Is More Quality Distinction Better?

The Welfare Effects of Adjusting Quality Grades

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Comments Welcome

I. *Introduction*

Grading of agricultural commodities for quality is ubiquitous. The USDA set quality grade standards for 92 distinct horticultural commodities alone (Dimitri, Horowitz and Lichtenberg, 1996). By ensuring that products meet a minimum level proscribed characteristics, grading mitigates the asymmetric information problem, eliminates the repetition of costly inspection, and harmonizes pricing. However, despite the potential for vast spectrum of very finely distinguished quality levels, only a limited number of coarse grades are typically available to consumers. For example, scallops are graded by size with only few categories being sold in the supermarkets and beef is graded by quality with only a few grades (Prime, Choice, Select) being available in consumer markets. While technology, costs and available information may limit the extent of grading, this coarseness, nonetheless, has important consumer and producer welfare effects. This paper shows that, even in the absence of consumer uncertainty and grading costs, both an increase in the number of available grades and a changing of the standards of existing grades can alter and redistribute the total gains from trade. Producer or consumer groups can potentially increase their gains to trade simply by influencing the grading system.

Consumer demand under grading is modeled using the vertical differentiation model of Mussa and Rosen (1978) in which risk-neutral consumers vary in their valuations of quality according to a single taste parameters. Given a set of prices and expected qualities, consumers pick the single good that gives them the highest surplus from a set of available graded products. Homogeneous producers in a competitive market supply the products with each goods quality depending on their effort input and a random shock to quality. If the good's quality exceeds the minimum standard for that grade, then the producer receives the sales price for that grade. Market shares and the distribution of

consumer preferences then determine the competitive equilibrium prices. Consumer and producer welfare values can then be calculated. Importantly, adjusting grade standards and the number of grades influences both market shares and prices. With prices are market shares producer welfare, consumer welfare, and, subsequently, total welfare can be determined for a fixed distribution of qualities. The paper then shows that welfare effects of adjusting grade standards and introducing new grades through comparative static solutions and simulations. Importantly, control over grading standards influences the both the *size and distribution* of total welfare. Since the policy objectives of establishing grading standards may vary depending on the relative weighting of consumer versus producer benefits, there may be a tradeoff in terms of efficiency and distribution of benefits in grading itself. Moreover, the introduction of private grades and finer gradations of quality are not unconditionally welfare enhancing as it is shown that the introduction of a new grade can actually reduce total welfare even when grading itself is costless and consumers are risk neutral.

The model was developed to consider the implications of recent changes in the marketing of U.S. beef. In the 1990´s, private producer organizations expanded their use of USDA quality certification programs as part of a concerted effort to develop branded beef. Under certification programs, USDA graders evaluate cattle carcasses on both the USDA quality grade standards and a separate set of standards determined by a private producer organization which can then market the product under a branded label. The Agricultural Marketing Service reports that branded beef now accounts for approximately 8% of all U.S. boxed beef sales and sells for a price consistently between that of Prime

and Choice graded beef. Simulations will be calibrated to approximate the conditions of

the beef industry in the final version of the paper.

II.   *An Overview of Beef Quality Evaluation*

Following earlier efforts to standardize the quality of consumer beef arose with

the Pure Food and Drug Act and the Meat Inspection Act, the USDA Federal Meat

Grading Service was developed in 1926 at the behest of large retailers and hotel chains to

harmonize the state grading systems with national standards for interstate sales (Food

Safety and Inspection Service, USDA, 2002).   After World War II, rising beef demand

and falling grain and transportation prices allowed producers to expand the use of

feedlots to improve yields prior to slaughter. Developments in animal husbandry and

genetic manipulation further increased cattle yields, and boxing, where beef is processed

into smaller, more manageable cuts for retail use, also helped lower costs.

In the late 1970's, the trend of rising beef demand abruptly reversed. Between

1976 and 1999, the beef demand is estimated to have fallen nearly 66% (Marsh, 2003) as

the poultry industry grew steadily.   Among other factors, including reductions in the

relative prices of chicken and other meat products, changes in consumer tastes, and health

concerns, poor quality assurance has also been cited by several authors as a reason for the

decline[1] in demand.   In 1987, the American Angus Association began expanding the

Certified Angus Beef Program, which was initially developed in 1978 in response to

concerns that changes in the Prime and Choice standards in USDA grading program

made them too inclusive of lower quality beef (Certified Angus Beef Program, 1999).

Administered by the USDA but developed and controlled by producer groups, USDA

certification programs grew steadily in number and size during the 1990's such that

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

approximately 13% of all cattle are currently certified. Once certified, beef can be

marketed under a branded label to retail outlets.

At the wholesale and retail levels, beef had historically been differentiated only

by cut and quality grade. In the grading process, USDA agents evaluate a carcass's

characteristics at the packing plant after slaughter and assign it both a yield and quality

grade. Two main carcass features –maturity (determined by examining the bones and

cartilage) and marbling (determined by examining the fat dispersion through the meat) –

determine which of the eight possible quality grades to which the carcass is assigned. In

order of quality, these grades are Prime, Choice, Select, Standard, Commercial, Utility,

Cutter, and Canner, but typically only Choice and Select beef are marketed to consumers[2]

while Prime beef are marketed to restaurant and hotel chains (Food Safety and Inspection

Service, USDA, 2002). Table (1) depicts summary statistics on weekly wholesale boxed

beef sales between January 2002 and February 2004 disaggregated by grade and whether

the beef was branded.

Under certification programs, USDA graders also evaluate animals for specified

carcass and live animal characteristics defined by the certification program in addition to

those under the USDA grading program. The oldest and most visible certification

program is the Certified Angus Beef (CAB) program, which was created in 1978 and has

grown steadily since 1987[3]. In this program, live cattle must have a hide that is 51%

black, have genetics traceable to registered Angus cattle, and must not have large humps

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[2]Standard and Commercial grades are often marketed as ungraded[2] or "store brand" beef and may be processed into products such as ground meat before sale
[3] The actual criterion for certification for the Certified Angus Beef Program was developed in 1978 by the American Angus Association in response to perceived weakening of the USDA grading standards, but the program was not used on any large scale until 1987, when yearly sales grew to 50 millions pounds annually before leveling off. Growth then accelerated rapidly after 1993.

to ensure that it has not been cross bred with Brahman. After slaughter, the cattle are also evaluated for carcass weight, rib eye size, and marbling.   The certification programs label is then used to market the beef at the retail level. Ownership of the brand name belongs to the developer of the certification program and is licensed to packers, fabricators, distributors, restaurants and retail stores by the American Angus Association. Other producer organizations, however, can producer similar certification programs, such as Washington Beef's Quality Plus Angus Beef and Creekstone Farm's Black Angus Beef, or they can focus on different breeds, such as Certified Hereford Beef or Tyson's Classic (Red) Angus Beef.   Currently, standards exist for 47 certification programs (Agricultural Marketing Service, 2004), most of which have been developed recently, as shown in Table (2). Figure (1) shows the percentage of total commercial cattle slaughter that was certified since 1993 and the percentage of the slaughter that was certified and qualified as upper Choice.

The increase in certification and value-based pricing is the result of evidence showing that consumers are willing to pay significant premiums for beef verified to be of higher quality. Lusk et al. (2001) 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 Warner Bratzler method. Similarly, Fuez and Umberger (2001) found that 29% of consumers were willing to pay $1.30 more for a USDA Choice steak over a USDA Select steak.   Shackelford et al. (1999) find that 89% of consumers would definitely or probably buy certified "tender select" beef if it were available at their local store. Such premiums exist because grading is thought to poorly measure important quality characteristics of beef.   Wheeler, Cundiff and Koch (1994) find that only 5% of the

variation in palatability traits are explained by the degree of marbling in beef, the prime

USDA grading criterion. Savell et al. (1987) also find that USDA grade standards are

ineffective at identifying meat tenderness.

Certification programs then served two purposes. First, they distinguished beef

quality through a mechanism that could be controlled by producers and did not rely on

national level standards for grading and, second, they allowed producer groups to brand

their beef to distinguish its quality in consumer markets. This paper treats certified beef,

whose quality standards are determine by private interest groups as a new grade of beef

whose quality standards is set by the producer group which creates it. In fact, the

definition of a branded beef is very similar to those defined for certain certification

programs and the price of branded boxed beef as reported in USDA AMS price reports is

consistently well ordered between that of the prime and choice grades. In the modeling

section of this paper, the welfare consequences of the introduction of a new grade are

discussed.

III. *Moral Hazard in Quality Production*
Grading is intended to eliminate the problem of asymmetric quality information

that impedes the functioning of efficient markets when quality varies across goods.

While Rosen (1974) shows that quality characteristics are efficiently supplied when

quality information is complete and symmetric, Akerloff (1970) shows that markets for

quality characteristics are highly inefficient when quality information is asymmetric due

to the adverse selection problems. While Akerloff's argument relies on a fixed

distribution of product qualities, his main conclusion that high quality products become

unavailable when consumers cannot verify a product's quality is also easily generalized

to moral hazard situations in which producers can only improve quality at a cost (Ligon, 2002). In this case, a moral hazard problem arises as producers reduce their investment in quality improvements while free-riding on the quality improvements of other producers. In the case of the beef industry, for example, Schroeder et al. (1995) criticize live- and dressed-weight pricing for making cattle producer payments dependent on the average quality of all cattle rather than just their own as it allowing cattle producer who do not invest in quality improvement to free ride on the increased value of those who do.

Within the cattle industry, improving beef quality creates significant opportunity costs in terms of changing the animal's size and heartiness and as improvements in breeding progressed through the 1960's and 1970's, producers may have become more willing to trade off size for quality. Holmstrom and Milgrom (1991) argue that when two desirable traits are negatively correlated but only one trait has a market incentive, the incentivized trait crowds out the other trait. In terms of the beef industry, incentives for weight gain may have crowded out quality improvement as new hybrid breeds of cattle were developed during the 1960's and 1970's with *Bos Indicus,* or *exotic*[4], genetics. While these hybrid breeds performed adequately on the USDA grading system, evidence shows that these breeds may be less tender than the European breeds (Wheeler et al., 1994). This quality problem is exacerbated by the long and diffuse nature of the supply chain which inhibited the preservation of quality information as the animal is transacted across multiple agents. Certification, which often examines the animals for breed characteristics in addition to those of the grading system, sought to address this problem

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[4] *Exotic* is industry jargon for Indian breeds including Brahmans and their crossbreds. English breeds, such as Hertford, Angus, and Shatham, were the first cattle to arrive in the U.S. Continental breeds, which arose on the European continent and include Charolais, Chianina, and Maine-Anjou, are less prevalent because of their late arrival in the U.S. Exotic breeds grow larger and are able to withstand harsher climate conditions but produce a less palatable meat.

through more rigorous testing of the carcass rather than through closer control and integration of the supply chain process, though often the two are used together.

IV. *An Equilibrium Model of Grading*

As producer payments are increasingly tied to the quality grades to which cattle are assessed and producer groups create certification programs to supplement regular grading, it becomes increasingly important to understand the welfare consequences of adjusting grades. Certification standards act as a new grade in addition to those of the existing USDA grading program, typically distinguishing cattle that are in the upper quality range of the choice grade from the remainder of that grade. However, whereas grade standards are uniform at the national level and inflexible over the short run, certification standards may be adjusted by producer groups as it suits them.

While the ostensible motivation for grading is to eliminate the moral hazard problem, it is not apparent whether these grades accomplish this goal in a welfare maximizing manner. Grade standards are typically fixed for long periods, presumably out of the necessity of establishing reputation, the short run re-distributional consequences of changing the grading program, the cost and inaccuracy of grading, and a limited ability of consumers to process quality information. This same fixedness may not prevent a maximization of the potential gains from trade which in turn causes producer or consumer groups to organize to establish independent quality standards.

This section provides an equilibrium model of grading when quality production is stochastic and then considers the welfare consequences from changing an existing grade standard and introducing a new grade are then considered. The Certified Angus Beef program, for example, cites the 1976 change in the USDA grading standards which

increased the permissiveness of the choice grade in the formation of its certification standard in 1978 (Certified Angus Beef Program, 1999).

