# *Quality Pricing in U.S. Soybean Exports*

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by

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# ABSTRACT

**Quality Pricing in U.S. Soybean Exports**

The article examines the quality-price relationship in U.S. soybean exports. Implicit prices for quality characteristics of U.S. soybean exports were estimated using a hedonic price function from a rich transaction-specific data set to major destination markets. The results of this analysis indicate that the price of soybeans exported is not affected by the oil and protein content of the soybeans. Moisture content was surprisingly found to positively affect price while foreign material reduced price after the 1989/90 marketing year. These results are extended to have implications for proposed changes in existing soybean market regulation.

## Introduction

The U.S. share of the international soybean market fell from 79 to 60 percent from 1986 to 1990. The decline in the U.S. share occurred during a period of continuing importer complaints about the low quality of U.S. soybean shipments (Smith 1990). This has caused concern about whether the current marketing system truly conveys the quality requirements of importers. Some researchers have argued that the loss of market share has partially resulted from the export of low quality soybeans which have low oil yields and high foreign material levels, compared to other soybean exporters (Haley 1990 and Kohn 1992).

This study estimates the implicit price of oil, protein, foreign material, damaged kernels and other soybean quality characteristics using an econometric model. The goal of the study is to determine whether buyers in major foreign markets pay more for higher quality U.S. soybeans. An extensive literature search revealed no previous hedonic analysis for soybeans, though several studies exist for wheat and other commodities.

The majority of previous studies on the relationship between prices and grain quality have concentrated on wheat trade, since that market exhibits both strong competition among rival exporters and diverse end-uses for the commodity (Wilson and Preszler (1992); Veeman (1987); Larue and Lapan (1992)). In addition the broad dividing of wheat into wheat classes for different end-uses permits analysts to focus on a subset of wheat price-quality relationships. The major shortcoming of previous studies is inadequate data. The data is either highly aggregated or covers a relatively narrow chronological period. In this study, the unit value of the shipment represents the negotiated f.o.b. price between the foreign buyer and U.S. exporter for the desired characteristics in the shipment.

Recent proposals for changes in the marketing system have included tightening of the specifications on No. 2 soybeans, to reduce the maximum level of foreign material, and incorporating the inherent characteristics of oil and protein in the price of soybeans or in the grades. Another regulatory issue in grains is the problem of using water as a dust suppressant in grain storage (Miller, 1993). Hill (1993) suggests that there are current market incentives to add moisture to grain and advocates a system which would remove the incentive to add water to grain. The study will contribute additional information to this debate by showing how quality is priced.

## Economics of Grain Characteristics

Hedonic price methodology is one method used to determine the value of components or characteristics of heterogenous goods. The general theory was developed by Lancaster (1966) and Rosen (1974) and was adapted by Ladd and Martin (1976) to focus on agricultural products which are used as inputs in a production process. More recently, Wilson (1989), Bowman and Ethridge (1992), Unnevehr and Bard (1993) and Mercier *et al* (1994) have also used hedonic analysis in determining the value of component characteristics of agricultural and food products such as wheat, cotton, beef cuts, and corn.

This model assumes that profit-maximizing processing firms operating in a perfectly competitive markets require the inputs for their effect upon output. For example, soybean processors require soybeans for their effect on output as the intrinsic characteristics of soybean oil and protein content in the soybean affect the yields of soybean oil and meal that the processor receives from the production process. The characteristics of economic importance are thus included in the production function. For a single firm, the production function is:

$$(1) \quad q_h = F_h(z_{1h}, z_{2h}, \ldots, z_{nh})$$

where $q_h$ is the quantity of the output *h* (h=1,2,...,H); and $z_{jh}$ is the quantity of input characteristic j (j=1,2,...,n).

The firm's objective function is assumed to be profit maximization:

$$(2) \quad \pi = \sum_{h=1}^{H} p_h \; F_h(z_{1h}, z_{2h}, \ldots, z_{mh}) \; - \; \sum_{h=1}^{H} \sum_{i=1}^{m} p_i x_{ih}$$

where $x_{ih}$ is the quantity of the *i*th input (i=1,2,...m) used in the production of output *h*; $p_i$ is the price paid for the *i*th input; and $p_h$ is the price received for the output *h*.

