theta),\theta)\dfrac{dq}{d\theta} \geq 0 \end{cases}$$

The second order constraint is satisfied if the Spence-Mirlees[10] condition is satisfied. This condition is:

$$\frac{\partial^2 u}{\partial \theta \partial q} \geq 0$$

By construction, my model assumes imposes this condition to satisfy the second order condition. The first order condition defines the prices that producers are able to charge for a product of a given quality. This condition basically indicates that the increase in price permitted as consumer valuations of quality increase must equal (or be less than) the increase in utility provided with the higher quality given to higher quality types. The first order condition defines the maximum price increase that may accompany a quality increase.

IV.B. Demand under Uncertainty in Quality

Whereas the simple model of vertical differentiation assumes that consumers have perfect information on product quality, in many agricultural goods, this is not the case. Exact product quality can not be guaranteed for a product due to production error, quality measurement or a non-integrated supply structure. Instead, in the case of graded products, quality is measured to be within a specific set of bounds and even those broad measures of quality are subject to measurement error. Imperfect grading allows the possibility of grading errors where a product being placed in grade when its quality does not fall within those grading bounds. Over-grading occurs when products are ranked higher than their actual quality while under-grading is when they are ranked lower. Over-grading errors offer the consumer unexpected benefits while under-grading errors provide unexpected costs.

Since quality is uncertain, consumers are modeled as expected consumer surplus maximizers. In this case, product choice is now:

$$E[CS] = \begin{cases} \theta\, E[Q_i^{\alpha}] - P_i & \text{if a consumer purchases a product with quality } Q_i \text{ at price } P_i \\ 0 & \text{if the consumer does not purchase a good.} \end{cases}$$

This specification does not change the substantive aspects of the demand model. Instead, it merely limits the direct of the mechanism with which producers could ultimately

[10] This condition is also known as the sorting condition and the single –crossing condition in the literature.

influence product quality. Provided the first and second order conditions of the incentive compatibility and individual rationality constraints are met, product demand will be:

$$D_1(P) = Z[1 - F((P_1 - P_2)/(E[Q^\alpha \mid G_1] - E[Q^\alpha \mid G_2])]$$
$$D_i(P) = Z[F((P_i - P_{i+1})/(E[Q^\alpha \mid G_i] - E[Q^\alpha \mid G_{i+1}]) - F(P_{i-1} - P_i /(E[Q^\alpha \mid G_{i-1}] - E[Q^\alpha \mid G_i])] \forall i < n-1$$
$$D_n(P) = Z[F((P_{n-1} - P_n)/(E[Q^\alpha \mid G_{n-1}] - E[Q^\alpha \mid G_n]) - F(P_n / E[Q^\alpha \mid G_n])] \forall i < n-1$$

The solutions for θ in the four good case are:

$$\theta_1 = (P_1 - P_2)/(E[Q^\alpha|G_1] - E[Q^\alpha|G_2])$$

$$\theta_2 = (P_2 - P_3)/(E[Q^\alpha|G_2] - E[Q^\alpha|G_3])$$

$$\theta_3 = (P_3 - P_4)/(E[Q^\alpha|G_3] - E[Q^\alpha|G_4])$$

$$\theta_4 = (P_4)/(E[Q^\alpha|G_4])$$

Grading errors may lower or raise consumer expectations of the underlying expected utility provided by each grade. Intuition suggests and the empirical literature shows that price of low value goods increases and high values decreases when grading error increases. In a general equilibrium setting, as the equilibrium price changes, the boundaries on θ for the consumers who purchase in the predetermined quality range also change. Consider Figure 4 briefly. This graph shows how the θ_i's are a dependent on prices and quality levels for each product. It is a relatively easy extension to show that the same process holds when consumers are expected surplus maximizers with the exception that instead of prices and expected quality are now at issue. When grading error is introduced the slopes of the consumers surplus lines change. At the lowest quality level, the lines gets steeper and at the highest quality level, the lines get flatter. The effects on the intermediate grades are indeterminant. Changes in the slopes of these lines necessarily causes the θ_i's to adjust in the absence of price changes.