This model assumes that quality standards for each grade are initially determined exogenously by the government. The standards for each grade and the distribution of consumer preferences determine market shares, prices, and average quality of each grade and can be used to determine consumer and producer surpluses. Entry and exit by outside producers over the long run drives the producer surplus to zero. Comparative statics are then presented for the effects of changing a grading standard and of introducing a new grade. Simulations show both the consumer and producer welfare effects. Simulations also demonstrate cases in which the consumer surplus either increases or decreases depending on the changes to the grading standards and the distribution of qualities.

IV.A. *Producers and Supply*

The market for graded products is modeled as three separate links in the supply chain: the producer, the sorter and the consumer. Each of the risk-neutral producers creates a single output with quality, q. Increased input of producer effort, e, improves product quality subject to a random error, and this quality is observable to both the producer and sorter after production occurs. The sorter's only role in production is to verify whether the producer's quality, q, has surpassed the minimum quality standard for a given grade, x_i. The minimum quality standard for the lowest grade, x_1, and the minimum quality standard for the highest grade is $x_{\bar{i}}$, where $\bar{i}$ is the best grade. The sorter pays the producer a payment, G_i, if the product's quality surpasses x_i. Risk-neutral consumers are unable to verify the actual quality of the good at the time of

purchase and therefore base their purchase on the expected quality of each grade, denoted μ_i. Sorters sell each graded product to consumers for P_i. Consumer preferences for quality, θ, are distributed across all consumers based on a strictly positive parametric distribution. Over the long run, producers and sorters make zero profits, and the payment to producers for making a grade, G_i, is equal to the price charged to consumers for that grade, P_i.

Producers are modeled as N identical agents who produce a good of quality q subject to an additive error. For simplicity, quality production is assumed to be linear, as follows:

$$q = e + \lambda \qquad \text{where } \lambda \sim F(0, \sigma) \qquad (1)$$

After production, quality is observable to both the sorter and producer. The market share of grade i is denoted $\pi_i(e)$, which is equal to the probability that q is between x_i and x_{i+1} for a given level of effort. For each grade, the market share is:

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\begin{aligned}
\pi_1(e) &= P(x_1 < q < x_2 \mid e) = F(x_2 - e) - F(x_1 - e) \\
\pi_i(e) &= P(x_i < q < x_{i+1} \mid e) = F(x_{i+1} - e) - F(x_i - e) \\
\pi_{\bar{i}}(e) &= P(x_{\bar{i}} < q) = 1 - F(x_{\bar{i}} - e)
\end{aligned}
\qquad (2)
$$

Table (4) presents an index of notations for grades and producer payments using the current USDA beef grading system as an example. Weekly Agricultural Marketing Service (AMS) reports[5] include Prime as the best quality grade and Ungraded as the lowest. Though not listed in the table, the AMS reports also include Branded beef as a quality category. This quality category as defined by the AMS includes beef that is:

> *"…produced and marketed under a corporate trademark or under one of USDA's certified programs where the base of the brand is quality, yield, or breed*

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[5] Available at http://www.ams.usda.gov/lsmnpubs/mbeefw.htm

characteristics of the product which are not unique to any one packer and can be produced by anyone in the industry, regardless of the brand."

On cutout reports, the AMS further explains that Branded beef only includes that in the upper Choice category. This quality category essentially represents a new intermediate quality grade with standards between Choice and Prime that has been introduced through a certification program.

Producers are assumed to be risk-neutral with a cost of exerting effort of *h(e)* that is increasing and convex. The producer surplus is then:

$$PS(e) = N\left(\sum_i G_i \pi_i(e) - h(e)\right) \tag{3}$$

Substituting in probabilities, Equation (3) can be alternatively written as

$$PS(e) = N\left(G_{\bar{i}} + \sum_2^{\bar{i}-1}\left((G_i - G_{i+1})F(x_{i+1} - e)\right) - G_1 F(x_1 - e) - h(e)\right) \tag{4}$$

Optimal producer effort, e', is the effort level that maximizes the producer's surplus. Noting that $\partial F(x_i - e)/\partial e$ is equal to $-f(x_i - e)$, a local first order condition for an optimum is:

$$\frac{\partial PS(e)}{\partial e} = N\left(G_1 f(x_1 - e') + \sum_2^{\bar{i}-1}\left((G_{i+1} - G_i)f(x_{i+1} - e')\right) - \frac{\partial h(e')}{\partial e}\right) = 0 \tag{5}$$

The first two terms in Equation (5) represent the marginal benefit of increasing effort in terms of changes in probabilities of making a certain grade. The third term represents the marginal cost of effort. As is typical, optimization implies that producers increase effort until the marginal cost of effort is equal to the marginal benefit. The possible non-monotonicity of the marginal benefit curve implies that the first-order condition yields multiple solutions, a problem that is noted by Laffont and Martimort (2002) among

others. Interestingly, only increases in $G_{\bar{i}}$, the payment to the uppermost grade, are certain to increase producer effort for the intuitive reason that higher payments to lower quality grades may discourage the production of higher quality.

An example of the production process is graphically depicted in Figure (2) where the error in production, λ, is uniform with parameters zero and one. Assuming that each grade has a positive market share, then $\pi_1(e')$ is $x_2 - e' + \frac{1}{2}$, $\pi_i(e')$ is $x_{i+1} - x_i$ and $\pi_{\bar{i}}(e')$ is $e' + \frac{1}{2} - x_i$. From Equation (3), the producer surplus is equal to:

$$PS(e') = N\left(G_1(x_1 - e' + \tfrac{1}{2}) + \sum_2^{\bar{i}-1} G_i(x_{i+1} - x_i) + G_{\bar{i}}(e' + \tfrac{1}{2} - x_{\bar{i}}) - h(e')\right) \qquad (6)$$

Notice that effort, e, only affects the surplus through the probabilities of the highest and the lowest categories, respectively. For intermediate grades, increases in effort equally change the probability of moving both into and out of the grade. Only changes to probabilities of qualifying for the highest and lowest categories are not offset. As is shown in Figure (2), the density of grades 2 and 3 remain the same regardless of whether effort is e_1 or e_2.

The same phenomenon can arise for marginal changes in effort under alternative distributions. At the optimum effort level, the first order condition in equation (5) is satisfied at the global optimum effort level, e'. The comparative static solution in equation (7) below represents the effect of an increase in the payment, G_i on the market share of grade i, an intermediate grade[6]. Recall that the distribution $f(\lambda)$ is the distribution of the error in production, λ, where $q = e' + \lambda$. The marginal effect of effort on the probability that quality surpasses a certain grade, $P(q > x_i)$ or $P(\lambda > x_i - e')$, is the

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[6] An intermediate grade is neither the highest nor lowest possible quality grade.

probability density function evaluated at $f(x_i - e')$. The effect of an increase in the payment for a grade is shown in Equation (7).

$$\frac{\partial \pi_i}{\partial G_i} = \frac{\partial \pi_i}{\partial e'} \frac{\partial e'}{\partial G_i} = \frac{-[f(x_{i+1} - e') - f(x_i - e')]^2}{-G_i \frac{\partial f(x_i - e')}{\partial e} - \frac{\partial^2 h(e')}{\partial e^2} + \sum_{i=2}^{\bar{i}-1} [G_i - G_{i+1}] \frac{\partial f_{i+1}(e')}{\partial e}} \quad (7)$$

Equation (7) indicates that the market share of good *i* is invariant to an increase in G_i if $f(x_{i+1} - e')$ and $f(x_i - e')$ are equal. The intuition for this result stems from an inspection of Figure (2). Once the densest part of the quality distribution is captured within the boundaries of grade 3, no change in producer effort can change the proportion of goods qualifying for the grade. The supply of a grade *i* may still increase in response to an increase in G_i, but only by inducing more producers to enter the market (increasing *N*) and not by causing producers to adjust effort levels. Once $f(x_{i+1} - e)$ and $f(x_i - e)$ are equal, it is likely that production of graded goods behaves as if grades are produced in fixed proportions. Therefore, if consumer preferences for beef were to shift so as to increase the price of Choice graded beef, perhaps due to a shift in diets or the invention of a complementary food processing good, producers will initially readjust their effort levels to increase the share of Choice they produce. The ability to increase the share of Choice produced is limited, however, once the producers have centered their effort levels within the upper and lower bounds of the Choice grade. If the price of Choice continues to rise, there is no further adjustment to effort that increases the production of Choice and only entry of outside producers or an adjustment of grade standards can increase Choice output.

Figure (3) shows the distribution of quality when the error in quality production is normal. Between the upper and lower portions of Figure (3), effort increases in response to an increase in the payment to a producer for making grade 3. While the market share of grade 3 has now increased, changes in effort can no longer increase the market share of grade 3, as $f(x_3)$ and $f(x_4)$ are equal. Now, only changes in the number of producers can influence the supply of grade 3. Essentially, the fattest part of the quality distribution is now captured in grade 3. Because the error in quality production determines the market share, the supply of a specific grade may not increase in response to an increase in producer payment.

IV.B. Consumers and Demand

Consumer demand follows the vertical differentiation model of demand used in Mussa and Rosen (1978). Consumer tastes for quality, θ, are distributed according to the cumulative distribution $S(\theta)$ with a strictly positive support[7] across M possible risk-neutral consumers. Consumers with larger θ values have stronger preferences for quality.

Let μ_i be the expected quality of goods that qualify for grade i so that:

$$\mu_i = \int_{x_i}^{x_{i+1}} \frac{f(\lambda)}{\pi_i(e)}(e+\lambda)d\lambda \qquad (8)$$

An individual consumer who chooses a good in grade i receives the following indirect utility as a function of expected quality, μ_i, and price, p_i:

$$u(\mu_i, p_i) = \theta\mu_i - p_i \qquad (9)$$

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[7] In similar work by Ligon (2001), consumers are assumed to maximize utility by choosing between quality and a *numeraire* good. In his model, heterogeneity in consumer's income rather than in quality preferences drives the selection of different grades.

Consumers select goods that fulfill both the individual rationality (IR) constraint and the incentive compatibility (IC) constraint. The IR constraint implies that the consumer must receive a surplus at least as large as their reservation utility, $\overline{U}$, so that:

$$u(\mu_i, p_i) = \theta\mu_i - p_i \geq \overline{U} \qquad\qquad \text{(IR)} \qquad\qquad (10)$$

The IC constraint implies that the consumer receives an indirect utility at least as large as that from selecting a different good.

$$\theta\mu_i - p_i \geq \theta\mu_j - p_j \quad \text{for all } i \neq j \qquad\qquad \text{(IC)} \qquad\qquad (11)$$

The IR constraint is only binding for consumers at the lowest quality grade as consumers of higher qualities receive a positive surplus when the IC constraint is satisfied.

As the number of producers, N, is smaller than M, the number of potential buyers, producers set prices so that only the $\frac{N}{M}$ proportion of possible consumers with the largest θ purchase goods as shown in Figure (4). In general, sellers seek to maximize the producer surplus by pricing to segment the market by preference type. Their pricing will ensure that only consumers with $\theta > \theta_{\bar{i}}$ purchase grade $\bar{i}$ and only consumers with $\theta_{i+1} > \theta > \theta_i$ purchase grade i. This allocation is efficient in that the consumers with the strongest preferences for quality receive the highest quality goods.