The first-order condition with respect to input *i* used to produce output *h* is:

$$(3) \quad \frac{\partial \pi}{\partial x_{ih}} = p_h \sum_{j=1}^{m} \left(\frac{\partial F_h}{\partial z_{jh}}\right)\left(\frac{\partial z_{jh}}{\partial x_{ih}}\right) - p_i = 0$$

Solving for $p_i$ results in the following demand equation for the firm:

$$(4) \quad p_i = p_h \sum_{j} \left(\frac{\partial F_h}{\partial z_{jh}}\right)\left(\frac{\partial z_{jh}}{\partial x_{ih}}\right)$$

The partial terms in equation 4 represent the marginal physical product of characteristics of characteristic *j* in the production of the output *h* and the marginal yield of characteristic *j* from the *i*th output. $p_h \partial F_h / \partial z_{jh}$ can be interpreted as the marginal or implicit price of the *j*th characteristic and is defined as $\beta_j$. For simplicity define the marginal yield $Z_{ji}$. This results in:

$$(5)\quad p_i = \sum_j \beta_j Z_{ji}$$

which is the usual hedonic regression estimated for valuing input characteristics. This hedonic regression has observed market prices as dependent variables and observed quality variables as explanatory variables.

An issue in estimating hedonic price functions with time series data is controlling for general shifts in supply and demand. Prices, the dependent variable in hedonic functions, are influenced by a number of factors other than quality characteristics, including variation in total supply and macroeconomic events such as changing exchange rates. These events cause the general price level of the commodity to vary. To account for these general shifts in supply and demand, we follow Bowman and Ethridge (1992) by using a reference price. In this method, a base grade is identified and quality factors for the base grade (which are constants) are subtracted from the measured value for the quality factors in each shipment. Quality differentials are used to explain price deviations from the reference price. With this modification the estimated equation becomes:

$$(6)\; P_{it} - P_t = B(Z_{it} - Z)$$

where $P_{it}$ is the observed price and $P_t$ is the reference price. $Z_{it}$ is the vector of quality characteristics while Z is the similar vector of quality characteristics associated with the reference quality.

**Data and Variables**

The shipment-level data used for estimating the hedonic price model are a subset of all U.S. soybean exports shipped between January 1990 and November 1991 (United States

Department of Commerce, 1992; United States Department of Agriculture, 1986 to 1991). The data analyzed represent the 198[1] shipments from U.S. Gulf ports to 3 destination markets, namely the European Community, Japan, and Korea, for which a complete set of quality variables was available. Table 1 indicates the number of shipments to each destination while Table 2 provides summary statistics for the data. The data cover three separate marketing years for soybeans as the soybean marketing year begins on September 1. The shipment-specific quality and price portion of the data set was constructed by matching FGIS export inspection data with export data on quantity and value collected by the Bureau of Census of the Department of Commerce. The data set was constructed by matching individual shipment observations based on import destination, United States port of exit, month and year of shipment, and shipment size. The price was derived by dividing shipment value by shipment size, and represents a transaction price for each particular shipment. These transaction prices reflect the price as recorded at export, so they are effective f.o.b. prices.

Prices at the Gulf ports are usually quoted for No. 2 soybeans only. Therefore, the No. 2 soybean price can be considered the reference grade to account for the general price level. The price one week prior to when the ship was actually loaded were used to account for the shifts in the reference price. Discussions with soybean exporters suggests that this is an appropriate proxy for supply and demand shifts.

The quality variables used as independent variables were foreign material, protein content, oil content, and moisture content which are all measured as percentage content. The data set reports actual levels of these factors measured in the shipments, serving as proxies for contractual limits that reflect the buyers expectations. The quality information is derived from the FGIS export data set. The expected sign of the coefficient can be drawn from knowledge of whether higher values of a variable detract from or enhance the quality of the final product. A number of other variables were also included in the analysis. The following section describes the quality variables, these other variables and the rationale for their selection and use.

Protein and oil content are considered to be one of the primary determinants of value in soybeans as they are the major determinants of the amount of soybean oil and meal that a processor can obtain from the beans. Higher oil and protein content are hypothesized to be positively related with the value of the shipment. There has been some question about the effectiveness of the marketing system in transmitting preferences for soybeans containing higher levels of oil and protein.