This specification itself is problematic, however, because the distribution of θ determines the market share for each product. Since expected quality and the distribution of θ is exogenous in this model, only prices can adjust to equate supply and demand. The presence of grading errors can potentially influence the expected quality of each grade making the problem complicated much more quickly. Knowing the distribution of θ however, allows an equilibrium set of prices to be determined if the likelihood of grading error decreases.

IV.C Estimation

In order to estimate the effect of grading error on prices, I will proceed in the several steps listed below.

1.) Assume a set of $\boldsymbol{\alpha}$ utility parameters that will be used in a 1st step estimation of the consumer utility in the consumer surplus function. The form of the utility should ensure that the Spence-Mirlees condition is satisfied and that consumers are risk averse in quality. For this reason, I suggest a utility function of the simple form $U=\theta Q^{\alpha}$ with α being between 0 and 1.

2.) Specify a structure for the distribution of quality within a grade. The choice of the error structure is specific to shape of the data on hand. In CJLS paper, prunes size within each grade is estimated with a Gamma distribution as grading error is known to be asymmetric *a priori*. The function $g(Q|\lambda_i;G_i)$ is the probability of get quality Q given the distribution parameters λ_i in grade G_i.

3.) Estimate λ_i for each grade. Estimating λ_i will obviously require an independent test other than that used in grading. With regard to the beef industry, tenderness may be a sufficient metric for quality. Meat science data may be sufficient to estimate tenderness values as several studies have estimated the distribution of quality within meat grades using the WBS method. Calculate $E[Q^{\alpha}|\lambda_i,G_i,B_i]$ for each grade.

4.) Calculate θ_i boundaries based on the expected quality qualities in step 6 and observed prices.

5.) Estimate a distribution of $F(\theta)$ using the observed θ boundaries and the market shares.

Starting from a distribution of θ, general equilibrium dynamics can be estimated. For example, reductions in the variance of quality for a given product will raise its expected utility, thereby increasing the price it may charge for any given effect on expected quality

IV.4 Summary

This paper provides a method of estimating the distribution of consumer tastes with regard to quality. From that distribution estimates to the changes in prices can occur in a general equilibrium setting. The changes in prices from a reduction in grading errors can be estimated when the variance of quality within a grade decreases. The immediate effect of reductions in the variance of quality is that it increases expected quality for that product increases. This model may be especially useful for analyzing the effect of tighter grading standards for the highest quality brand since competition is only one-sided in that case.

Branded beef products are being introduced to address specific concerns regarding the degree of quality assurance provided by the USDA grading standards. The certification and process verification programs that have arisen over the last decade are aimed at improving the average quality and reducing the variance in quality to improve beef prices and returns. In light of the rapid adoption of such programs this paper presents a model by which the benefits of such programs may be potentially measured.

V. Bibliography

Akerlof A. "The Market for 'Lemons'; Quality, Uncertainty and the Market Mechanism" *QJE*, Volume 84, Issue 3, August 1970

Boland, Michael and Schroeder, Ted "Marginal Value of Quality Attributes for Natural (Organic) Beef, July 2000, *Selected Paper of the 2000 Annual Meeting, June 29-July 1, 2000,* Vancouver, British Columbia

Boland, Michael, Barton, David, and Domine, Matthew, "Economic Issues with Vertical Coordination," December 1999, *KSU Research and Extension Agricultural Economics Library*, http://www.oznet.ksu.edu/library/agec2, Not Dated

Boleman, S J, Boleman, S L, Miller, R K, Taylor, J F, Cross, H R, Wheeler, T L, Koohmarie, M, Shackelford, S D, Miller, M F, West, R L, Johnson, D D, Savell, J W. "Consumer Evaluations of Beef of Known Categories of Tenderness", *Journal of Animal Science*, 1997

Brent, Hueth and Melkonyan, Tigran, "Quality Measurement and Contract Design: An Example from Agriculture" *Working Paper,* August 2, 2001

Brester, Gary W. and Schroeder, Ted C. "The Impacts of Brand and Generic Advertising on Meat Demand," *American Journal of Agricultural Economics* 77 (November 1995)

Chalfant, James, James, Jennifer, Lavoie, Nathalie, and Sexton, Richard, "Asymmetric Grading Error and Adverse Selection: Lemons in the California Prunes Industry," *Journal of Agricultural and Resource Economics* 24(1): 57-79, 1999

