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Abstract

The objective of this paper was to present a methodology for determining the efficiency of a grading system. The methodology was used to compare the efficiency of the 1979 feeder cattle grading system with an alternate grading system. The potential economic gain of implementing the more efficient system was determined.

A METHOD TO MEASURE THE EFFICIENCY OF FEEDER CATTLE GRADE STANDARDS

In the fall of 1979, the USDA implemented a new feeder cattle grading system which utilized three frame sizes and three thickness groups to classify feeder cattle into one of nine categories (USDA, 1979). Frame size was roughly defined as an animal's skeletal size--its height and length relative to its age. The three frame sizes were used to classify feeder animals into homogeneous groups according to the weight at which they were expected to reach a specified USDA carcass grade. For example, large-framed steers should reach USDA Low Choice carcass grade at a slaughter weight exceeding 1200 pounds, medium-frame steers reach USDA Low Choice at slaughter weights between 1000 and 1200 pounds, and small-frame steers reach USDA Low Choice at less than 1000 pounds.

The second attribute, muscle thickness, identified the effect of muscle thickness on ultimate yield grade. Thickness Number 1 represented feeder cattle formerly classified as USDA Prime or USDA Choice grades, Thickness Number 2 included feeders formerly in USDA Good or USDA Standard grades, and Thickness Number 3 included feeders below USDA Standard grade.

The objectives of this paper are: (1) to present a methodology for determining the efficiency of a grading system, and (2) to present an example of economic gains---if a more efficient feeder grading system is implemented. The methodology compares the efficiency of the present feeder cattle frame size categories to an alternate grading system using an index of weight adjusted for age to categorize feeder cattle into frame sizes. Several economists (Briemyer, Purcell, Nelson and Rhodes) have examined the economic functions of grades to determine what constitutes an effective grading standard, but economic analyses and methods to measure the coordinative efficiency of grade standards are not reported in the literature.

To examine the efficiency of feeder cattle grade standards, we must recognize that the carcass quality (defined as a combination of attributes which determine consumer acceptance) is determined by management practices, including the length of the finishing period. The desired quality of lean meat is communicated by the consumer to the cattle feeder via the price system and carcass grade standards. However, the value of a feeder animal, irrespective of supply and demand, is determined by its growth potential and its grade before slaughter.

Theoretical Basis for Grade Standards

To understand the theoretical basis for feeder cattle grades, assume there are two beef quality levels, X and Y, and that the beef is produced in groups so that the possible combinations of output are represented by the product transformation curve XY in Figure 1 (Clifton and Shepherd, 1953). If due to lack of knowledge, buyers and sellers are unable to differentiate between grades X and Y at the stocker-feeder interface, an average price will be paid for the feeders. Thus, the stocker operator's iso-revenue curve will be line $P_f P_f$, which is the negative ratio of the price of Y to the price of X. Equilibrium in production is at point E_1, where the marginal rate of transformation equals the slope of the iso-revenue curve ($MRT_{YX} = \frac{-P_Y}{P_X} = -1$).

Assume consumers discriminate between X and Y. A representative consumers' indifference curve for beef consumption is represented by Curve I. Both the indifference curve and the relative prices of X and Y are projected from the consumer to the cattle feeder via the relative prices paid by the consumer and the carcass grading standards. Because an average price is paid for X and Y in production, quantities Q_X of X and Q_Y of Y are produced. Allocation of Q_X of X and Q_Y of Y at consumption is controlled by the price mechanism. At equilibrium in consumption, the price ratio of Y and X is represented by the line P_RP_R and the marginal rate of substitution of Y for X is equal to the slope of the retail price ratio ($MRS_{YX} = \frac{-P_Y}{P_x} < -1$).

Equilibrium is obtained at production and at consumption, point E_1. However, the market is not in equilibrium because $MRT_{YX} > MRS_{YX}$. Without price differentiation via feeder cattle grades to differentiate between qualities X and Y, there is no incentive for cow-calf producers to adjust production to meet consumer demand.