For the highest quality grade, the quantity supplied is $N\pi_{\bar{i}}$, which is the proportion of output qualifying for grade $\bar{i}$, multiplied by the number of producers. The quantity demanded is $M(1 - S(\theta_{\bar{i}}))$. The boundary for preferences for which consumers purchase the top graded good, $\theta_{\bar{i}}$, is:

$$\theta_{\bar{i}} = S^{-1}\left(1 - \tfrac{N}{M}\pi_{\bar{i}}\right) \qquad\qquad (12)$$

The boundary for preferences on the second highest graded good is:

$$\theta_{\bar{i}-1} = S^{-1}\left(1 - \tfrac{N}{M}\left(\pi_{\bar{i}} + \pi_{\bar{i}-1}\right)\right) \tag{23}$$

Subsequent boundaries for lower grades are obtained similarly. The smallest value of θ for which a consumer still purchases a good is $S^{-1}\left(1 - \tfrac{N}{M}\left(\sum \pi_i\right)\right)$ or $S^{-1}\left(1 - \tfrac{N}{M}\right)$. Figure (4) shows a graphical depiction and Table (4) presents a hypothetical case with four grades. Prices are set to maximize the producer's surplus while ensure that both the IR and IC constraints are satisfied for each grade. Of the $\tfrac{N}{M}$ proportion of consumers that purchase goods, the top $\pi_{\bar{i}}$ proportion of consumers purchase the highest quality goods with average quality $\mu_{\bar{i}}$. The next $\pi_{\bar{i}-1}$ proportion of consumers purchases the grade $\bar{i}-1$ with average quality $\mu_{\bar{i}-1}$. The portion of the distribution greater than θ_1 represents the portion of all possible consumers to which goods are sold. Of that truncated distribution, the probability mass between θ boundaries represents the portion of active consumers purchasing each grade.

With the θ_i values depicted in Figure (4), prices can be determined by solving first for the price of the lowest graded good. Prices of the lower quality goods can then be be used to determine the prices of the next highest graded good. Since higher graded goods are of higher quality, consumers will always prefer the higher grade to the lower grade good if their prices are equal. Similarly, consumers with higher values of θ have a greater willingness to pay for quality than other consumers. For higher quality goods, sellers will raise the price until consumers with low θ's drop out of the market and consumers with high θ's are indifferent between buying that good and the lower quality good. Consumers with low θ's essentially have only one consumption choice, the lowest quality good. Profit maximizing sorters charge consumers of the lowest graded good the

price that sets the indirect utility of the marginal consumer (with preferences of θ_1) equal to $\overline{\overline{U}}$, which is hereafter assumed to be zero. At that price, the participation constraint binds for the marginal consumer, or:

$$P_1 = \theta_1 \mu_1 \tag{14}$$

While the marginal consumer of the second grade receives no surplus to trade, intermediate consumers with θ between θ_1 and θ_2 receive a positive consumer surplus owing to their stronger preferences for quality.

For higher graded goods, the sorter must set prices to ensure that the consumer does not switch to a lower quality good. In other words, the IC constraint of Equation (18) must be satisfied in addition to the participation constraint. The price which solves both these constraints is:

$$P_{i+1} = \theta_{i+1}\left(\mu_{i+1} - \mu_i\right) + P_i \tag{15}$$

For the second quality grade, the marginal consumer now receives a surplus of $\theta_{i+1}\left(\mu_{i+1} - \mu_i\right)$. Consumers of the second grade would purchase the second graded good if the price were equal to $\theta_2 \mu_2$ and no other grade were available. At this price, the consumer's surplus from purchasing the good exceeds his reservation utility. The availability of lower grades, however, offers the consumer a surplus. The presence of lower grades obligates the seller to reduce the price of second graded good in the manner analogous to the way an increase in a consumer's reservation utility forces the seller to lower the price of the grade 1 goods. The value of this price reduction is known as the *information rent* within contract theory as it reflects the value of the consumer's private knowledge of their preferences for quality. While consumers with the stronger

preferences pay higher prices for higher graded good, they also receive increasingly

larger information rents.

The iterative nature of prices under the vertical differentiation structure links

prices across all goods as shown in Table (4). For example, a decrease in the price of

chicken that increases the reservation utility of the typical consumer, $\overline{U}$, decreases the

price of the lowest quality good, which then causes the prices of all higher graded goods

to decrease as well. Alternatively, a decrease in the number of producers, N, increases

the price of all grades through its initial effect on the lowest graded good.

IV.C. Supply and Demand in Equilibrium

In a fashion similar to that of the monopolistic competition of demand, the

producer and sorter surplus converges to zero over the long run equilibrium[8]. Sorters

earn a zero surplus as payments from sorters to producers, G_i, equal the payments from

consumer to sorters, P_i, in a competitive market for sorters. Producer entry and exit

eliminates the producer surplus over the long run as prices, weighted by the shares

produced of each quality grades, equal the cost of effort.

When producers earn a positive surplus (profits), outside producers enter the

market and existing producers expand operations. As N increases, the prices of the

lowest graded good, $P_1 = S^{-1}(1 - \frac{N}{M})\mu_1$, and all higher graded goods decrease. The

expanded supply drives prices down until the expected producer surplus is equal to zero.

Conversely, producer losses encourage exit from the industry. As firms leaves the

industry, N decreases and prices increase which eliminates producer losses over the long

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[8]Ligon (2001) approaches grading from a continuous grading framework and models consumers in a
slightly different utility framework. Ligon focuses on the pricing structures that emerge under different
information structures and does not address discrete grading.

run. Other things equal, the distribution of qualities is invariant to the number of

producers. Because firm entry and exit generates price effects, however, the optimal

effort level chosen by producers is likely to change. In the simulation section, the

producer, consumer, and total surpluses are simulated for a given set of grades in a

market, assuming that effort is constant, and shows that the producer surplus is

decreasing in the number of firms.

IV.D. *The Effect of Changing a Grading Standard*

Grade standards are often outside the immediate control of either producer or

consumer groups, and are not changed frequently. Comparative statics show that changes

in grade standards may significantly influence the size of the total surplus to trade in the

short run, and the distribution of that surplus between producers and consumers.

The consumer surplus from trade is:

$$CS = M \sum_i \left(\int_{\theta_i}^{\theta_{i+1}} (\theta \mu_i - P_i) s(\theta) d\theta \right) = M \sum_i \left(\mu_i \int_{\theta_i}^{\theta_{i+1}} (\theta) s(\theta) d\theta \right) - N \sum_i \pi_i P_i \qquad (23)$$

The first term represents the benefits to the proportion of active consumers who purchase

the good, while the second represents payments to producers. Notice that the second

element of Equation (23) is simply the revenue from the producer surplus defined in

Equation (4). In considering the effect of a grade standard change on the consumer

surplus, it is useful to assume that effort, e, is constant.   Essentially, this specification

assumes that the distribution of quality is fixed, a plausible assumption if the cost of

effort function, $h(e)$, is vertical or if production decisions regarding effort are fixed in the

short run. With the quality distribution fixed, grading only serves to reallocate qualities

across consumers of different preference types. In this case, the total surplus is the sum of the producer surplus, Equation (4), and the consumer surplus, Equation (24), or:

$$TS = PS + CS = M\left(\mu_1 \int_{\theta_2}^{\theta_2} \theta s(\theta)d\theta + \mu_2 \int_{\theta_2}^{\theta_3} \theta s(\theta)d\theta + \mu_3 \int_{\theta_3}^{\theta_4} \theta s(\theta)d\theta + \mu_4 \int_{\theta_4}^{\infty} \theta s(\theta)d\theta\right) - Nh(e) \quad (24)$$

A change in the standard for grade 4 only affects the portions of the producer surplus derived from changes in revenue from goods making grade 3 and grade 4, represented as PS_3 and PS_4. The change in producer surplus is then:

$$\frac{\partial PS}{\partial x_4} = \frac{\partial PS_4}{\partial x_4} + \frac{\partial PS_3}{\partial x_4} = N\left(\frac{\partial(\pi_3 P_3)}{\partial x_4} + \frac{\partial(\pi_4 P_4)}{\partial x_4}\right) \quad (25)$$

The change in PS_3 from a change in x_4 is:

$$\frac{\partial PS_3}{\partial x_4} = N\left((f(x_4 - e))(\theta_3(\mu_3 - \mu_2) + \ldots) + (F(x_4 - e) - F(x_3 - e))\frac{\partial\mu_3}{\partial x_4}(\theta_3)\right) > 0 \quad (26)$$

Raising x_4 increases the number of goods in grade 3, making the first term of Equation (26) positive, and increases the quality and price of grade 3, making the second term positive as well. The change in PS_4 from a change in x_4 is:

$$\frac{\partial PS_4}{\partial x_4} = N(-f(x_4 - e))(\theta_4(\mu_4 - \mu_3) + \theta_3(\mu_3 - \mu_2) + \ldots)$$
$$+ N(1 - F(x_4 - e))\left(\frac{\partial\theta_4}{\partial x_4}(\mu_4 - \mu_3) + \theta_4\left(\frac{\partial\mu_4}{\partial x_4} - \frac{\partial\mu_3}{\partial x_4}\right) + \theta_3\left(\frac{\partial\mu_3}{\partial x_4}\right)\right) \quad (27)$$

Raising x_4 decreases the number of goods in grade 3, making the first term negative. Raising x_4 also increases the quality of grade 4, but may reduce the price of grade 4 if $\partial\mu_3/\partial\mu_4$ is larger than $\partial\mu_4/\partial\mu_4$. For this reason, the net effect on the producer surplus from a change in x_4 is ambiguously signed.

The derivatives $\partial PS / \partial x_4$, $\partial CS / \partial x_4$, and $\partial TS / \partial x_4$ show the effect that changes in the grade standard for the highest grade have on the producer surplus, the consumer surplus, and the total surplus respectively.

Let CS_i equal $\left(M\mu_i \int_{\theta_i}^{\theta_i} \theta s(\theta)d\theta - N\pi_i P_i \right)$, the consumer surplus that accrues only to consumers of good i. Changing x_4, the grade standard for grade 4, only affects consumers of grades 3 and 4 so that:

$$\frac{\partial CS}{\partial x_4} = \frac{\partial CS_4}{\partial x_4} + \frac{\partial CS_3}{\partial x_4} \tag{28}$$

Consumers of the third graded good receive a total surplus of:

$$
\begin{aligned}
CS_3 &= M\mu_3 \int_{\theta_3}^{\theta_4} \theta(\theta)d\theta - N\pi_3 P_3 \\
&= M\mu_3 \int_{\theta_3}^{\theta_4} \theta(\theta)d\theta - N\pi_3 \left(\theta_3 (\mu_3 - \mu_2) + \ldots \right)
\end{aligned}
\tag{29}
$$

A change in x_4 changes the consumer surplus as follows:

$$\frac{\partial CS_3}{\partial x_4} = M\left(\frac{\partial \mu_3}{\partial x_4} \int_{\theta_3}^{\theta_4} (\theta)s(\theta)d\theta + \mu_3 \frac{\partial \int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta}{\partial x_4} \right) - N\left(f(x_4 - e)P_3 - \pi_3\theta_3 \left(\frac{\partial \mu_3}{\partial x_4} \right) \right) \tag{30}$$

This change in Equation (30) is ambiguously signed. The terms $\partial \mu_3 / \partial x_4$ and $\partial \int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta / \partial x_4$ are both positive, ensuring that the first term is positive. Increasing x_4 raises the standard of grade 4 but also expands the upper bound for grade 3. As higher quality goods are now included in grade 3, its quality and its market share increases. This second term is ambiguously signed. Increasing the upper boundary for grade 3 increases

the number of consumers paying P_3, decreasing their surplus but also increases the quality those consumers receive.