Foreign material is the percentage of other non-soybean material in the shipment. It is generally expected that foreign material will decrease the value of the soybean shipment because it represents dead weight in the shipment and foreign material must be removed through cleaning before the soybeans can be processed. Foreign material thus increases the cost of shipping a unit of useable amount and increases the cost of processing. After the 1989/90 marketing year a change was made in the way that the FGIS measured foreign material, making it more difficult for foreign material to be undetected. To incorporate this institutional change an interaction term of foreign material by marketing year 1989/1990 was added to the regression.

Splits are soybeans with more than one-fourth of the bean removed and that are not otherwise damaged. Splits above the 10-15 percent level affect oil yield and quality (Bender and Hill, 1989). Further, splits are associated with growing, harvesting, and storage conditions which in themselves may negatively affect quality. A high number of splits may indicate poor handling or harvesting conditions and are also often used as a proxy for high free fatty acids. Thus splits should have a negative relationship with price.

Damaged kernels are a grade determining factors with a maximum level of 2 percent for No. 2 soybeans. Damaged kernels measure damage arising from mold and a number of factors which can reduce the value of the soybean shipment.

The expectation is that higher levels of moisture lead to lower price since increased moisture lead to lower levels of useable soybean oil and protein. Higher levels of water are also associated with a higher probability of mold damage. Further, since water does not contribute to the processing value of a shipment then its presence within the range found in the shipments is costly because its weight must be shipped along with the useful protein and oil. However, moisture may reduce shattering in soybeans so that higher levels of moisture lead to reduced levels of damage while shipping.

Quantity is the volume of the total shipment. It is expected that it would be cheaper per unit to load a large volume of soybeans as compared to a shipment of a smaller volume. This effect would be expected to decline as the quantity increases, so a log specification is given for this variable.

It is also possible for processors' demand and valuation of quality to vary by time and destination. To account for temporal shifts we included time dummy variables representing marketing years. Destination differences in prices paid for a shipment arise from the fact that the demand for soybeans from the processor is based upon the institutional factors in a particular market.

Including time and destination dummy variables yields equation 7:

$$(7)\ P_{it} - P_t = \beta(Z_{it} - Z) + \vartheta RATIO + \delta MY + \gamma(COUNTRY) + \theta FM89/90$$

where $P_{it}$ is the observed per bushel price of the shipment, $P_t$ is the price of No. 2 U.S. soybeans one week prior to shipment, $Z_{it}$ is the vector of quality characteristics which in this case are average moisture, average oil content, average protein content, splits, foreign material, and damaged kernels[2], RATIO is the natural log of the ratio of individual shipment size to average shipment size[3], COUNTRY is a set of dummy variables indicating if the destinations are Korea and Japan, FM89/90 is the amount of foreign material multiplied by the dummy variable for the 1989/90 marketing year, and Z is the vector of quality characteristics associated with the reference grade. If these qualities are not included in the reference grade then the average quality for the entire period is used[4]. MY is a set of marketing year dummy variables for the marketing years 1989/1990 and 1990/1991. This is the equation that was estimated for a regression pooling the observations of all 3 marketing years. Separate regressions were also estimated for the separate marketing years without the marketing year dummy variables.

## Empirical Results

The specific functional form of the relationship between price and quality is not determined theoretically (Rosen, 1974). There are a number of potential relationships used including linear, logarithmic, semi-logarithmic, and higher order relationships[5]. Each of these types of forms were examined and discarded in favor of the linear model except for the RATIO variable due to a better statistical fit of the linear model.

The unit values of the shipments less the reference price were regressed as indicated by equation 4. The results are presented in Table 3 for an aggregate regression covering three marketing years and separate regressions for each marketing year[6]. The coefficient estimates are interesting in that all the coefficients for the quality characteristics except oil, protein, and splits had the expected signs in the aggregate regression. Furthermore, the coefficients for moisture, foreign material, damaged kernels and quantity were all significant at the 10% level in the aggregate regression.

The Breusch-Pagan-Godfrey Test[7] and the Harvey Test[8] were utilized to check for heteroskedasticity. These tests did not reject the null hypotheses of homoskedastic variance for any of the regressions except for the 1989/90 marketing year in its specific regression[9]. The Belsley, Kuh, and Welsch (1980) diagnostic for multicollinearity yielded a condition number of 14, indicating that multicollinearity was not a problem.

The coefficient for foreign material was found to be significant at the 10 percent level and marketing year dependent. At the beginning of the 1990/91 marketing year the way foreign material was checked for was changed. This change resulted in a reduction in the possibility that undetected foreign material would occur. This institutional change evidently had a large impact on pricing efficiency as foreign material had the expected negative sign after the institutional change.