Now, assume an efficient feeder grading system is implemented. Given the $MRT_{YX} > MRS_{YX}$, the price of X received increases relative to the price of Y at production. Producers increase the production of X and decrease the production of Y. Therefore, the price of X at retail decreases relative to the price of Y. The quantities and prices of X and Y serpentine as the market system approaches equilibrium at point E_3. At E_3, $MRT_{YX} = MRS_{YX}$ and an optimum point of production and consumption is obtained.

Implementing the grading system increases the production of X and decreases the production of Y. Consumers move to a higher indifference curve, I', which implies an increase in consumer satisfaction. The producer and consumer gain obtained from the grading system is relative to the distance from E_2 to E_3. Market allocation of the gain between producers and consumers will be determined by the elasticities of supply and demand.

A Method to Measure the Efficiency of Grade Standards

A procedure to measure the efficiency of a grading system can be derived from the above analysis. The optimal point of production and consumption was point E_3 (Figure 1). However, point E_3 can only be obtained if the feeder cattle were efficiently classified (graded) into homogeneous groups. Without an efficient grading system, input cannot be accurately classified into homogeneous groups. Therefore, production would vary around point E_3 (Figure 2). Assume production of X varied from X_1 to X_u and the production of Y varied from Y_1 to Y_u. Optimal production levels of X and Y were X_o and Y_o, respectively.

Assume the expected range of production was rr' and the probability of r and r' was one-half, respectively. The expectation cord rr' was one of a finite number of possible cords around point E_3. Since producers had imperfect knowledge (inefficient grades), they would discount the grading information and would attempt to produce at an expected level of production; E_e, rather than E_3 (Friedman and Savage, 1949). The expected point of production on each expectation cord could be used to develop the expected production transformation curve X'Y'. For simplicity, only cord rr' was used to illustrate the theory supporting a method to measure the relative efficiency of grade standards.

With an inefficient grading system, both production and consumer satisfaction were at a lower level. Expected production of X and Y was X_e and Y_e and consumers were on indifference curve I which was lower than indifference curve I'.

The expected range of production around point E_3 could be reduced by implementing a more efficient grading system. A more efficient grading system improved the producers' information, thus the expectation curve, rr', shifted toward point E_3. With higher expectations, production of X and Y increased to X_e' and Y_e' and consumers moved to a higher indifference curve I". Production and consumption were in equilibrium at point E_4 where both producers and consumers benefited.

The above theoretical application shows that if a grading system for inputs is efficient, the variance around the desired level of production is minimized. Minimizing the variance maximizes consumer satisfaction and producer net return. Therefore, a measure of the relative efficiency of a grading system is the system's ability to predict the final product or explain its variation.

Comparative Efficiency of Two Frame Size Definitions

The methodology presented above was used to compare the coordinative efficiency of two definitions of frame size. Thus, only the enigma of determining the slaughter weight a beef animal will reach a specified USDA carcass grade was addressed.

Primary data were a composite of four independent but coordinated studies related to Southern Regional Research Project S-116[1]. Actual feeder steer weights, estimates of frame size, estimates of age to the nearest month and actual carcass data were collected on 838 steers. Frame sizes were scored large frame equal to 1, medium frame equal to 2 and small frame equal to 3. In the analysis, hot carcass weights were used in lieu of live slaughter weights because prior research has shown that hot carcass weight is the more consistent measure of weight (Meyer et al., 1960).

Only animals with USDA carcass grades between high standard and choice are included in the analysis. Animals not in this range are excluded because there are an insufficient number of observations. The average ratio of hot carcass weight to live slaughter of 0.61 was used to convert hot carcass weight to live slaughter weight when explaining the results.