The change in CS_4 is similar:

$$CS_4 = M\mu_i \int_{\theta_4}^{\infty} \theta(\theta)d\theta - N\pi_4 P_4$$

$$= M\mu_i \int_{\theta_4}^{\infty} \theta(\theta)d\theta - N\pi_4 \left(\theta_4(\mu_4 - \mu_3) + \theta_3(\mu_3 - \mu_2) + \theta_2(\mu_2 - \mu_1) + \theta_1\mu_1 - \overline{U}\right)$$

(31)

The effect of the same grading change on consumers of the highest graded good is:

$$\frac{\partial CS_4}{\partial x_4} = M\left(\frac{\partial \mu_4}{\partial x_4} \int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta + \mu_4 \frac{\partial \int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta}{\partial x_4}\right)$$

$$- N(-f(x_4 - e))(\theta_4(\mu_4 - \mu_3) + \theta_3(\mu_3 - \mu_2) + \ldots)$$

(32)

$$- N(1 - F(x_4 - e))\left(\frac{\partial \theta_4}{\partial x_4}(\mu_4 - \mu_3) + \theta_4\left(\frac{\partial \mu_4}{\partial x_4} - \frac{\partial \mu_3}{\partial x_4}\right) + \theta_3 \frac{\partial \mu_3}{\partial x_4}\right)$$

Equation (32) is also ambiguously signed. The sign of the first term is ambiguous as $\partial \mu_4 / \partial x_4$ is positive, while $\partial \int_{\theta_4}^{\theta_i}(\theta)s(\theta)d\theta / \partial x_4$ is negative because raising the standard for grade 4 increases its average quality while decreasing its market share. The second term is negative, as fewer consumers pay P_4 after the grade change. The third term, representing the price effect, is more difficult to interpret. Increasing the quality standard of grade 4 simultaneously increases the quality of both grades 3 and 4[9], while also raising θ_4, since $\partial \theta_4 / \partial x_4$ is positive. As the average quality of grade 3 increases, its price also increases. Since prices are linked across goods, the price of grade 4 also increases. Again, the net effect of the third term is ambiguous. Equation (33) compiles the two effects below.

---

[9] $(\partial \mu_3 / \partial x_4, \partial \mu_4 / \partial x_4 > 0)$

$$\frac{\partial CS}{\partial x_4} = M\mu_4 \left(\frac{\partial \int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta}{\partial x_4} + \frac{\partial \int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta}{\partial x_4} \right) + Nf\left(x_4 - e\right)\left(\theta_4\left(\mu_4 - \mu_3\right)\right)$$

$$+ \left(-N\pi_3\theta_3 + N\pi_4\left(\theta_3 - \theta_4\right) + M\int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta \right)\frac{\partial \mu_3}{\partial x_4}$$

$$+ \left(M\int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta + \theta_4\pi_4 \right)\frac{\partial \mu_4}{\partial x_4} + \left(\mu_4\pi_4 - \mu_3\pi_4\right)N\frac{\partial \theta_4}{\partial x_4} - N\pi_3\theta_3\mu_2$$

$$= M\left(\mu_4 \frac{\partial \int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta}{\partial x_4} + \mu_4 \frac{\partial \int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta}{\partial x_4} + \frac{\partial \mu_3}{\partial x_4}\int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta + \frac{\partial \mu_4}{\partial x_4}\int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta \right) - \frac{\partial PS}{\partial x_4}$$

$$(33)$$

Combining Equation (37) and the effect described in Equations (26) and (27), the net change in the total surplus is given below.

$$\frac{\partial TS}{\partial x_4} = M\left(\frac{\partial \mu_3}{\partial x_4}\int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta + \mu_3 \frac{\partial \int_{\theta_3}^{\theta_4}(\theta)s(\theta)d\theta}{\partial x_4} + \frac{\partial \mu_4}{\partial x_4}\int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta + \mu_4 \frac{\partial \int_{\theta_4}^{\infty}(\theta)s(\theta)d\theta}{\partial x_4} \right)$$

$$(34)$$

Equation (34) is also neither necessarily positive nor necessarily negative. Altering x_4 influences the total surplus both through its effect on average qualities and its effect on the θ_i terms which define the boundaries of consumer preferences for each grade. The simulation section shows that lowering the level of x_4 may either increase or decrease the total surplus from trade.

IV.E. *The Effect of Introducing a New Grade*
To consider the effect of introducing a new grade between the third and fourth, let $x_{3.5}$ represent a new quality standard between x_3 and x_4. This new grade might represent branded beef that arose in the 1990's in addition to the USDA grading program. Assume that this new grade is marketed in an identical manner to those on the ordinary

grading system. Prices, quality standards, θ preferences, and market shares are denoted under the new standards with an apostrophe so that average qualities are $\mu'_3, \mu'_{3.5}$, and μ'_4, prices are $P'_3, P'_{3.5}$ and P'_4, and θ preferences are $\theta'_3, \theta'_{3.5}$ and θ'_4. The intermediate grade only influences the qualities of the third grade so that $\mu'_3 < \mu_3 < \mu'_{3.5}$ and $\mu'_4 = \mu_4$. As the market share of grade 4 is unaffected so that $\pi_4 = \pi'_4$, its theta boundary is unaffected so that $\theta_4 = \theta'_4$. The market shares of the new third grade, π'_3, and the intermediate grade, $\pi'_{3.5}$, sum to the share of the original third grade, π_3, which implies that $\theta_3 = \theta'_3 < \theta'_{3.5}$. The price of grade 3 falls with the introduction of the new grade due to the reduction in quality so that $P'_3 < P_3$ while the price of the intermediate good is larger than that of grade 3 before the introduction so that $P'_{3.5} > P_3$. Because the price of the grade 4 good is tied to the price of lower-graded goods through information rents, its price may increase or decrease.

The producer surplus change under the old grading system is

$$PS^{Old} = \sum_i \pi_i P_i - h(e) = N(... + \pi_3 P_3 + \pi_4 P_4 - h(e)) \qquad (35)$$

while the producer surplus under the new grading system is:

$$PS^{New} = \sum_i \pi'_i P_i - h(e) = N(... + \pi'_3 P'_3 + \pi'_{3.5} P'_{3.5} + \pi'_4 P'_4 - h(e)) \qquad (36)$$

For simplicity, it is again assumed that effort, e, is unchanged. The net change in the producer surplus is:

$$\Delta PS = N((P_3 - P'_3)\pi'_3 + (P_3 - P'_{3.5})\pi'_{3.5} + (P_4 - P'_4)\pi'_4) \qquad (37)$$

or, alternatively, after simplification:

$$\Delta PS = \theta'_3(\mu_3 - \mu'_3)(\pi'_3 + \pi'_{3.5} + \pi'_4) - \theta'_{3.5}(\mu'_{3.5} - \mu'_3)(\pi'_{3.5} + \pi'_4) + \theta'_4(\mu'_{3.5} - \mu'_3)\pi'_4 \qquad (38)$$

Notice that if the introduction of the new grade is trivial so that $x_{3.5} = x_4$, then $\mu_3 = \mu_3'$, $\pi_{3.5}' = 0$, and $\theta_{3.5}' = \theta_4'$, then there is no change in the producer surplus.

The change in the consumer surplus can also be isolated into its effect on grade 3 and grade 4. Where the original consumer surplus is:

$$CS^{OLD} = \ldots + M\mu_3 \int_{\theta_3}^{\theta_4} \theta s(\theta)d\theta - N\pi_3 P_3 + M\mu_4 \int_{\theta_4}^{\infty} \theta s(\theta)d\theta - N\pi_4 P_4 \tag{39}$$

The new consumer surplus is:

$$CS^{NEW} = M\mu_3' \int_{\theta_3'}^{\theta_4'} \theta s(\theta)d\theta - N\pi_3' P_3' + M\mu_{3.5}' \int_{\theta_{3.5}'}^{\theta_4'} \theta s(\theta)d\theta - N\pi_{3.5}' P_{3.5}'$$
$$+ M\mu_4' \int_{\theta_4'}^{\infty} \theta s(\theta)d\theta - N\pi_4' P_4' \tag{40}$$

The change in consumer surplus can then be simplified to:

$$\Delta CS = CS^{OLD} - CS^{NEW}$$
$$= M\left((\mu_3 - \mu_3')\int_{\theta_3'}^{\theta_4'} \theta s(\theta)d\theta_3 + (\mu_3 - \mu_{3.5}')\int_{\theta_{3.5}'}^{\theta_4'} \theta s(\theta)d\theta + (\mu_4 - \mu_4')\int_{\theta_4'}^{\infty} \theta s(\theta)d\theta \right) \tag{41}$$
$$- N\left((P_3 - P_3')\pi_3' + (P_3 - P_{3.5}')\pi_{3.5}' + (P_4 - P_4')\pi' \right)$$

$$\Delta CS = M\left((\mu_3 - \mu_3')\int_{\theta_3'}^{\theta_4'} \theta s(\theta)d\theta_3 + (\mu_3 - \mu_{3.5}')\int_{\theta_{3.5}'}^{\theta_4'} \theta s(\theta)d\theta + (\mu_4 - \mu_4')\int_{\theta_4'}^{\infty} \theta s(\theta)d\theta \right)$$
$$- \Delta PS \tag{42}$$

The change in total surplus is the first term in Equation (42) or:

$$\Delta TS = M\left((\mu_3 - \mu_3')\int_{\theta_3'}^{\theta_4'} \theta s(\theta)d\theta_3 + (\mu_3 - \mu_{3.5}')\int_{\theta_{3.5}'}^{\theta_4'} \theta s(\theta)d\theta + (\mu_4 - \mu_4')\int_{\theta_4'}^{\infty} \theta s(\theta)d\theta \right) \tag{43}$$

Equation (43) shows that the total surplus may either increase or decrease even after accounting for the redistribution of the surplus between consumers and producers. This result stems from consumers selecting goods based on average quality and being risk-

neutral. Introducing a new good can sufficiently change average qualities to increase or decrease the total surplus from trade. Moreover, introducing a new grade improves allocative efficiency by increasing the segmentation of the market by quality type. The simulations also demonstrate that Equation (43) is ambiguously signed.

V.   *Simulation Results*

Three simulation experiments demonstrate the entry and exit process of reaching long-run equilibrium and the ambiguous effects on welfare of both changing a grade standard and introducing a new quality grade. The first simulation demonstrates that the producer surplus is decreasing in the number of producers in the industry. The long run equilibrium number of producers is then found for a given consumer preference distribution and set of quality standards. The second simulation demonstrates that the producer, consumer, and total surplus changes as the grade standard for the highest quality grade ranges over a continuum of levels. The grade standards that maximize each of those values are different, implying that control over grade standards may have value to producers and consumers. The third simulation demonstrates that the producer, consumer and total surplus also changes with the introduction of a new grade between the existing grade 3 and grade 4 standards. Surprisingly, the introduction a new grade can reduce the total surplus depending on where it is placed.

Simulations were performed assuming that there are 20,000 potential consumers with preferences drawn from the beta distribution.[10]   An *N* number of producers make a single good with a random quality determined by Equation (2). Effort is set to the level

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[10] Estimates not reported here were also performed with θ being drawn from the other distributions with similar results. Distributions that do not have closed supports, such as the normal and gamma distributions can show large swings from the presence of outliers. These distributions showed more variation between simulations especially with regard to welfare measures of the highest quality grades.

of 200 and the error in quality production is normal with a mean of 60 and a standard deviation of 25. In each of the simulations, the effort level is fixed at 200 with a cost of 8. This specification implies that effort is trivially inexpensive until the level of 200 and then prohibitively expensive afterwards. More appropriately, however, this specification can alternatively be interpreted as producers not being able to re-optimize effort levels in response to a change in grading standards. In the first simulation experiment, values are calculated for N between 8000 and 12000; In the other simulations, N is fixed at 10,000.

Given a set of quality and preference distributions, grade shares are determined using the grading standards in Equation (3) and expected qualities are determined as in Equation (15). Shares define θ boundaries as in Equation (19) and (20) and these values are used to determine prices as in Equations (21) and (22). Finally, the integrals that define consumer surplus in Equation (23) are numerically estimated by calculating each simulated consumer's individual surplus, then dividing by the total number of active consumers, N.[11] The producer surplus stated in Equation (4) is also estimated with prices and market shares.

The first simulation considers the number of producers in the market over the long run for grades fixed at the following levels: grade 1, 200; grade 2, 235; grade 3, 260; and grade 4, 290. Figure (5) relates the total producer surplus to the number of firms in the industry. The jaggedness of the line is caused by the re-simulation of qualities with each calculated producer surplus. The trend shows that the producer surplus is decreasing in N. In accordance with the earlier discussion, a positive producer surplus induces entry, which drives down prices and dissipates producer revenues. Table

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[11] To account for error using numerical estimation with random distributions, the simulation was performed with 1,000,000 and 500,000 simulated consumers and producers. The results were essentially identical.

