Differentiation and Implicit Prices of U.S. Wheat Exports

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This investigation looks at whether the grade determining and official criteria factors identified by the Federal Grain Inspection Service influence the price of wheat for export and, in turn, the competitiveness of United States wheat in the world market. Using data on the transactions price for hard red winter wheat, hard red spring wheat, and soft white wheat and the associated quality characteristics covering the period January 1990 through December 1991 and exported to 63 countries, the results suggest that the test weight, the percentage of shrunken and broken kernels, the protein content, the presence of aflatoxin, the presence of insects, and the falling number are characteristics consistently valued by the market.

Complaints by foreign grain buyers have generated an intense debate among farmers and exporters concerning the quality of U.S. grain exports (Hill [1990], Johnson and Wilson [1992], Marlenee [1987], Pick, et al. [1992], and Wilson and Preszler [1992]). The attention has focused on the difference in quality between that stated on the certificate of export and that received in the processors' plants. Frost and mold damage, excessive broken kernels, insect infestation, and low yields of processed products are the most frequent complaints (Hyberg, et al. [1993] and Mercier [1989]). Although U.S. exports have sometimes declined following a year of an unusually large number of complaints, there is no empirical evidence to support a cause-and-effect relationship between quality and market share (Hill [1993]). Nevertheless, the likelihood that customer dissatisfaction influences future purchases has been used to justify numerous congressional actions.¹

A variety of changes have been proposed. These consist of four types including redefining grade determining factors, adding new grade factors, varying the factor limits, and regulating marketing and handling practices. Change in factor definitions is illustrated by the debate in the early 1990s about treating shrunken and broken kernels and foreign material (BCFM) as one grade factor or two. The issue was studied extensively in the 1930s and 1970s (Hill [1990]), but the studies were not sufficiently conclusive to support separation of BCFM into two categories.

Requests for additional grade factors are typically motivated by the search for indicators of product yield (Office of Technology Assessment [1989]). In 1986, for example, the Grain Quality Improvement Act (P.L. 99-641) included value-in-end-use as a purpose of grade and standards and required future grade changes to take end use value into account. The debate on this issue has now centered on which uses shall be reflected in grades and which measurable characteristics are correlated with each end use (e.g., General Accounting Office [1987], Johnson and Wilson [1992], Marlenee [1987], and Wilson [1987]).

The Standards for Grain

Grades and standards are based on numerical values for a set of factors selected to reflect the quality of each type of grain. Quality characteristics may be included as grade determining factors, where factor limits determine numerical grade, as standards where values do not affect numerical grade, or as official criteria where values are determined and reported only when requested by the importer.

¹ Most recently, Title XX of the Food, Agriculture, Conservation and Trade Act of 1990 (P.L. 101-624) mandates the Federal Grain Inspection Service of the U.S. Department of Agriculture to examine the benefits and costs of providing cleaner grain to the export market.
Under Section 4 of the Grade Standards Act, factors in the grades must be measured whenever an official inspection is performed. Factors considered as official criteria, however, are measured only upon request. This suggests that only those nongrade characteristics of greatest importance to the largest number of consumers would be incorporated as standards. Those of lesser importance, or of importance to only a few consumers, would be official criteria available upon request to those buyers who require them. For wheat, breakage susceptibility, kernel hardness, heat damage, and falling number (a measure of gluten strength) are some factors that are available to be made official criteria (Federal Grain Inspection Service [1989]).

At issue is whether characteristics other than those included as part of the official grades and standards are valued by the market and should become uniformly available in order to effectively fulfill the requirements of the Grain Quality Improvement Act of 1986. An investigation of this is the subject of what follows.

The Economics of Grain Quality

Overview

A specific grain is typically heterogeneous in nature, exhibiting differences in quality, variety, and other physical and intrinsic characteristics. In a competitive market, a variety of forces operate to assign a price to this grain. This price reflects the presence and relative merits of all important attributes. Price differences between similar grains with somewhat differing characteristics - referred to as differentiated products (grains) - represent the difference in the value associated with whatever inherent differences exist between them. Because of this, the price of a specific grain can be viewed as being determined by a combination of implicit prices associated with individual attributes and characteristics of the grain.