Efficiency of USDA's Frame Size

To estimate the efficiency of USDA's frame sizes in determining the hot carcass weight at which a steer will reach a specific USDA carcass grade, hot carcass weight of 888 steers was regressed on the USDA carcass grades and the USDA frame scores. Zero-one dummy variables were used to better reflect the discontinuous characteristic of feeder cattle grade standards. The dummy variables for high standard carcass grade and medium frame were omitted to avoid a singular matrix. The USDA carcass grade was included to facilitate analyzing hot carcass weight for a constant carcass grade. The derived equation was:

$$\begin{aligned} \text{HOTWEIGHT} = 586 &+ \underset{(12.32)}{40\ \text{LGOOD}} + \underset{(11.13)}{39\ \text{GOOD}} + \underset{(10.98)}{44\ \text{HGOOD}} + \underset{(10.17)}{73\ \text{LCHOICE}} \qquad (1) \\ &+ \underset{(13.44)}{58\ \text{CHOICE}} - \underset{(10.30)}{56\ \text{SFRAME}} + \underset{(6.89)}{59\ \text{LFRAME}} \qquad R^2 = 0.18 \\ &\qquad\qquad\qquad\qquad\qquad\qquad \text{STD DEV} = 79.6 \end{aligned}$$

where the significance levels are in parentheses and

HOTWEIGHT = hot carcass weight in pounds,

LGOOD = zero-one dummy variable for USDA Low Good carcass grade,

GOOD = zero-one dummy variable for USDA Good carcass grade,

HGOOD = zero-one dummy variable for USDA High Good carcass grade,

LCHOICE = zero-one dummy variable for USDA Low Choice carcass grade,

CHOICE = zero-one dummy variable for USDA Choice carcass grade,

SFRAME = zero-one dummy variable for grader specified Small Frame, and

LFRAME = zero-one dummy variable for grader specified Large Frame.

The working hypothesis tested by the above equation was that the frame size should explain the variance of hot carcass weight given a USDA carcass quality grade. All the coefficients associated with frame size were highly significant ($P < 0.0001$) which indicated that the frame size was a significant variable in predicting hot weight for a given USDA carcass grade. The standard deviation of hot weight after it was regressed on USDA carcass grade and grader frame was 79.6 pounds. Actual standard deviation of hot weight was 87.5 pounds. Therefore, nine percent of hot weight standard deviation was explained. Anderson (p.75) compared the efficiency of USDA's frame size with frame size derived from an index of actual feeder height divided by the logarithm of estimated age. The amount of hot carcass weight standard deviation explained was approximately equal to the amount explained by the USDA's frame size.

Efficiency of an Alternate Frame Size

Brungardt researched which feeder cattle attributes could be used to determine the slaughter weight at which a beef animal would reach a specific USDA carcass grade. The results indicated that weight adjusted for age was a more powerful indicator of frame size than height and length adjusted for age. Therefore, weight divided by the natural logarithm of estimated age was used to separate the feeder animals into three frame size groups (Anderson, pp. 71-74).

The mean of the index, actual weight divided by the log of estimated age, was 258.51, the standard deviation was 32.81 and the range of values was between 145.5 and 366.8. Steers with index values less than 244.1 were classified as small frame, and steers with indices greater than 299.1 were classified as large frame. According to this classification system, there were 282, 526 and 80 small, medium and large framed steers, respectively. The number of steers in each frame category was consistent with a visual check of the data set.

Regressing hot carcass weight on the carcass quality grade and the index frame size categories produced the following equation:

$$\begin{aligned} \text{HOTWEIGHT} = 617 &+ \underset{(10.49)}{33}\ \text{LGOOD} + \underset{(9.49)}{37}\ \text{GOOD} + \underset{(9.35)}{35}\ \text{HGOOD} \\ &+ \underset{(8.61)}{53}\ \text{LCHOICE} + \underset{(11.43)}{49}\ \text{CHOICE} - \underset{(5.09)}{74}\ \text{SMFRAME} + \underset{(8.25)}{113}\ \text{LRFRAME} \end{aligned} \quad (2)$$

$R^2 = 0.39$ Standard deviation = 68.5

with the standard error in parentheses and

SMFRAME = zero-one dummy variable for frame size determined by dividing actual feeder weight by the log of estimated age. Indices < 244.2 indicated small frame.

LRFRAME = zero-one dummy variable for frame size determined by dividing actual feeder weight by the log of estimated age. Indices > 299.2 indicated large frame.

The standard deviation of hot weight was reduced to 68.5 when hot weight was regressed on the weight ÷ log (age) index. All variables were significant at P < .002 or better. Twenty-two percent of the hot weight standard deviation was explained. The R^2 was 0.38. The index frame size explained 13 percent more of the hot weight standard deviation than the USDA's frame size. Thus, frame size was more efficiently defined by feeder weight divided by the log of estimated age than height and length relative to age.