Protein and oil content coefficients were positive but not statistically significant at the 10% level. This agrees with the earlier observation that while buyers may attach a positive value to the protein and oil yields of soybeans, the current marketing system does not allow these values to be transmitted in the price (as a premium or discount to existing grades). Hence, U.S. farmers do not have an incentive to produce soybeans with higher quantities of oil and protein. Shippers do not generally segregate loads containing higher or lower protein and oil content (Stitzlein, 1994).

The coefficient for moisture was significant and positive. The results suggest a strong incentive for handlers to re-wet or at least maintain moisture levels of grain in the marketing system. This is surprising in that increased moisture serves as deadweight in a shipment of soybeans and should detract from the unit value of the shipment. The results may be partially explained by the fact that contracts specify minimum quality standards which provide no incentives for actually providing less water to the market. Further, increasing levels of moisture decrease breakage susceptibility which is a positive quality and is unobserved in the data set.

## Implications for the Marketing System

Information on the values of quality characteristics could be of use to producers, merchandisers, and elevators as they make decisions about what quality to provide to buyers. The results of this study will contribute to the current debate over what kinds of changes in the existing soybean grades and standards will allow buyer valuations to be transmitted through the marketing system. As mentioned earlier, some have proposed that the United States should lower the level of foreign material in No. 2 soybeans from 2% to 1%. There has also been concern that the importers' valuation for protein and oil is not transmitted clearly through the existing marketing system.

The results of the study indicate an incentive for high moisture content in soybeans over the range studied. Increasing amounts of moisture actually seem to increase the value of the shipment[10]. Hill (1993), proposed a marketing system where moisture is discounted from the total of shipment is adjusted to the weight at a base moisture. This removes the incentive to "re-wet" grain; however this proposal does not take into account the potential benefit that moisture provides in reducing breakage susceptibility. More study of the relationship between moisture and value to processors is needed before such a system is implemented in soybeans.

It has long been argued that decreasing the level of foreign material in soybean exports will increase the value of the shipment. The implicit price of foreign material from this study suggests that buyers will discount for higher foreign material, or conversely, buyers will pay more for grain with lower foreign material especially after the institutional changes at the end of the 1989/90 marketing year. The implicit price of foreign material therefore provides information about the potential benefits of cleaner soybeans.

The results of this study suggest little (or no) premium for higher protein and oil content in the current marketing system. Importers have not paid explicit discounts or premiums for higher or lower oil and protein[11]. One way to increase the effectiveness of the U.S. soybean marketing system would be to include protein and oil explicitly in the market transactions. This would provide clearer signals about buyer's preferences for higher protein and oil content.

In general, the potential problem with providing the quality needs of buyers is the multidimensional nature of quality. Transactions costs of negotiating on the basis of individual quality characteristics and shipping segregated lots may be greater than the perceived benefit. A well structured grading system (one that more accurately conveys buyer preferences) will improve marketing efficiency.

## Conclusion

The results of this analysis indicate that the price of soybeans exported is not affected by the oil and protein content of the soybeans. Moisture content was surprisingly found to positively affect price while foreign material reduced price after the 1989/90 marketing year. Damaged kernels also negatively affected export price.

In this era of increasing competitiveness the United States faces the challenge of developing innovative methods to compete effectively. The provision of higher quality beans could be one such source of competitive advantage (Heien and Pick, 1991). However, as the results of this study indicate, the current marketing system provides incentives for increased moisture and does not provide incentives for soybeans with higher protein and oil content. Therefore, there is a need to modify the market system and pricing system to more accurately transmit the quality requirements of buyers to U.S. producers and exporters.

Table 1. Countries and Observations in the Data Set

| Country | Shipments |
|---|---|
| Japan | 59 |
| Korea | 24 |
| Netherlands | 67 |
| Germany | 3 |
| Italy | 1 |
| England | 8 |
| Portugal | 5 |
| Belgium | 10 |
| Spain | 19 |
| France | 2 |

Note 1: Includes only observations used in the analysis.

Note 2: The Netherlands, Germany, Italy, Britain, Portugal, Belgium, Spain, and France are all part of the European Economic Community.