Wheat is one agricultural commodity that possesses considerable variation in variety and quality which potentially influences its price. Wheat is grouped according to growing habit, color, and kernel texture. The major distinction, however, is the growing season. Winter wheats are planted in the fall and harvested in the fall. Both winter and spring wheats produce grain that is red, white, or yellowish amber in color. Wheat is also grouped according to whether it is hard or soft. Spring and winter hard varieties tend to be higher in protein and are principally used in bread flour. Softer wheats, both white and red types, contain lower protein and are milled into flour for cakes, cookies, pastries, and crackers. Durum wheat, which is very hard, is milled into semolina for pasta products (Wheat Flour Institute [1981]). These general groupings have resulted in the establishment of seven basic classes of wheat: Hard Red Spring, Hard Red Winter, Soft Red Winter, Soft White, Durum, Unclassed, and Mixed.

The quality of wheat is generally determined by the Federal Grain Inspection Service (FGIS) by such factors as weight per bushel, percentage of heat-damaged kernels, percentage of foreign material (non-wheat material of similar size and weight to wheat kernels), percentage of shrunken and broken kernels, and moisture content. The percent of shrunken and broken kernels and foreign material consist of non-millable or poorly millable material and are the factors typically referred to when the issue of grain cleanliness is discussed as in the Grain Quality Title (Title XX) of the Food, Agriculture, Conservation and Trade Act of 1990 (Economic Research Service [1991]).

Theoretical Constructs

The demand for wheat in general is a derived demand (Stigler [1966]). That is, the demand for wheat is not based on any intrinsic desire for the wheat itself, but rather on the need to use the flour resulting from the milling of the wheat to produce bread, rolls, pastries, crackers, etc. This means that the demand for wheat is determined in the final markets by the demand and supply for wheat derivative products being sold. Thus, the derived demand for wheat is indirectly based on the elements which generate the demand and supply for wheat derivative products produced from wheat. These latter considerations, however, will not be explicitly incorporated into the analysis because of data limitations. Rather, just the demand for wheat by processors (millers) will be explicitly considered.
Each characteristic of wheat is viewed as an input into a production process. Under this approach, a differentiated product like wheat is demanded by processors because of the particular physical and intrinsic characteristics that it possesses. These characteristics are identifiable inputs in the production of flour (processed wheat). It is possible to express the implicit price associated with each characteristic.

Assume, as does Ladd and Martin [1976], a profit maximizing processor operating in a competitive environment. The production function is assumed to be composed of the wheat characteristics in addition to the other factors of production used in milling flour. Let this production function for output \( x \) be represented as \( f_x(z) \) where \( z \) is a vector of inputs including the physical and intrinsic characteristics of wheat. The first-order conditions (developed in Ladd and Martin [1976]) assuming profit maximization give an implicit price for input \( v \), \( p_v \), as:

\[
\begin{align*}
    p_v &= p_0 \sum_{k=1}^{m} \left( \frac{\partial f_x}{\partial z_{kv}} \right) \left( \frac{\partial z_{kv}}{\partial v_k} \right) \\
    &= p_0 \sum_{k=1}^{m} A_k \gamma_{kv}
\end{align*}
\]

where \( p_v \) is the price of input \( v \) (e.g., wheat), \( p_0 \) is the price of the output (e.g., flour), \( m \) is the number of physical and intrinsic characteristics of the input, \( \partial z_{kv}/\partial v_k \) is the marginal yield of the \( k \)th characteristic in the production of \( x \) from input \( v \), and \( p_0 (\partial f_x/\partial z_{kv}) \) is the value of the marginal product of characteristic \( k \) used in the production of \( x \). The term \( p_0 (\partial f_x/\partial z_{kv}) \) is the implicit price of the \( k \)th characteristic. Relationship (1) indicates that the price of each input is equal to the sum of the implicit prices of the characteristics possessed by the input multiplied by the marginal yield associated with each of those characteristics.