Economic Evaluation

Relative prices of different grades of commodities vary over time. Impacts that alter the supply or demand function of a given product change its relationship to the supply of and demand for competing products and their relative prices. Continuous changes in the range and magnitude of beef prices make it difficult to determine the economic value of an improved grading system, However, an example using specific costs and returns is presented below to illustrate the economic value of a more efficient feeder grading system.

Economic Gains from Implementing a more Efficient Grading System

A mathematical model developed by Nelson was used to simulate the relationship between beef slaughter weight and net return per head per day for various weights of cattle development. Nelson's computer simulation model incorporated the "California Net Energy System" of feeder animal net energy maintenance and gain requirements (Lofgreen and Garrett), costs of gain and ration formulations from Gill, and a price function developed by Ikerd. The growth equation projected the daily feedlot gain based on the available ration and the feeder's weight and growth potential. Costs of gain were a function of the ration cost, interest, and other feedlot fixed and variable costs.

Ikerd's price equation combines the actual feeder animal price with the expected feeder price and a grade discount to develop a price equation that reflects the slaughter animal price as the carcass grade and yield grade change during growth. In the initial feedlot phase, the price declines until the animal reaches its minimum slaughter weight--normally high standard carcass grade. As the carcass grade increases, the price per pound increases, until the deposition of fat decreases the carcass value relative to the increase in value from increasing the carcass grade, e.g., going from yield grade 3 to yield grade 4. At this stage in growth, the price declines as fat increases.

In the example, it was assumed that 806-pound (774-pound shrunk) feeder steers were purchased for $76 per hundred weight (cwt.). For a simulated 2.8 pounds average daily gain, the gain costs wer $54.13 and the slaughter sale price at the target grade (low choice) was $73.89 per cwt. The simulated net return per head per day was $0.36 for 1,156 pound steers fed 126 days. Steers simulated for 215 days weighed 1,358 pounds, sold for $69.84 per cwt. and yielded a net return per head per day of -$0.01.

The net returns relative to weight simulated from minimum slaughter weight to the slaughter weight of approximately yield grade 5 were used to derive a net return equation. The derived example equation was:

$$\Pi = -8.79102843 + 0.01579908\ WGT - 0.00000688\ WGT^2$$

$$(0.0001) \quad (0.0001) \qquad (0.0001)$$

$$R^2 = 0.93$$

with significance levels in parentheses and

Π = net return per head per day,

WGT = slaughter animal weight in pounds, and

WGT^2 = slaughter animal weight in pounds squared

The analysis and results in this study were based on the hypothesis that a cattle feeder's net returns increased as the carcass quality grade variance or the slaughter weight variance from the profit maximizing weight for individual cattle within pens of slaughter cattle was reduced. This assumption was tested by use of a general net return equation and deriving, in general terms, the expected net return of a pen of cattle relative to the slaughter weight variance around the point of maximum net return. Slaughter weight was assumed to have a normal distribution with mean μ and standard deviation σ.

Expected net return $E[\Pi(w)]$ as a function of weight was depicted as:

$$E[\Pi(w)] = \int_{-\infty}^{\infty} \Pi(w)\ f(w/\mu_o,\sigma_o) \qquad (4)$$

where

$f(w/\mu,\sigma)$ = probability distribution function of slaughter weight

w = slaughter weight

μ_o = mean slaughter weight for maximizing net return, and

σ_o = standard deviation of slaughter weight

Inserting the general form of the derived net return function:

$$E(\Pi) = \int_{-\infty}^{\infty} (c + bw + aw^2)f(w)dw \qquad (5)$$

$$c < 0,\ b > 0,\ a < 0$$

Integrating for $w \sim N(\mu_o,\sigma_o)$

$$E(\Pi) = c + b\mu_o + a\mu_o + a\sigma_o^2 \qquad (6)$$

Note in the quadratic net return equation, the estimate of a was negative. Therefore, partial differentiation of equation 6 with respect σ_o, shows that net return was maximized when σ_o equaled zero. Given $a < 0$, the second order conditions for a maximum were met:

$$\frac{\partial E(\Pi)}{\partial \sigma_o} = 2a\sigma_o \qquad a < 0,\ \sigma_o \geq 0$$