Food Safety and Inspection Service, USDA. "Inspection and Grading: What are the Differences?" http://www.fsis.usda.gov/OA/pubs/ingrade.html, not dated

Fuez, Dillon M., Schroeder, Ted C., and Ward, Clement W. "Fed Cattle Pricing" http://www.ianr.unl.edu/pubs/farmmgt/g1353.htm, June,1998

Hayenga, Marvin, Schroeder, Ted, Lawrence, John, Hayes, Dermont, Vukina, Tomislav, Ward, Clement, and Purcell, Wayne, "Meat Packer Vertical Integration and Contract Linkages in the Beef and Pork Industries: An Economic Perspective," *Paper prepared for the American Meat Institute, Arlington, VA*, 2000

Hennessy, David A. "Information Asymmetry as a Reason for Food Industry Vertical Integration," *American Journal of Agricultural Economics,* November 1996

Holmstrom, Bengt and Milgrom, Paul, "Multi-task Principal Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design," *Journal of Law, Economics, and Organization*, December, 1991

Hueth, Brent, and Melkonyan, Tigran, "Quality Measurement and Contract Design: An Example from Agriculture," August 2001, Working paper available at http://agecon.lib.umn.edu/

Huffman, K L, Miller, M F, Hoover, L C, Wu, C K, Brittin, H C, and Ramsey, C B. "Effect of Beef Tenderness on Consumer Satisfaction with Steaks Consumed in the Home and Restaurant" *Journal of Animal Science* (January 1996): 91-7

Huffman, K L, Miller, M F, Hoover, L C, Wu, C K, Brittin, H C, and Ramsey, C B, "Effect of Beef Tenderness of Consumer Satisfaction in the Home and Restaurant" *Journal of Animal Science,* 1996

Javell, J W, Branson, R E, Cross, H R, Stiffler, D M, Wise, J W, Griffin, D B, and Smith, G C, National Consumer Retail Study: "Palatability Evaluations of Beef Loin Steaks that Differed in Marbling" *Journal of Food Science* 52: 512-517, May/June 1987

Katz, Jeffery P., Boland, Michael A new value-added strategy for the U.S. Beef Industry: the case for U.S. Premium Beef Ltd. *Supply Chain Management: An International Journal* Vol 5, Issue 2, 2000

Lamb, Russell and Beshear, Michelle, "From the Plains to the Plate: Can the Beef Industry Regain Market Share", *Economic Review of the Federal Reserve Bank at Kansas City*, Winter 1998

Leffler, Keith B., Malishka, Peter, and Rucker, Randal R. "By-The-Each or By-The-Pound? The Role of Transactions Costs in Fresh Produce Pricing," Unpublished Draft, June 2001

Lusk, Jayson L., Fox, John A., Schroeder, Ted C., Mintert, James, and Koohmarie, Mohammed "In-Store Valuation of Steak Tenderness." *American Journal of Agricultural Economics* 83(3) August 2001: 539-550

Miller, M F, Huffman K L, Gilbert, S Y, Hammon, L L, and Ramsey, C B, "Retail Consumer Acceptance of Beef Tenderized with Calcium Chloride," *Journal of Animal Science* 73 (August 1995): 2308-2314

Miller, M F, Huffman, K L, Gilbert, S Y, Hamman, L L, Ran, C B, "Retail Consumer Acceptance of Beef Tenderized with Calcium Chloride," *Journal of Animal Science*, 1995

Neely, T R , Lorenzen, C L, Miller, R K, Tatum, J D, Wise, J W, Taylor, J F, Buyck, M J,Reagan, J O, Savell, J W. “Beef Customer Satisfaction: Role of Cut, USDA Quality Grade, and City on In-Home Consumer Ratings,” *Journal of Animal Science,* 1998

Purcell, Wayne, “The Source of Better Prices for Cattle Producers” *Research Bulletin 6-99 Research Institute on Livestock Pricing,* Virginia Technical University, Blacksburg, VA, 1999

Rosenman, Robert E. and Wilson, Wesley W. “Quality Differentials and Prices: Are Cherries Lemons?” *The Journal of Industrial Economics*, Volume 34,1991