(5) presents welfare measures and prices for several N values in the simulation. Figure (5) and Table (5) show that the producer surplus is decreasing in the number of firms and that the producer surplus is closest to zero and the market is in long run equilibrium when there are 10,348 firms in the market.

The second simulation considers the effect of changing the standard for grade 4, x_4, by varying it over 1000 evenly spaced points between 261 and 350[12]. Each simulation occurs with 10,000 producers and 20,000 potential consumers. Preference parameters are drawn from the beta distribution with alpha 0.2 and beta 0.8, and the quality error distribution is again normal with mean 60 and standard deviation 25. As with each of the simulations, producer effort is fixed at the level of 200 with cost 8 throughout the simulation. The standard for the first three grades are again assumed to be 200, 235, and 260, respectively. Figures (6), (7) and (8) show the total surplus, total producer surplus, and total consumer surplus as x_4 varies. The increasing jaggedness of the line as x_4 increases is the result of the small number of goods with high qualities. Table (6) shows that adjusting grading standards affects the size of the total surplus and that the total surplus is maximized when x_4 is approximately 278.89. The distribution of the total surplus is also dependent on the grading standard, as the consumer surplus is maximized when x_4 is 267.71, while the producer surplus is maximized when x_4 is 292.75. Moreover, the grading standard that optimizes the total surplus is not that which optimizes the producer or consumer surplus.

Control over the standards of grading has value to producers and consumers. Grades improve allocative efficiency, as they divide the quality distribution more finely

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[12] A quality boundary could not be set equal to 260 as this would set the market share of grade 3 to zero which causes computational problems.

and therefore allow for a better matching of qualities with consumer preferences. The setting of grades also influences average qualities of individual grades, which alters the size and distribution of the total surplus to trade. Periodically, producer groups, such as the American Angus Association after 1976, express discontent with grading standards. Alterations to standards for grades are typically subject to public comment preceding the introduction of a new market rule by the AMS. Harris, Cross and Savell (1988) note that the National Cattlemen's Beef Association is very active in the development of grade standards. While this paper does not attempt to evaluate claims of producer and retail groups regarding the control of grade standards, it does show that control over the institutional mechanism controlling grading is valuable to interested parties.

The third set of simulations illustrates the effect of introducing a new quality grade by simulating 200 new grade standards between grade 3 and grade 4 in the interval between 261 and 289. Figure (9), (10), and (11) show the sizes of the total surplus, producer surplus, and consumer surplus as they vary over the grade standard with the remaining grades. The right and left endpoints on the graph show the approximate values that occur when no new grade is added. Table (7) shows welfare estimates and prices for several values of $x_{3.5}$. In general, the grade standard which maximizes the total surplus, 274.65, differs from the standard that maximizes the producer surplus, 276.9, although it is close to the standard which maximizes the consumer surplus, 273.24.

The maximum total surplus, consumer surplus and producer surplus are higher both when grades are adjusted and when new grades are added. Figures (9), (10), and (11) suggest that the introduction of a new grade strictly increases the total surplus as well as the consumer surplus and the producer surplus. Figure (12), however, shows that

this result is sensitive to the choice of quality distribution. In this simulation, effort remains at 200, but now the distribution of the error in quality is now the beta distribution with parameters of 3 and 4[13]. In this figure, the total surplus is shown to be decreasing for a distinct range of grade values indicating that a new grade can decrease the total surplus in certain situations.

Introducing a new grade benefits consumers by allowing for a better distribution of qualities while increasing the power of sellers to price discriminate as more grades are offered. At the same time, more consumption options on the market force producers to offer larger information rents to consumers. A larger number of grades need not benefit both consumers and producers, as indicated by Equation (43). In this case, the change in the average quality of grades from reassigning goods between grades is sufficiently large as to reduce the total surplus, as shown in Figure (12).

The number of grades again has important impacts on total welfare and its distribution between consumers and producers. These effects are purely informational and occur in the absence of both consumer and producer risk aversion and supply effects. As producer groups use certification to create finer divisions of quality in the beef industry, significant welfare improvements may arise even in the absence of incentive effects that change the level of producer investment in quality improvement.

VI. *Summary and Conclusions*

The 1990's witnessed a substantial expansion of quality certification programs in the beef industry. As certification programs potentially changed the control over the

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[13] The error distribution is widened and re-centered so that it ranges between 0 to 112. All grades are thus assured of having positive market shares.

standards for and the number of quality grades, new concerns arose regarding their effects on consumer and producer welfare. This paper presents an equilibrium model of quality grading where grading is costless and economic agents are risk neutral. Comparative static analysis and simulations show that placement and number of quality standards have significant effects on the size and distribution of the total benefits to trade. Moreover, finer division of the quality distribution through the introduction of a new grade can actually reduce either consumer welfare or total welfare.

The expansion of beef branding and certification is often lauded for improving incentives for quality improvement. This paper shows that a significant redistribution of welfare may be associated with short run changes in grading standards. As certification and branding become more prominent, finer distinctions in quality become available. While this potentially improves allocative efficiency, it also allows producers to segment the market by consumer type.

Future versions of this paper will allow for include a section explicitly calibrating the model to the beef industry with its market shares and prices. Additionally, it will consider the introduction of a new grade into an already optimally designed grading system. Importantly, this paper does not consider market power in the creation of grade standards. Since branding introduces the possibility of price-setting or quantity-restricting behavior, it may be an important to consider the introduction of a new grade as an optimization process for producers only as a topic for future research as well.

VII.   Bibliography

Agricultural Marketing Service, USDA, "Comparison of Certified Beef Programs", http://www.ams.usda.gov/lsg/certprog/industry.htm, July 13th 2004

Akerloff, George A. "The Market for 'Lemons'; Quality Uncertainty and the Market Mechanism", *Quarterly Journal of Economics*, Volume 84, Issue 3, August 1970

Berry, S, Levinsohn, J and Pakes, A, "Automobile Prices in Market Equilibrium," *Econometrica*, Vol. 63, No. 4 (July, 1995) 841-890

Berry, Steven T., "Estimating Discrete-Choice Models of Product Differentiation," *Rand Journal of Economics*, Vol. 25, No. 2, Summer 1994

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," KSU Research and Extension Agricultural Economics Library, http://www.oznet.ksu.edu/library/agec2/, December 1999

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

Certified Angus Beef Program LLC Promotional Materials, "Two Decades of Leadership", http://www.cabprogram.com, circa 1999

Dikeman, M.E., "Fat Reduction in Animals and the Effects on Palatability and Consumer Acceptance of Meat Products," *Proc. Recip. Meat Conference* 40 (1987):93

Ferrier, Peyton and Lamb, Russell, "What a Long, Strange Ride It's Been: Government Regulation of the U.S. Beef Industry," NCSU Working Paper, 2004

Food Safety and Inspection Service, USDA, "Inspection and Grading: What are the Differences?" http://www.fsis.usda.gov/factsheets/inspection_&_grading, retrieved in May 2002

Fuez, D M, and Umberger, W J, "Consumer Willingness to Pay for Flavor in Beef Steaks: An Experimental Economics Approach," *Cornhusker Economics*, March 21, 2001, Institute for Agriculture and Natural Resources, University of Nebraska-Lincoln.

Fuez, Dillon M. "Market Signals in Value Based Pricing Premiums and Discounts" *Journal of Agricultural and Resource Economics* 24(2):327-341

Fuez, Dillon M. "Issues to consider when selling Cattle on a Grid or Formula," http://www.ianr.unl.edu/pubs/farmmgt/g1352.htm, June 1998

Grossman, Sanford J. and Hart, Oliver D., "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *The Journal of Political Economy*, August 1986

Harris, J.J., H.R. Cross, and J.W. Savell, "History of Meat Grading in the United States", http://meat.tamu.edu/history.html, May 1988

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," 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

Holmstrom, Bengt and Milgrom, Paul, "The Firm as an Incentive System," *The American Economic Review*, Volume 84, Issue 4, September, 1994

Holmstrom, Bengt, "Moral Hazard in Teams," *The Bell Journal of Economics*, Autumn, 1982

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

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(May/June 1987): 512-517

Laffont, Jean-Jacques and Martimort, David, *The Theory of Incentives*, Princeton University Press, 2002

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

Lawrence, John D., "Quality Assurance 'Down Under': Market Access and Product Differentiation," MATRIC Briefing Paper 02-MBP 1, Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa, 2002

Lazear, E P, "Salaries and Piece Rates," *Journal of Business*, 1986, Vol. 59, no. 3

Libecap, Gary, "The rise of the Chicago Meatpackers and the Origins of Meat Inspection and Antitrust", *Economic Inquiry*, April 1992

Ligon, Ethan, "Quality and Grading Risk", A Comprehensive Assessment of the Role of Risk in U.S. Agriculture, edited by R. Just and R. Pope, Kluwer Academic Publishers: Dordrecht, 2002

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

Mascollel, Andreu, Whinston, Michael D. and Green Jerry R., *Microeconomic Theory:* Chapter 14, 1995, Oxford University Press, NY

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

Mintert, J.R., Brazle, F.K., and Schroeder, T.C., "Fed Cattle Quality: How Does It Affect Prices Received by Cattle Feeders?" KSU Research and Extension Agricultural Economics Library, http://www.oznet.ksu.edu/library/agec2/, July 1993,

Mintert, James, Brazle, Frank, and Schroeder, Ted, Factor Affecting Auction Prices of Feeder Cattle, KSU Research and Extension Agricultural Economics Library, http://www.oznet.ksu.edu/library/agec2/, January 2001,

Mussa, Michael and Rosen, Sherwin, "Monopolistic Competition and Product Quality," *Journal of Economic Theory,* 1978

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

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, 1974

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

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 (May/June 1987) 512-517

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. Summer 1998

Schroeder, Ted, Ward, Clem, Lawrence, John, and Fuez, Dillon, "Fed Cattle Marketing Trends and Concerns: Cattle Feeder Survey Results," *Kansas State University*, 2002, http://www.oznet.ksu.edu/library/agec2/mf2561.pdf

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

Sherwin Rosen, Kevin M. Murphy, Jose A. Scheinkman, "Cattle Cycles," *The Journal of Political Economy*, Vol. 102, No. 3. (Jun., 1994), pp. 468-492.

Sinclair, Upton, The Jungle, See Sharp Press, 1906

Skaggs, Jimmy, Prime cut : livestock raising and meatpacking in the United States, 1607-1983, 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 Report of 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, December 1995

Stiglitz, Joesph, "Post Walrasian and Post Marxian Economics," *Journal of Economic Perspectives*, Volume 7, Number 1- Winter 1993.