This implied that as σ_o increased, $E(\Pi)$ decreased and the maximum net return was:

$$\hat{\Pi} = c + b\mu_o + a\mu_o^2.$$

The analysis above showed that net return was maximized if slaughter weight variance was zero. In the previous illustration, it was assumed that the animals were slaughtered at μ_o. The following analysis was completed to determine the σ_o that maximizes net return if the mean slaughter weight does not equal μ_o. Let

$$E[\Pi\mu(w)] = c + b\mu + a\mu^2 + a\sigma^2 \qquad (7)$$

$$c < 0,\ b > 0,\ a < 0,\ \mu > 0,\ \sigma > 0$$

be the expected net return for average weight μ ($\mu \neq \mu$). The reduction in net return, when the average slaughter weight was not μ, was

$$\Delta = \hat{\Pi}\mu_o - E[\Pi\mu(w)] = c + b\mu_o + a\mu_o^2 - c - b\mu - a\mu^2 - a\mu^2. \qquad (8)$$

To maximize net return, the change in net return (Δ) should be minimized. The effect of σ on Δ was derived by taking the partial derivative of Δ relative to σ:

$$\frac{\partial \Delta}{\partial \sigma} = -2a\sigma$$

Since $a < 0$, Δ was minimized when σ equaled zero. Thus, in all cases net return would be increased by reducing the variance irrespective of the mean slaughter weight.

Using the derived net return equation and different levels of slaughter weight variance, a numerical example of the economic gains from decreasing the slaughter weight variance was developed (Table 1). Standard deviation of slaughter weight was calculated in 22 percent increments, from 128 to 61 pounds, which represented the improved efficiency from implementing the feeder cattle grading system developed in this study. Note that the values presented in this example were estimates of only one set of a large number of possible economic conditions.

If the standard deviation of slaughter cattle was reduced 22 percent, from 100 pounds to 78 pounds, the net return per head per day would increase $0.027, from $0.21 to $0.237 or for a 155-day feeding period, $4.19 per head. In 1979 approximately 27.74 million cattle were fed out by cattle feeders (USDA, 1980) and the average number of days on feed was approximately 155-days (PCC). Given the economic conditions assumed in this illustration, the potential economic gain to the U.S. beef industry would be $116,091,900 per year.

The potential economic gain to the beef industry from reducing the standard deviation was less under the assumption of a lower original standard deviation. If the standard deviation was reduced 22 percent, from 78 to 61 pounds, the potential economic gains to the industry was $68,795,200 per year ($0.016 times 27,740,000 times 155 equals $68,795,200).

Summary

This manuscript's purpose was to present a method for determining the coordinative efficiency of a grading system, use the method to compare two definitions of frame size, and then develop an example of the

TABLE 1. Net Return Per Head Per Day of Feedlot Cattle.[a]

Standard Deviation of Slaughter Cattle (Pounds)	Net Return Per Head Per Day Fed (Dollars)	Difference in Net Return Per Head Per Day Fed (Dollars)
128	0.166	
100	0.210	0.044
78	0.237	0.027
61	0.253	0.016
.		
.		
.		
0	0.279	

[a]An example of loss in net revenue due to the slaughter weight variance for a homogeneous group of feeder cattle.

economic gains provided by implementing a more efficient grading system. It was determined that the grading system which explained the largest amount of hot carcass weight variance was the most efficient. The analysis indicated that feeder weight divided by the log of age was more efficient than height relative to age in identifying frame size.

Implementing a more efficient feeder cattle grading system would have positive economic gains. Although data were unavailable for determining the costs of implementing a more efficient system or to derive the costs of using the present versus a more efficient grading system, it was hypothesized that a more efficient feeder cattle grading system would cost no more to use than the current system. Thus, the only additional cost would be the expense of introducing the feeder grades to the beef industry. Past actions of the beef industry and consumers have indicated that efficient grading standards are mutually beneficial.