Salanie, Bernard, *The Economics of Contracts: A Primer,* The MIT Press, London, 1997

Savell, J W, Branson, R E , Cross, H R, Stiffler, D M, Wise, D B, and Smith G C, “National Consumer Retail Beef Study: Palatability Evaluations of Beef Loin Steaks that Differed in Marbling,” *Journal of Food Science* (52)512-517, 1987

Schroeder, T C, Ward, C E, Mintert, J R, and Peel, D S, “Value Based Pricing of Fed Cattle: Challenges and Research Agenda,” *Review of Agricultural Economics,* Volume 20, Number 1, Pages 125-134, 1998

Shackelford, S D, Wheeler, T L, Meade, M K, Reagan, J O, Byrnes, B L, and Koohmarie, M. “Consumer Impressions of Tender Select Beef,” *Journal of Animal Science,* 2001

Shackelford, S.D., Wheeler, T L, and Koohmarie, M., “Tenderness Classification of Beef:IV Effect of USDA Quality Grade on the Palatability of "Tender " Beef Longissimus When Cooked Well Done,” *Journal of Animal Science*, 1999

Shackelford, S D, Wheeler, T L, and Koohmarie, M., “Tenderness Classification of Beef: II Design and Analysis of a System to Measure Beef Longissimus Shear Force Under Commercial Processing Conditions,” *Journal of Animal Science,* 1999B

Skaggs, Jimmy, *Prime Cut : Livestock Raising and Meatpacking in the United States, 1607-1983,* College Station : Texas A&M University Press, 1986

Smith, G C, Savell, J W, Dolezal H G, Field, T G, Gill, D R, Griffin, D B, Hale, D S, Morgan, J B, Northcutt, S L, and Tatum, J D, “Improving the Quality, Consistency, Competitiveness, and Market Share of Beef. The Final Reportof the Second Blueprint for Total Quality Management in the Fed-Beef (Slaughter Steer/ Heifer) Industry.” *National Beef Quality Audit. Conducted by Colorado State University, Texas A & M University, and Oklahoma State University for the National Cattlemen’s Association,* 1995

Taylor, Robert, and Field, Thomas, *Beef Production and Management Decisions*, Prentice Hall, Upper Saddle River, New Jersey, 1999

Tirole, Jean, *The Theory of Industrial Organization,* MIT Press, London, 1995

Umberger, Wendy, Fuez, Dillon, Calkins, Chris, Killinger, Karen, "The Value of Beef Flavor: Consumer Willingness to Pay for Marbling in Beef Steaks" *Selected Paper of the 2000 Annual Meeting, June 29-July 1, Western Agricultural Economics Association,* Vancouver, British Columbia

Wheeler, T L, Cundiff, L V, and Koch, R M "Effect of Marbling Degree of Beef Palatability in *Bos taurus* and *Bos indicus* Cattle" *Journal of Food Science* 72, December 1994: 3145-3155

Wheeler, T L, Cundiff, L V, and Kock, R M, "Effect of Marbling Degree of Beef Palatability in *Bos taurus* and *Bos indicus* Cattle," *Journal of Animal Science,* 1994

Wheeler, T. L., Shackelford, S. D. and Koohmaraie, M. "Tender Classification of Beef: III. Effect of the Interaction Between End Point Temperature and Tenderness on Warner-Bratzler Shear Force of Beef Longissimus," *Journal of Animal Science,* 1999A

Figure 1. Production of Meat (in Millions of Pounds)