Table 2. Summary Statistics for the Data Set

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Price* ($/bu) | 0.040 | 0.161 | -0.386 | 0.477 |
| RATIO (tons) | 0.008 | 0.702 | -2.968 | 1.155 |
| Damaged Kernel* (%) | 0.970 | 0.345 | 0.300 | 2.500 |
| Foreign Material* (%) | -0.233 | 0.398 | -1.200 | 1.000 |
| Splits* (%) | -1.123 | 0.262 | -1.700 | 0.000 |
| Protein Content* (%) | 0.007 | 0.420 | -1.100 | 0.900 |
| Oil Content* (%) | 0.099 | 0.396 | -0.900 | 1.000 |
| Moisture Content* (%) | -0.014 | 0.599 | -1.500 | 1.700 |

*Note: All the variables indicated are the differences from the base grade. This means that the variables described above were the variables actually used as explanatory variables in the regression.

Table 3. Hedonic Soybean Price Regression for 1990-1991

| Variable | Aggregate | Marketing Year | | |
|---|---|---|---|---|
| | | 1989/90 | 1990/91 | 1991/92 |
| RATIO | -0.037* (-2.24)[2] | -0.067* (-1.95) | -0.025 (-1.14) | -0.002 (-0.04) |
| Damaged Kernels | -0.054* (-1.69) | -0.021 (-0.49) | -0.053 (-0.99) | -0.077 (-0.70) |
| Foreign Material | -0.101* (-2.94) | 0.114* (1.76) | -0.094* (-2.17) | -0.094 (-1.17) |
| -Foreign Material, 1989/90 | 0.203* (3.14) | | | |
| Splits | 0.014 (0.44) | 0.014 (0.24) | -0.074 (-1.65) | 0.058 (0.50) |
| Protein Content | -0.003 (-0.08) | 0.043 (0.54) | 0.032 (0.78) | -0.164 (-0.10) |
| Oil Content | 0.019 (0.44) | -0.072 (-0.82) | -0.016 (-0.22) | 0.054 (0.47) |
| Moisture Content | 0.063* (2.48) | -0.016 (-0.23) | 0.041 (1.29) | 0.052 (0.96) |
| Japan | 0.035 (1.44) | -0.004 (-0.09) | 0.014 (0.40) | 0.142* (2.26) |
| Korea | 0.059* (1.73) | -0.164* (2.42) | 0.009 (0.18) | -0.003 (-0.04) |
| Marketing Year 1989/90 | 0.086* (1.96) | | | |
| Marketing Year 1990/91 | 0.088* (2.94) | | | |
| $R^2$ | 0.24 | 0.22 | 0.22 | 0.44 |
| No. of Observations | 198 | 65 | 98 | 35 |

2 Represents t-statistics, * denotes significance at the 10% level.

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1. Twenty-four observations were dropped from the sample because it was judged they represented soybeans to be used for direct processing into food products such as tofu and tempé.

2. The definition of these variables is shown in the next section.

3. The average quantity is 2,100 metric tons.

4. The average observed values for moisture, oil content, and protein content are 12%, 18.8% and 35.5% respectively.

5. Some authors (Cropper *et al.*, 1988; and Craig *et al.*, 1991) have recommended the use the linear and/or quadratic Box-Cox forms to determine the functional form of the relationship. This regression procedure is not appropriate in this case because both the dependent and independent variables take on values of zero as they are deviations from the base grade. This makes it impossible to apply the Box-Cox form.

6. An alternate possibility would be that quality demand was differentiated by destination markets. This possibility would preclude the unique estimation of demand parameters in a aggregate regression as has been discussed by Epple(1987) and as was done in the empirical analysis of this study. A Chow test was used to determine if separate regressions for Japan, Korea, and the European Community were significantly different from the aggregate regression. The F (12,174) statistic of 1.25 generated failed to reject the aggregate model hypothesis at the 5% level. This result is consistent with earlier research (Pick and Park, 1991) which also did not find appreciable product differentiation by country for soybeans.

7. see Judge et al, Equation 11.3.4.

8. see Judge et al, Equation 11.2.60.

9. This heteroskedasticity was not corrected for. The main results are drawn from the aggregate regression.

10. This is similar to the Gillmeister *et al.* study (1992) which found that water in milk increased it value.

11. There are some indications that this may be changing. In the Fall of 1992 the Japanese offered premiums for soybeans with a higher content of oil and received an average of 0.4% more of oil.