FOOTNOTE

Kim B. Anderson is an assistant extension professor, University of Kentucky and Alan E. Baquet is an assistant professor, Oklahoma State University.

[1]The research on which this article is based was conducted at Oklahoma State University as part of Southern Regional Project S-116. Data and consultation were received from Drs. Donald E. Farris, Texas A & M; Kenneth E. Nelson, USDA, University of Illinois; and Warren C. Couvillion, Mississippi State University. Drs. John E. Ikerd and Ronald W. McNew were instrumental in the theoretical development.

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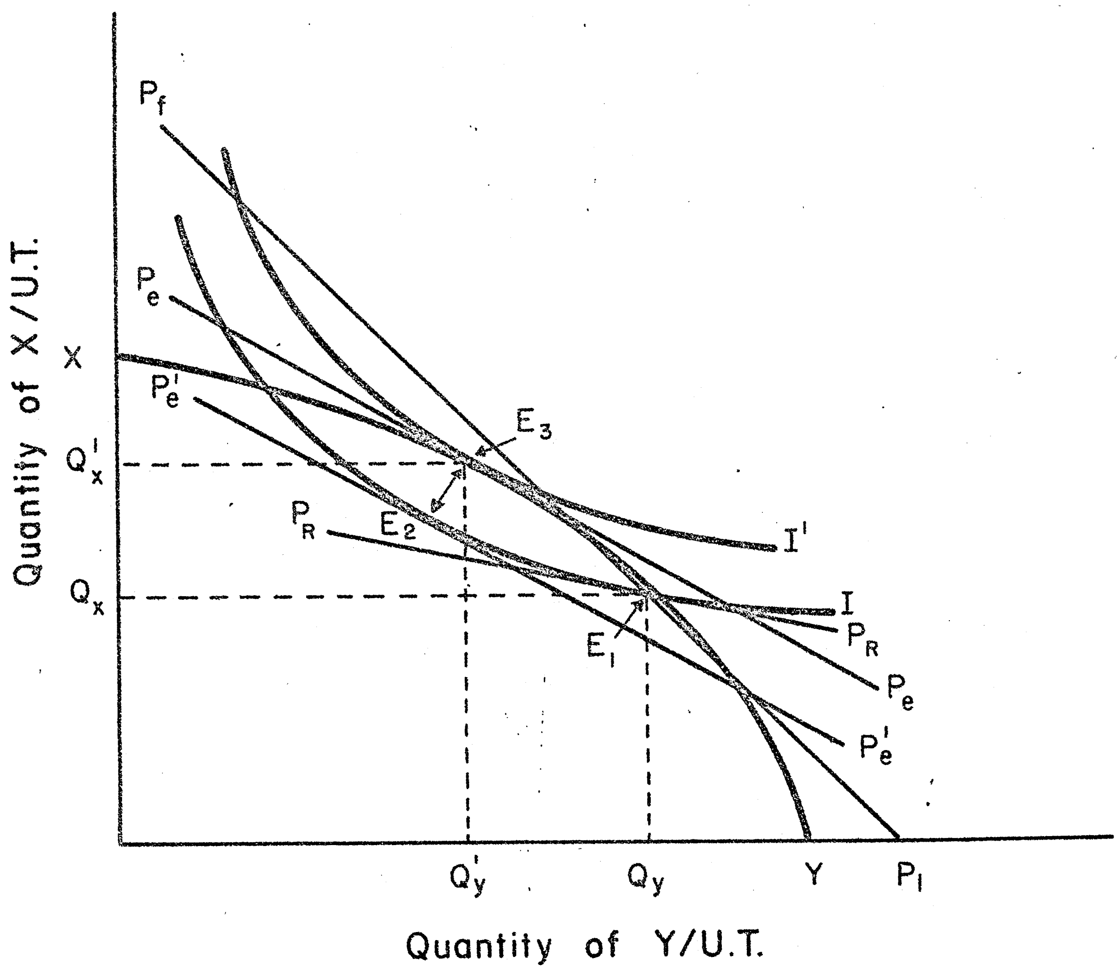