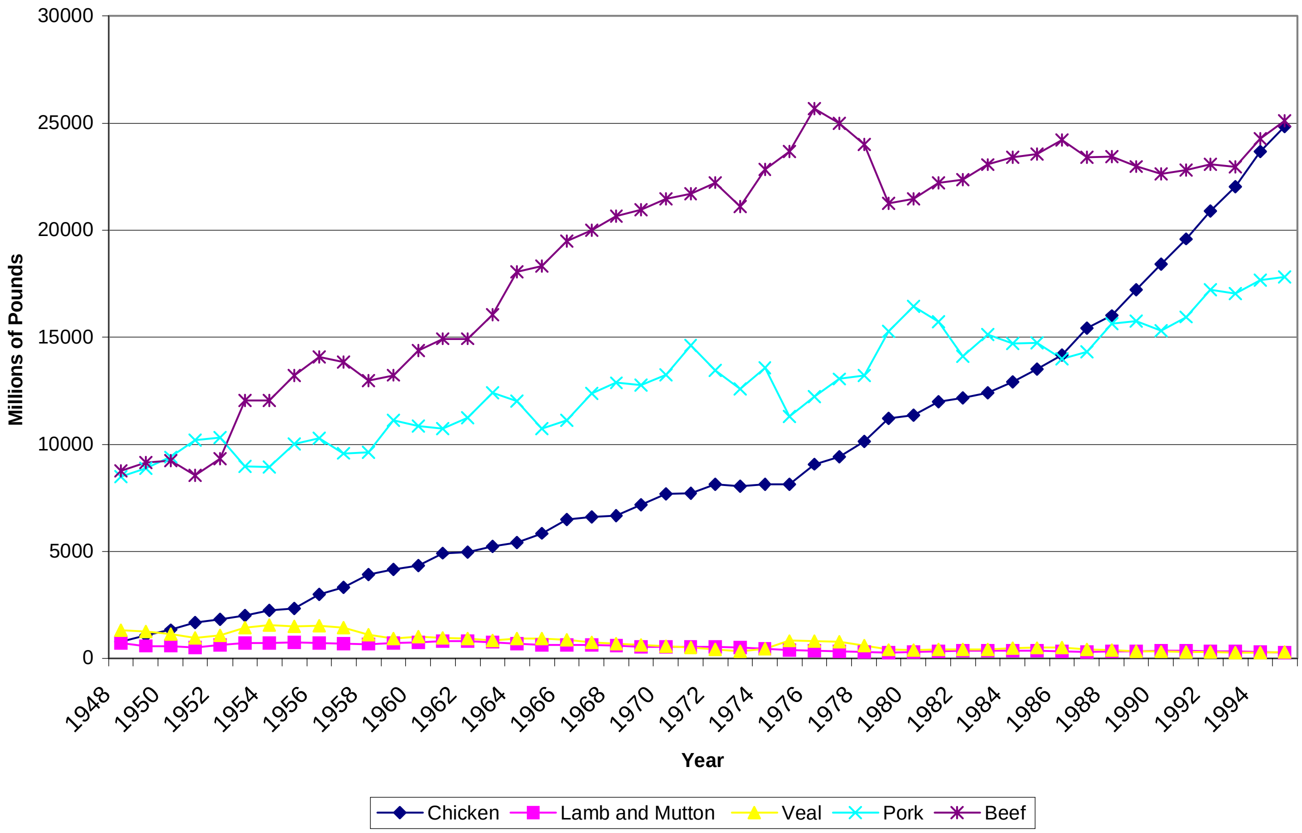


Figure 2. Percentage of Total Commercial Meat Production

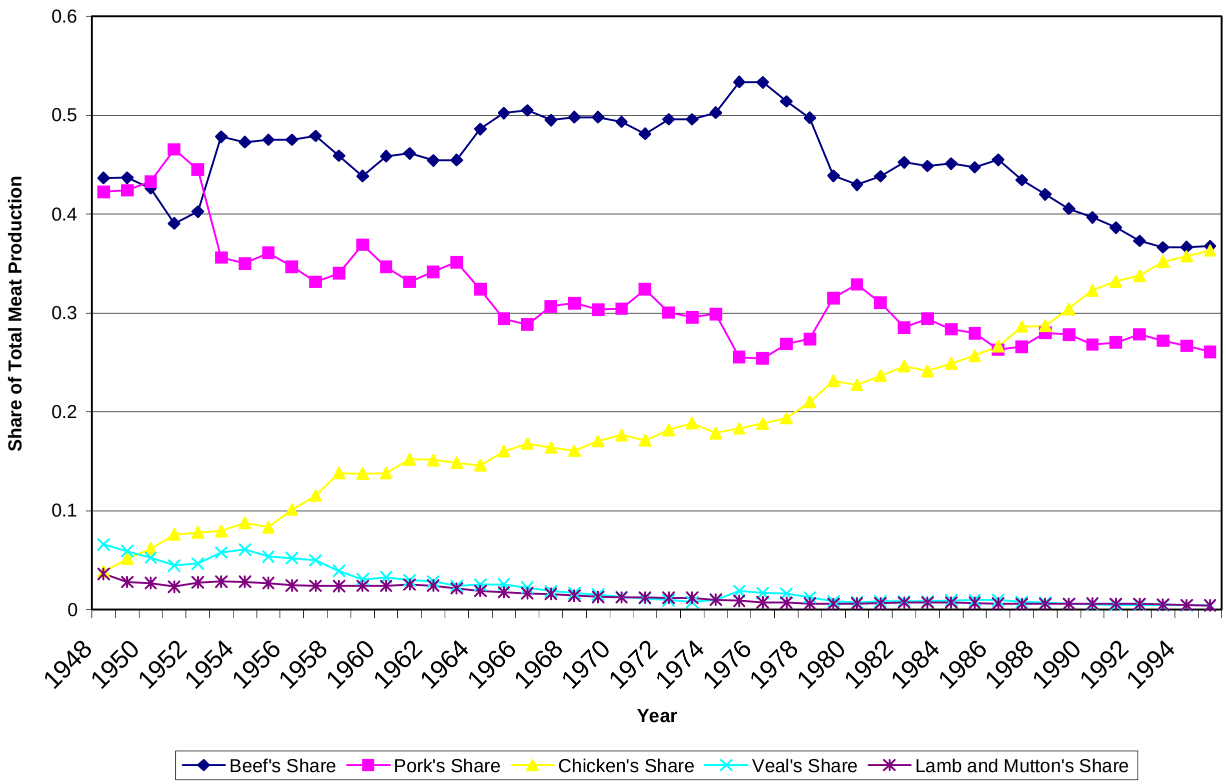


Figure 3.
The Utility Curve assuming that grading errors
are a linear combination of Utility Values