Ward, Ronald W. and Stevens, Thomas "Price Linkages in the supply chain: The chase for structural adjustments in the Beef Industry" *American Journal of Agricultural Economics*, 82 (Number 5, 2000):1112-1122

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., 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*, 1999
– "Consumer Impressions of Tender Select Beef," *Journal of Animal Science*,
1999
– "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*, 1999
– "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,* 1999

VIII. Tables and Figures

Table -1 - Summary Statistics on Weekly Output of Beef Grades

Mean	Prime	Brand	Choice	Select	Ungraded
Shares	0.77%	6.80%	31.08%	25.30%	36.06%
Price (Dollars/cwt)	144.43	133.43	127.58	118.81	117.51
Quantities (in Millions)	1.730	15.246	69.721	56.761	80.894

Table-2 - Certification Program Formation

Year	Active Certification Programs:
1993	3
1994	3
1995	5
1996	7
1997	8
1998	12
1999	20
2000	26
2001	34
2002	36
2003	38
2004	47

Table -3 - Index of Notations for Supply

Grade	Index	Payment	Market Share
Prime	$\bar{i} = 4$	$G_{\bar{i}}$	$\pi_4 = 1 - F(x_4 - e)$
Choice	$i = 3$	G_3	$\pi_3 = F(x_4 - e) - F(x_3 - e)$
Select	$i = 2$	G_2	$\pi_2 = F(x_2 - e) - F(x_1 - e)$
Ungraded	$i = 1$	G_1	$\pi_1 = F(x_2 - e) - F(x_1 - e)$

Table -4 - Index of Notations for Demand

Grade	Index	Price, Market Share
Prime	$\bar{i} = 4$	$P_4 = \theta_4(\mu_4 - \mu_3) + \theta_3(\mu_3 - \mu_2) + \theta_2(\mu_2 - \mu_1) + \theta_1\mu_1 - \bar{U}$ $\theta_4 = S^{-1}\left(1 - \frac{N}{M}\pi_4\right)$
Choice	$i = 3$	$P_3 = \theta_3(\mu_3 - \mu_2) + \theta_2(\mu_2 - \mu_1) + \theta_1\mu_1 - \bar{U}$ $\theta_3 = S^{-1}\left(1 - \frac{N}{M}(\pi_4 + \pi_3)\right)$
Select	$i = 2$	$P_2 = \theta_2(\mu_2 - \mu_1) + \theta_1\mu_1 - \bar{U}$ $\theta_2 = S^{-1}\left(1 - \frac{N}{M}(\pi_4 + \pi_3 + \pi_2)\right)$
Ungraded	$i = 1$	$P_1 = \theta_1\mu_1 - \bar{U}$ $\theta_1 = S^{-1}\left(1 - \frac{N}{M}(\pi_4 + \pi_3 + \pi_2 + \pi_1)\right)$

Table -5 - Welfare Measures and the Number of Producers

	TS	PS	CS	Prices (P_1,P_2,P_3,P_4)	θ_i $(\theta_1, \theta_2, \theta_3, \theta_4)$
N = 8,000	982,510	68,922	913,580	9.721,11.527, 16.707,42.25	0.0435,0.0724, 0.2113,0.8834
N = 9,000	998,980	36,664	962,310	6.246,7.538, 11.893,35.674	0.02797,0.0514, 0.1745,0.8281
N = 10,000	1,009,500	8,410	1,001,100	3.881,4.784, 8.313,29.538	0.0174,0.0362, 0.1428,0.7450
N = 10,348	1,012,500	19	1,012,500	3.237,4.021, 7.335,28.814	0.0145,0.0312, 0.1334,0.7333
N = 11,000	1,014,400	-16,116	1,030,500	2.297,2.892, 5.787,25.899	0.0102,0.0243, 0.1176,0.7039
N =12,000	1,017,800	-36,256	1,054,100	1.282,1.675, 4.031,22.911	0.0057,0.0156, 0.0943,0.6564

Table -6 - Welfare Measures and the Grade 4 Standard

	TS	PS	CS	*Prices* (P_1,P_2,P_3,P_4)	θ_i $(\theta_1, \theta_2, \theta_3, \theta_4)$
$X_4 = 278.89$	1,002,200	4,229	998,000	3.89, 4.77, 7.69, 18.33	0.0174, 0.0353, 0.1434, 0.4366
$X_4 = 292.75$	996,700	8,976	987,730	3.89, 4.77, 8.39, 33.93	0.0174, 0.0353, 0.1434, 0.8566
$X_4 = 267.71$	997,100	-4,818	1,001,900	3.89, 4.77, 6.95, 11.79	0.0174, 0.0353, 0.1434, 0.2292

Table -7 - Welfare Measures and the Grade 4 Standard

	TS	PS	CS	*Prices* (P_1,P_2,P_3,P_4, P_5)	θ_i $(\theta_1, \theta_2, \theta_3, \theta_4, \theta_5)$
$X_4 = 274.65$	1,023,100	11,056	1,012,000	3.88, 4.76, 7.40, 12.40, 27.81	0.0173, 0.0353, 0.1426, 0.3425, 0.7474
$X_4 = 277.04$	1,022,900	11,128	1,011,800	3.88, 4.76, 7.55, 13.32, 27.76	0.01734, 0.0353, 0.1426, 0.3882, 0.7474
$X_4 = 273.24$	1,023,000	10,965	1,012,100	3.87, 4.76, 7.32, 11.88, 27.89	0.01734, 0.0353, 0.1426, 0.3170, 0.7474
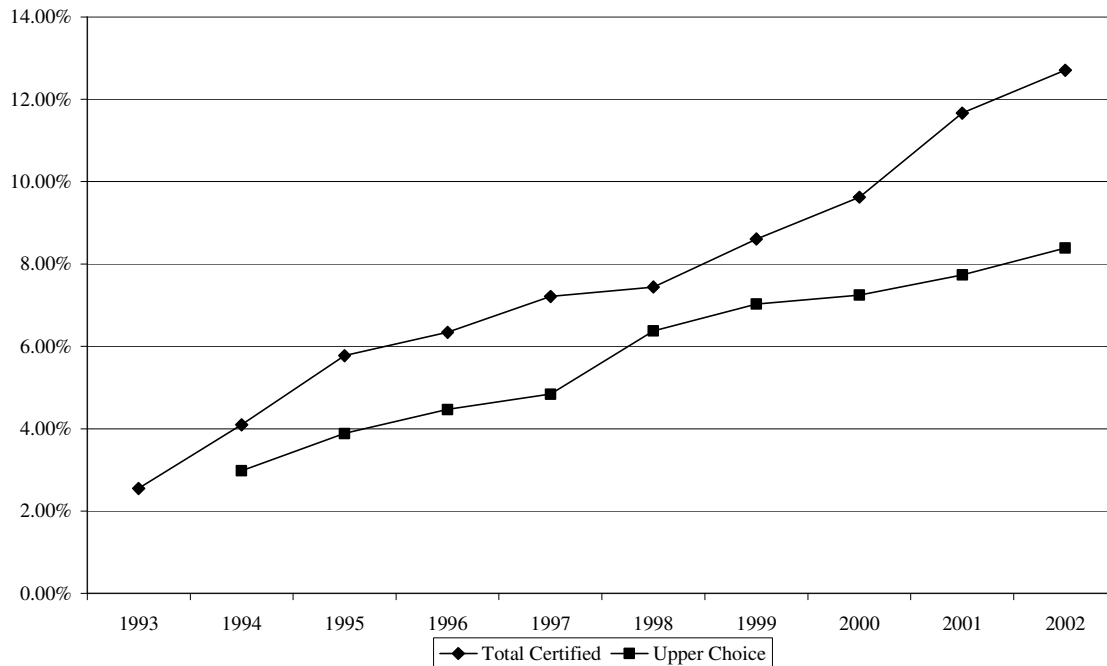
Figure -1 - Percentage of the Total Commercial Slaughter Certified
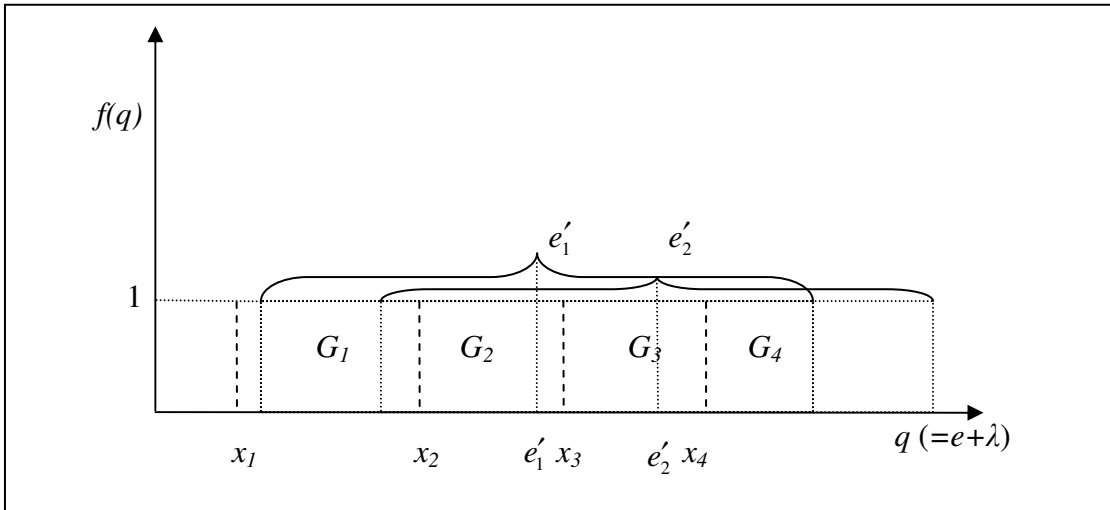
Figure-2 - Market Shares when the Error Distribution is Uniform
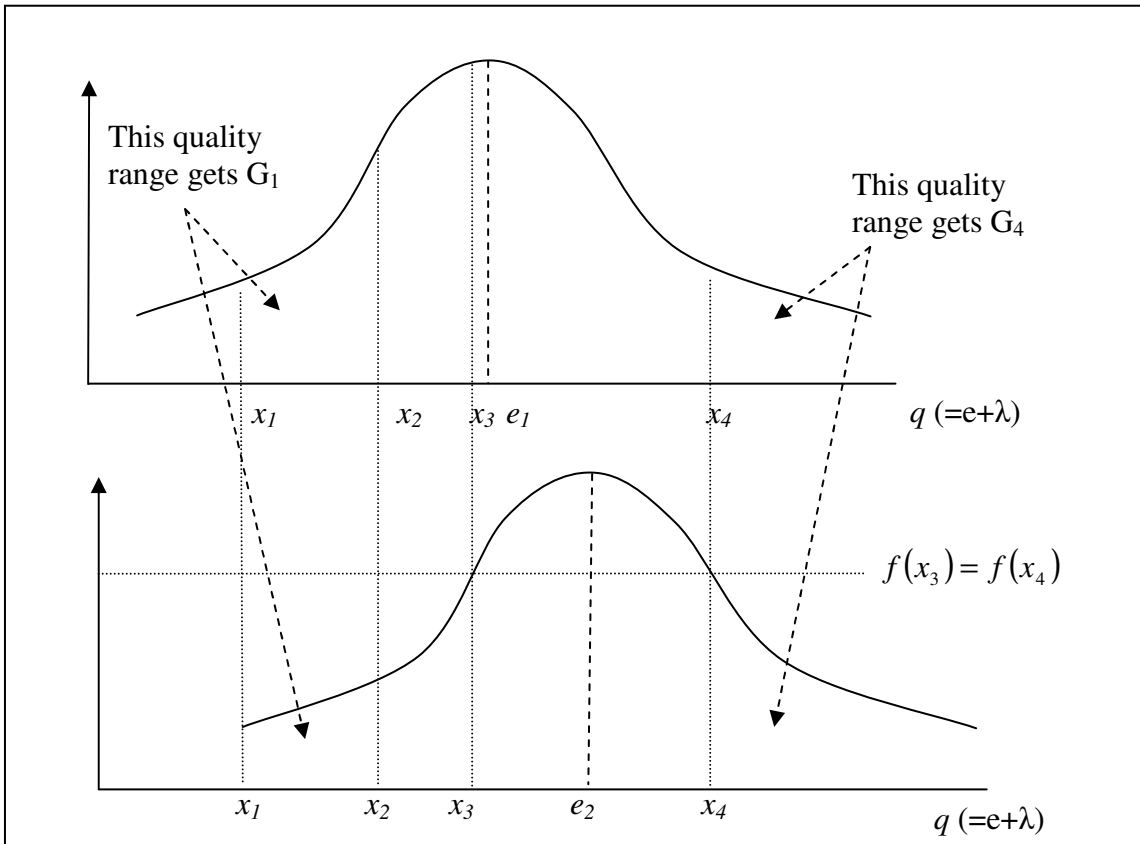
Figure -3 - Production of Grades when the Production Error is Normal
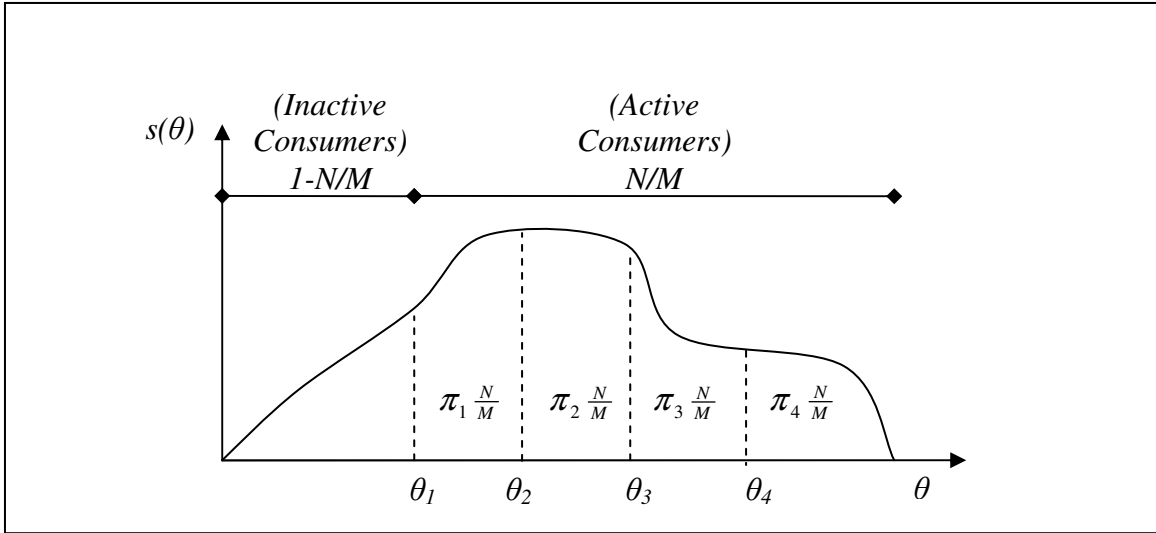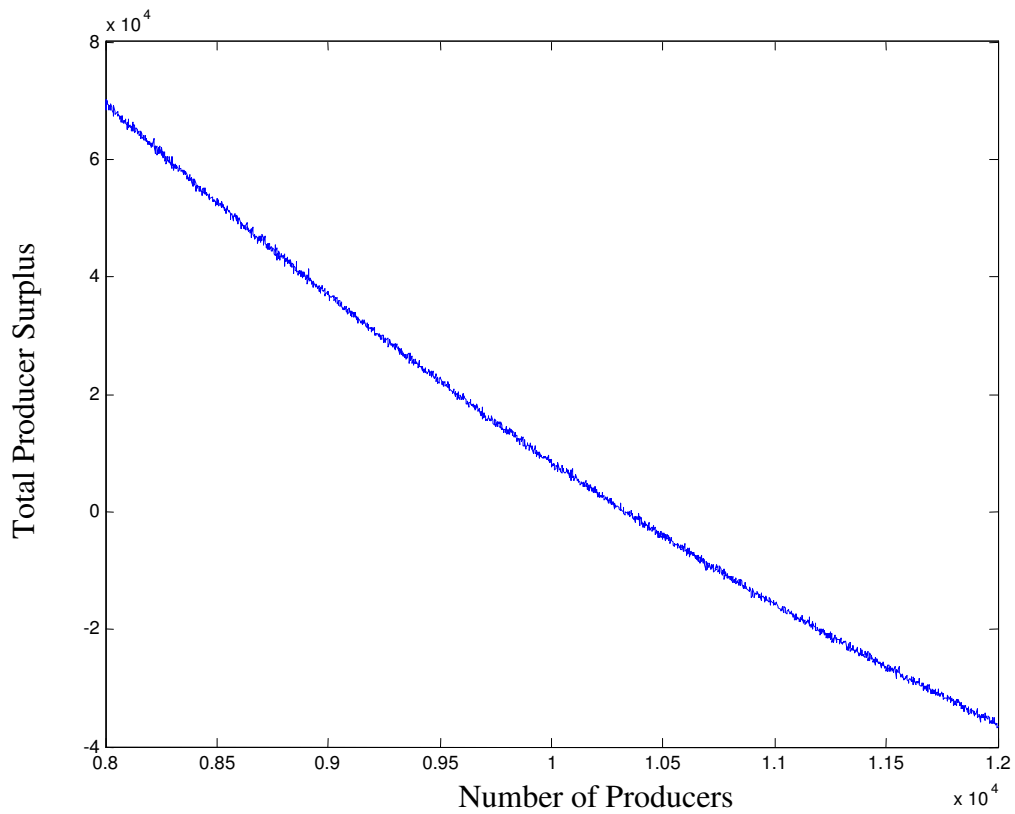
Figure-4 - Market Shares and Consumer Preferences
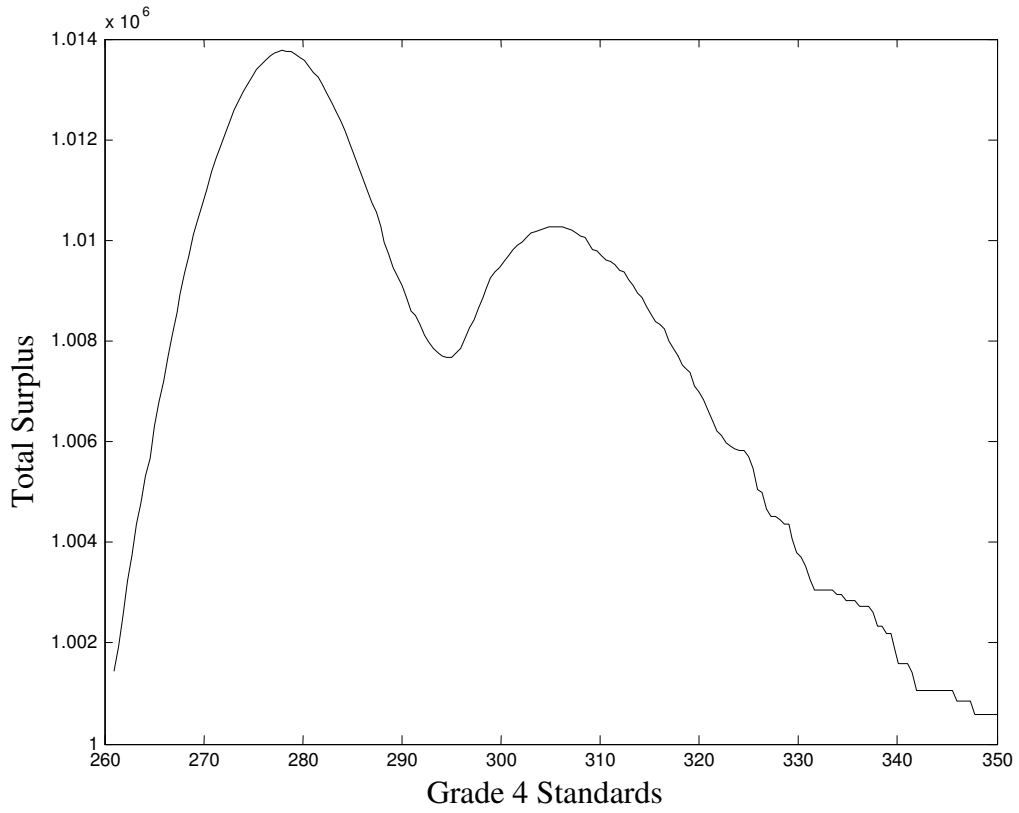