Figure 1. Economic Gain from an Efficient Grading System

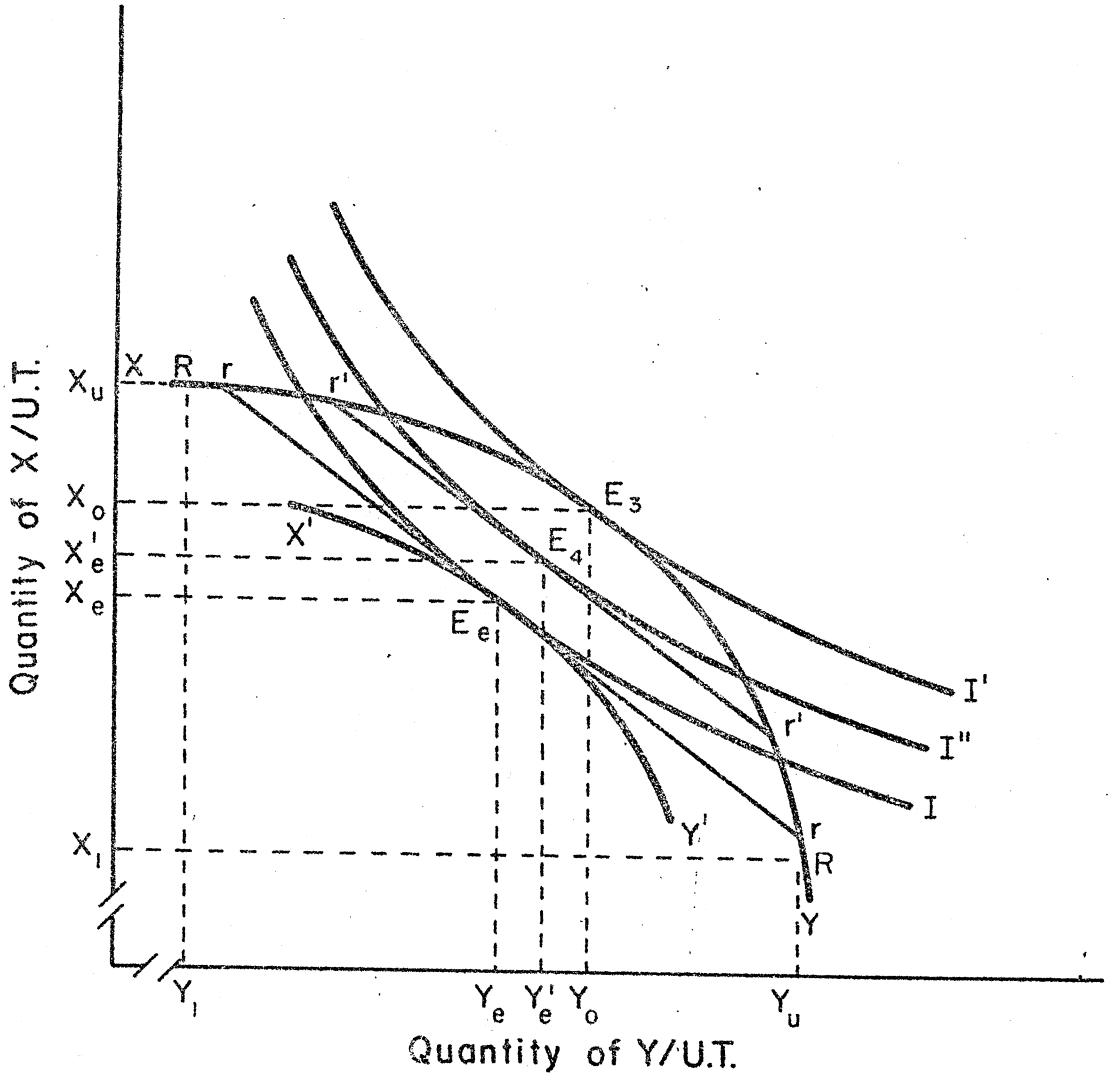

Figure 2. A Measure of Economic Gain from Increased Efficiency of Feeder Cattle Grading Standards.