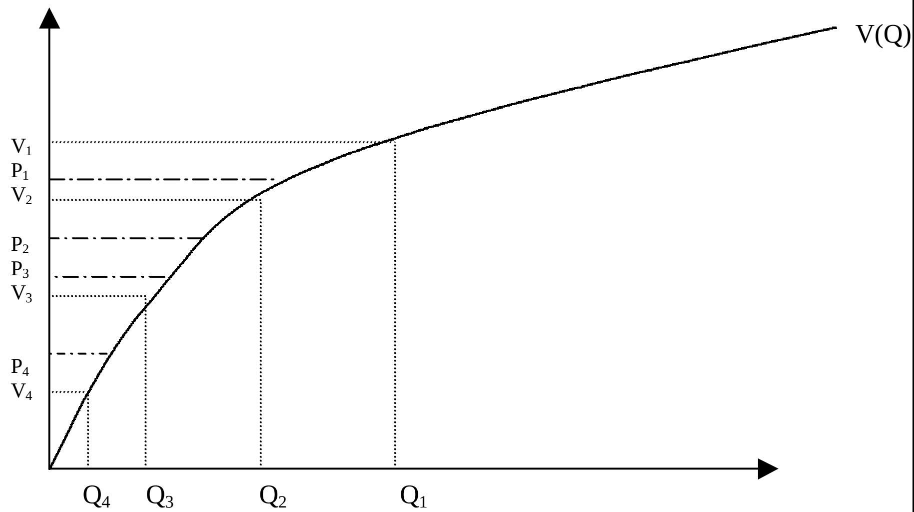


Table 1. USDA Certification Programs	
Effective Start Year	Active Certification Programs
1993	2
1994	4
1995	6
1996	10
1997	13
1998	18
1999	19
2000	23
2001	25