Figure-5 - Producer Surplus and the Number of Producers
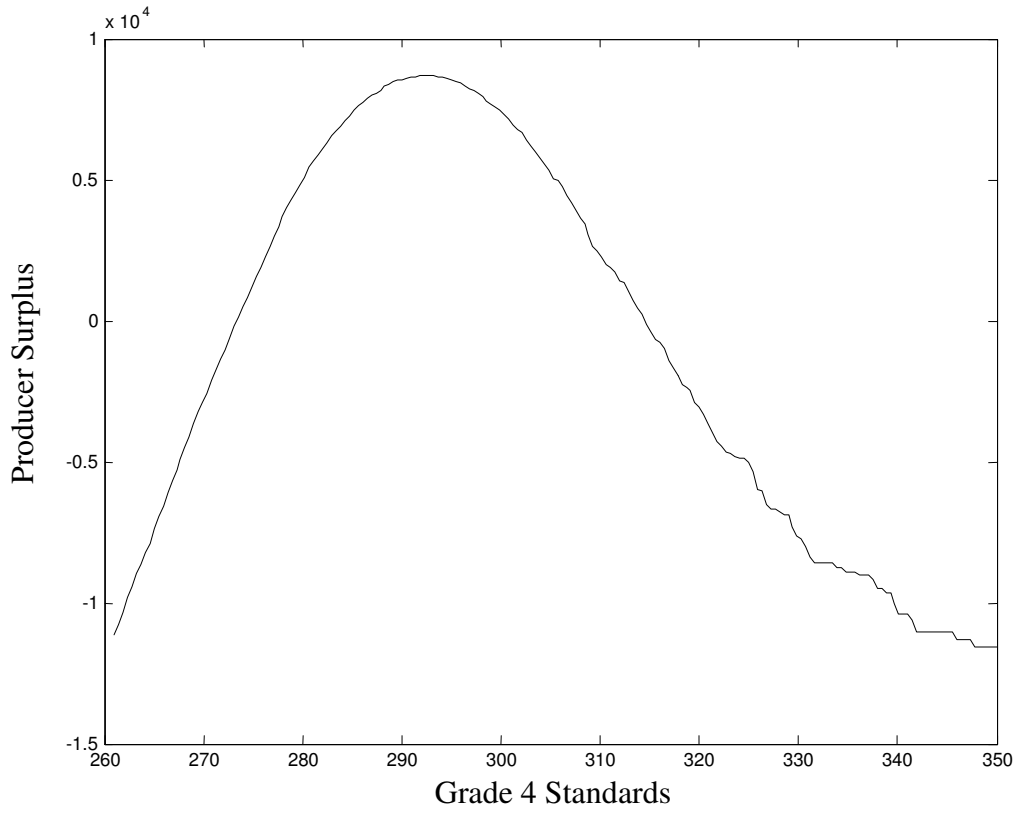
Figure -6 - Total Surplus and the Grade 4 Standard
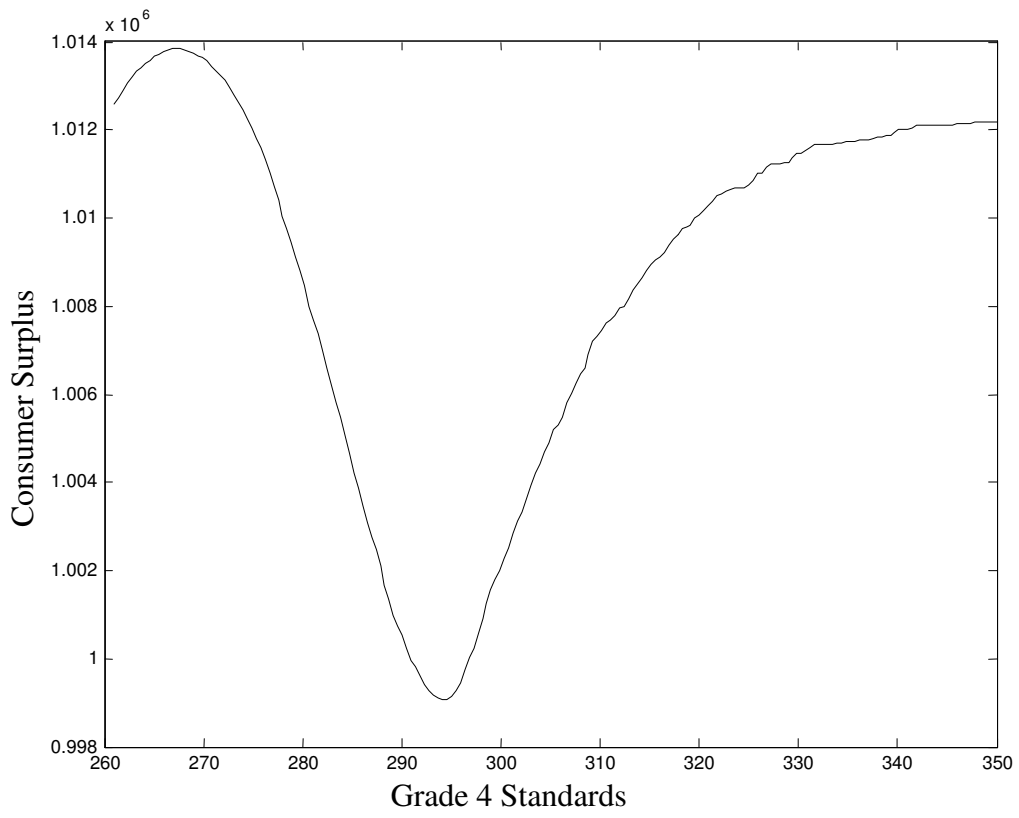
Figure -7 - Producer Surplus and the Grade 4 Standard
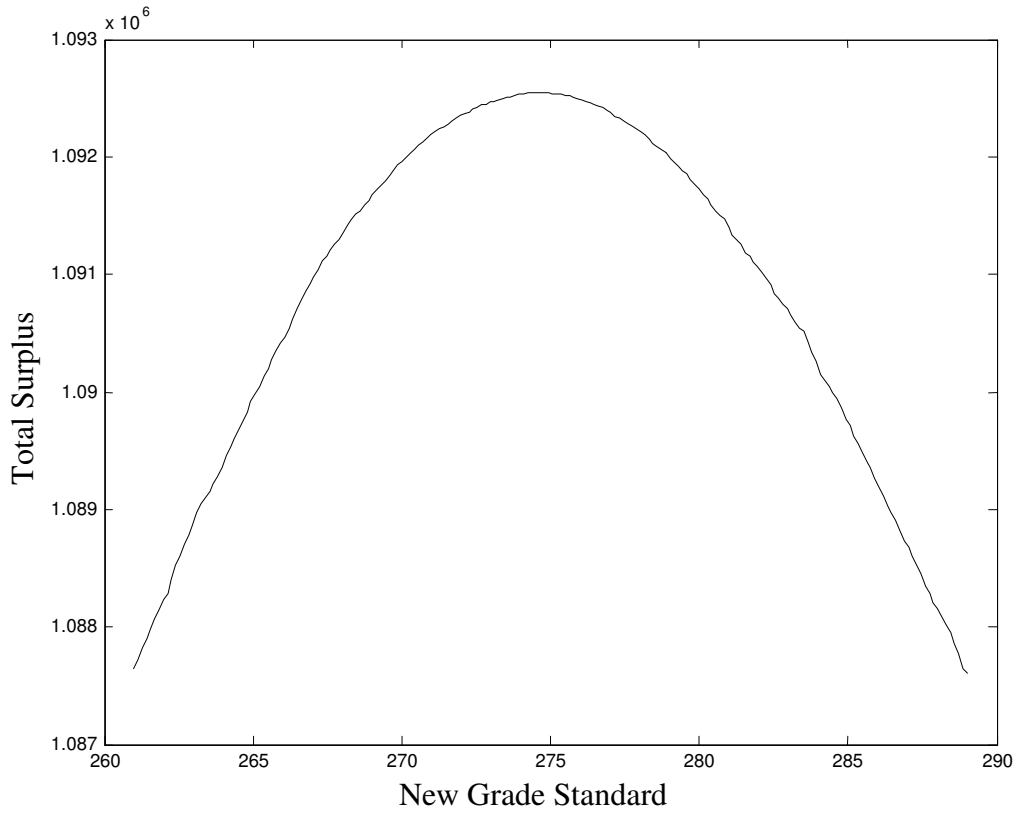
Figure -8 - Consumer Surplus and the Grade 4 Standard