Source: USDA Agricultural Marketing Service

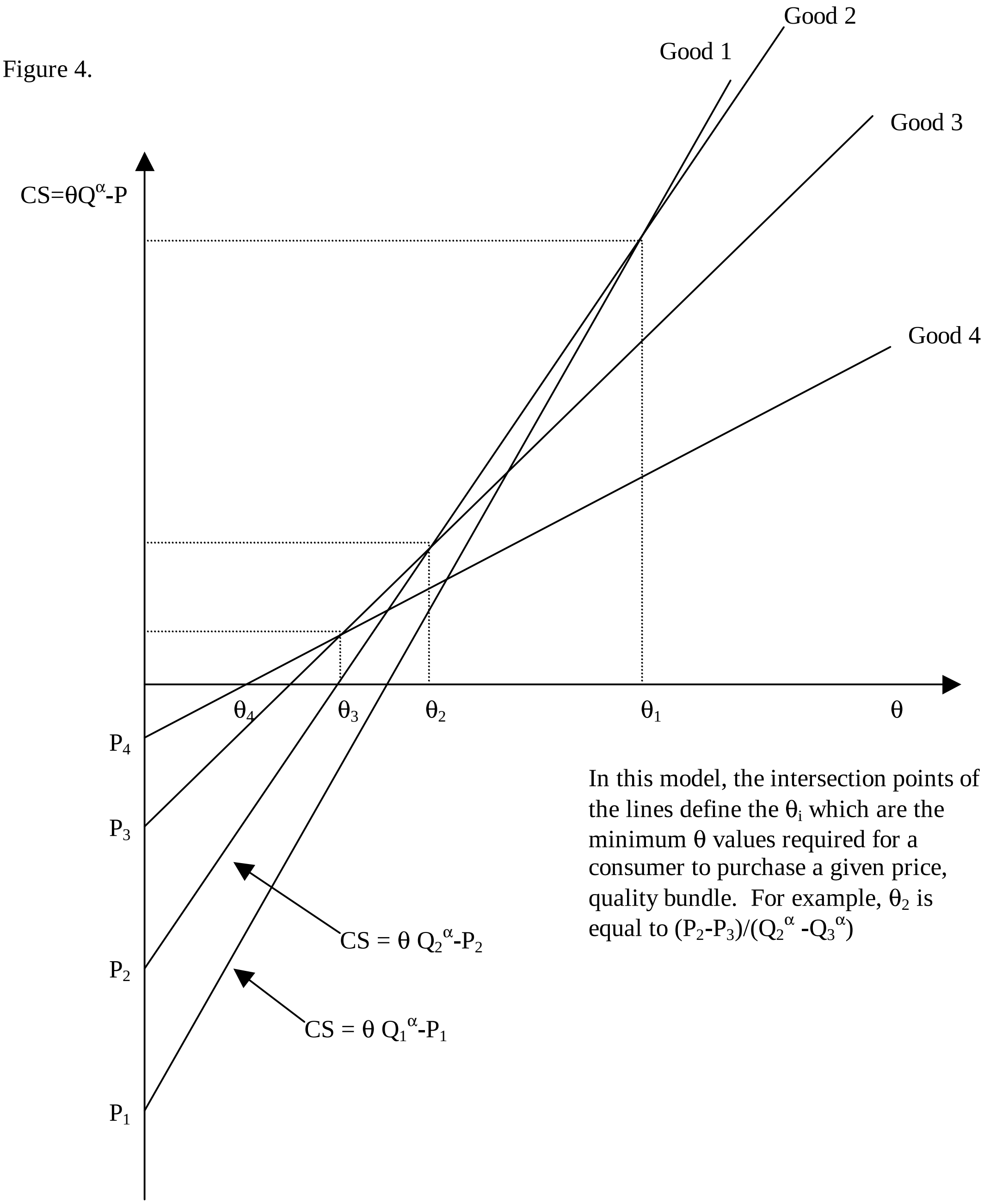
Table 2

Major U.S. Beef Breeds Ranked By Annual Registration Numbers (in Thousands)

	Year					
Breed	**1997**	**1995**	**1985**	**1985**	**1980**	**Year Association Formed**
Angus	239.5	224.8	159	175.5	257.6	1883
Hereford	105.6	112.9	170.5	180.0	353.2	1881
Limousin	61.5	79.3	71.6	44.5	13.8	1968
Beefmaster	56.6	47.1	38.4	32.1	30.0	1961
Charolais	49.2	55	44.8	23.2	23	1957
Simmental	35.7	30.0	15.4	12.0	12.5	1969
Red Angus	35.7	30.0	15.4	12.0	12.5	1954
Gelbvieh	30.1	33.8	22.8	16.1	NA	1971
Brangus	27.7	31.0	32.1	30.3	24.5	1949
Shorthorn	15.5	20.0	18.0	16.7	19.4	1872
Brahman	15.1	15.4	13.0	29.9	36.4	1924

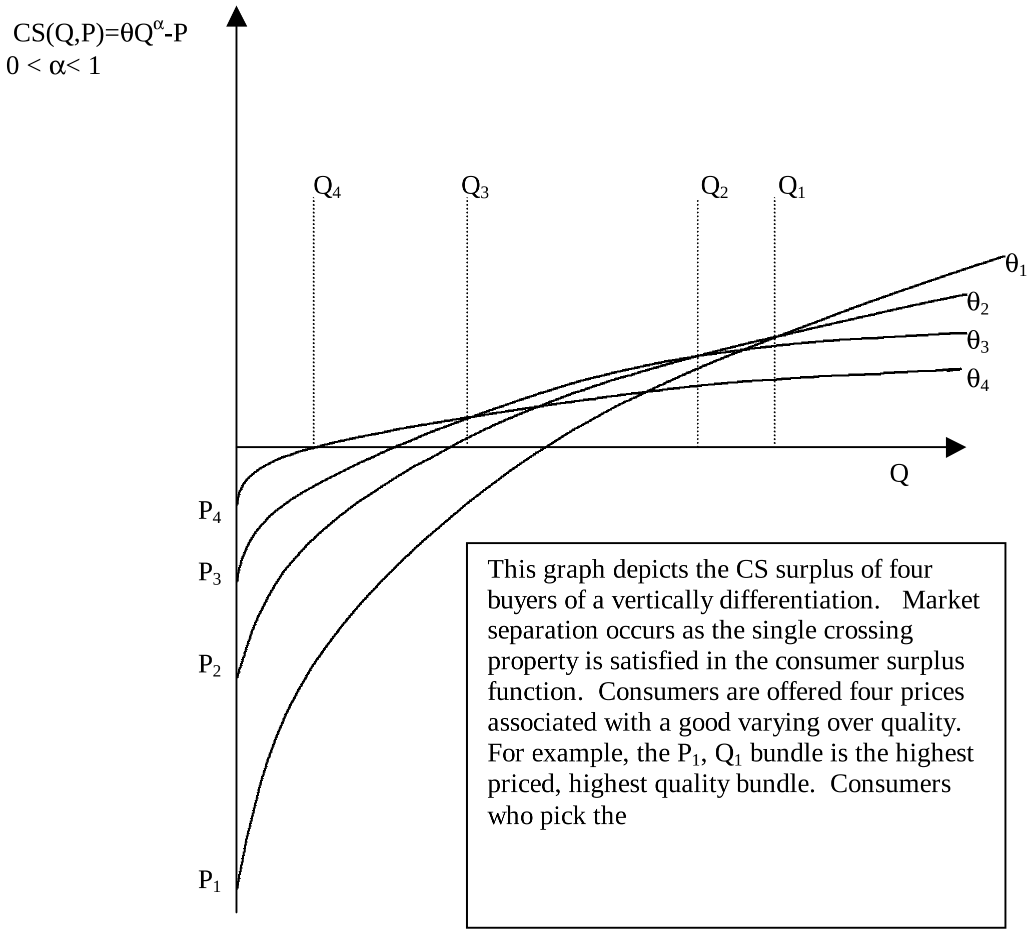
Source: Taylor and Field 1999

Figure 4.



In this model, the intersection points of the lines define the θ_i which are the minimum θ values required for a consumer to purchase a given price, quality bundle. For example, θ_2 is equal to $(P_2-P_3)/(Q_2^{\alpha} - Q_3^{\alpha})$

Figure 5.


CS(Q,P)=θQ^α-P
0 < α< 1
Q4
Q3
Q2
Q1
θ1
θ2
θ3
θ4
Q
P4
P3
P2
P1
This graph depicts the CS surplus of four buyers of a vertically differentiation. Market separation occurs as the single crossing property is satisfied in the consumer surplus function. Consumers are offered four prices associated with a good varying over quality. For example, the P1, Q1 bundle is the highest priced, highest quality bundle. Consumers who pick the