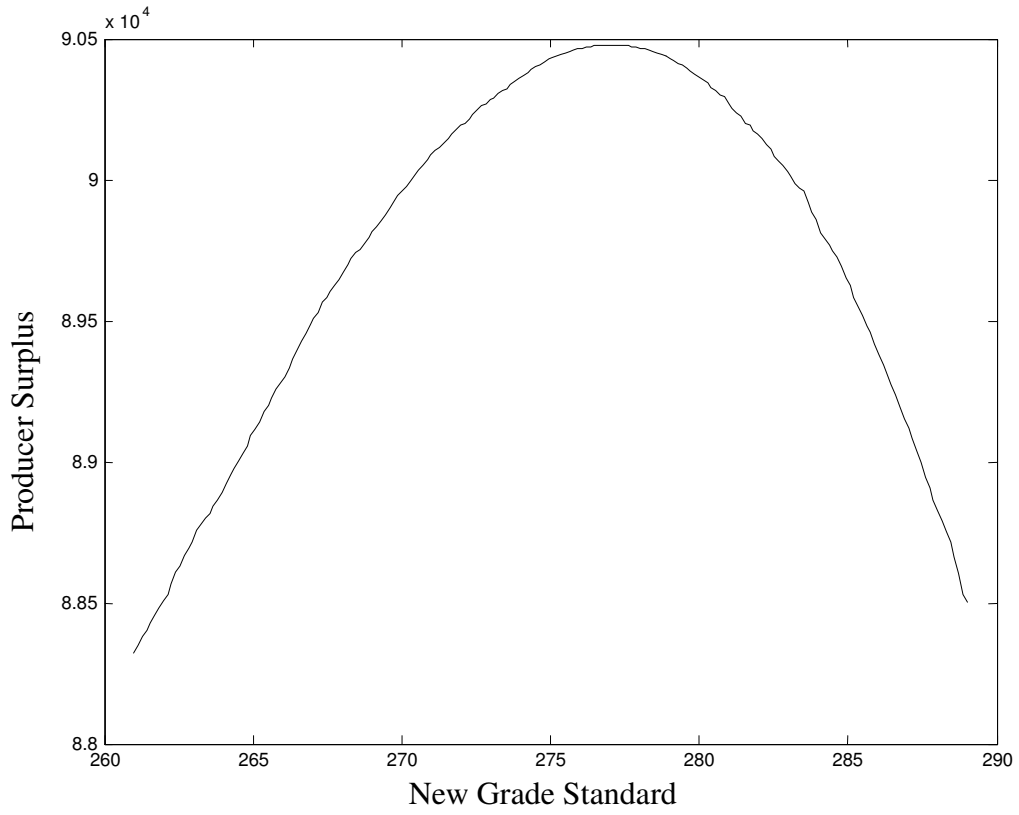**Figure -9 - Total Surplus and the Introduction of a New Grade**

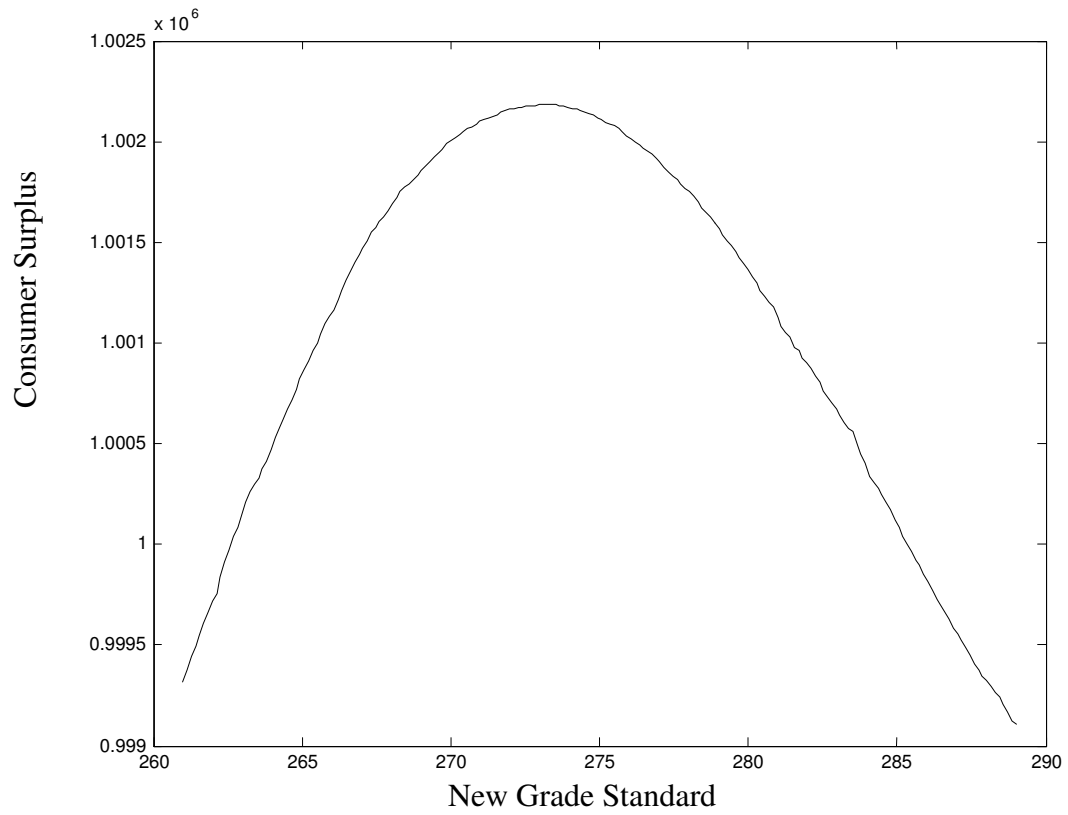**Figure -10 - Producer Surplus and the Introduction of a New Grade**

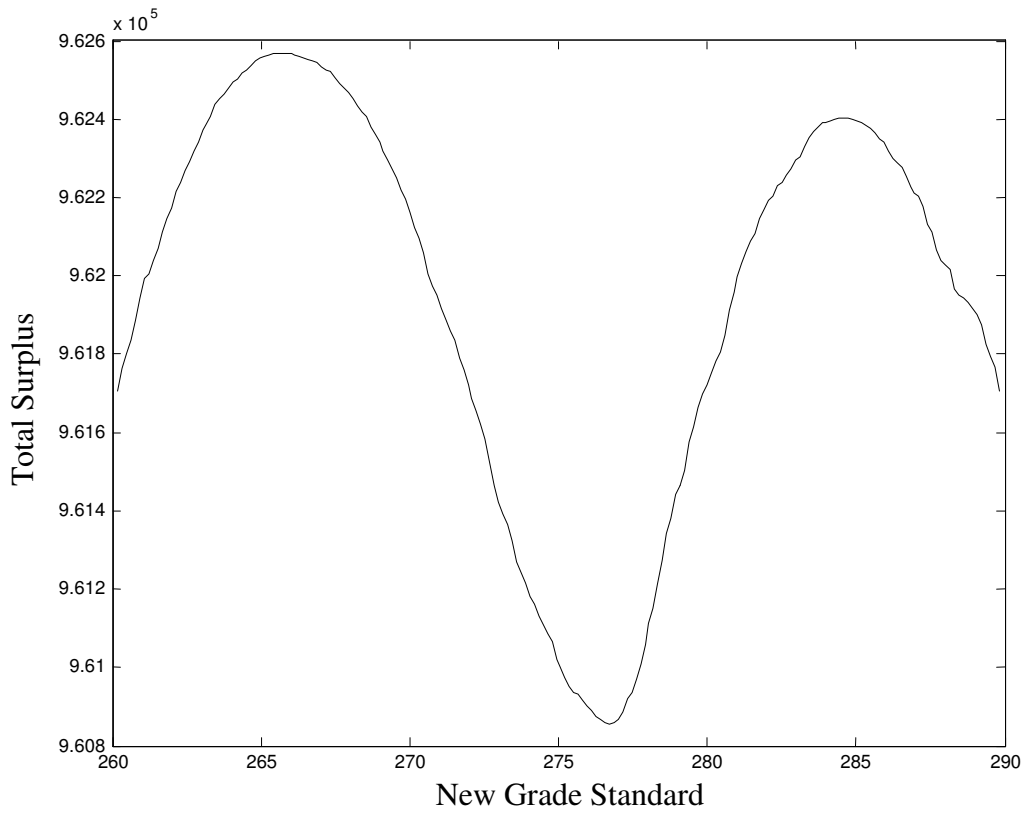**Figure -11 - Consumer Surplus and the Introduction of a New Grade**

Figure -12 - Total Surplus and the Introduction of a New Grade