It is possible to simplify relationship (1) by assuming that only one product is being produced (e.g., flour). Let \( p_0 (\partial f_x/\partial z_{kv}) = A_k \) and \( \partial z_{kv}/\partial v_k = \gamma_{kv} \). Additionally, assume that \( A_k \) and \( \gamma_{kv} \) are constant. That is, assume that each additional unit of input \( v \) (e.g., a bushel of wheat) contributes the same amount of the \( k \)th characteristic (e.g., protein) to the production function and that the implicit price for characteristic \( k \) is constant (Ladd and Martin [1976]). Given these considerations, relationship (1) can be rewritten as:

\[
(2) \quad p_v = \sum_{k=1}^{m} A_k \gamma_{kv}
\]

where \( A_k \) is the marginal value of physical or intrinsic characteristic \( k \) and \( \gamma_{kv} \) is the quantity of characteristic \( k \) contained in each unit of input \( v \) that goes into the production of \( x \). \(^2\)

**Variables of Interest**

As noted previously, the concern here is with whether buyers value not only the physical and intrinsic characteristics that serve as the basis for determining the grade for which the FGIS collects and reports data but other nongrade determining characteristics as well. For wheat, the FGIS (FGIS [various months]) collects and reports for a sample of wheat exported from the United States information by grade ranging from 1 to 5, GV1, GV2, GV3, GV4, and GV5, on a number of grade determining characteristics including test weight per bushel, WGT, the percentage of foreign material, FM, the percentage of shrunken and broken kernels, SBK, and moisture content, MOIS.

The grade measure is a composite of factors and is based on quantitative limits (either a minimum or maximum) in place for each factor for each of the grades. Given the way the grades are defined, a higher grade should be associated with a higher price for wheat.

Test weight (in pounds per bushel) measures the density of wheat kernels and thus is an indicator of flour yield. The higher the test weight, the greater the expected flour yield so that test weight should be positively related to price. The percent of foreign material and the percent of shrunken

\(^2\) The development here has assumed that the relationship between the price of the input and the implicit value of the quality characteristics and the quantity of the characteristics is linear. This implies that each processor utilizes the input in the same fashion as every other processor so that they all have identical production functions. This, of course is not necessarily realistic. That is, different processors might have differences in preferences among characteristics (e.g., more protein content versus less moisture content) for different uses (e.g., bread production versus cracker production). In this situation, the price relationship would not be linear. Whether the relationship is linear is an empirical issue that must be investigated.
and broken kernels are non-millable or poorly millable material and yield little or no useable flour. Consequently, the quantity of each of these factors should be inversely related to the price of wheat.

Finally, moisture content in percent is ostensibly significant in that a higher moisture content is indicative of a lower amount of dry, millable matter. Additionally, as the moisture content increases, the likelihood of damage during storage associated with mold increases (Brookreson [1987] and Milling and Baking News [1988]). Thus, an elevated moisture content is expected to be inversely related to the price of wheat.

There are nongrade determining physical and intrinsic characteristics that are potentially important in determining the price of wheat and which the FGIS has the capability of measuring (i.e., official criteria). Whether the market values these is of concern here. These include such things as protein content, PROT, dockage (material other than wheat that can be removed by scalping, aspiration, and screens), DOCK, heat damage, HD, frost damage, FD, mold damage, MD, the presence of aflatoxin, AFLOT, falling number (a measure of sprout-induced starch damage in wheat),^3^ FNUM, the presence of insects, INSECT, the use of fumigants to control for the presence of insects, FUM, the presence of smut, SMUT,^4^ and kernel hardness, HARD.

The protein content percentage measure is used to indicate the quantity of a given wheat’s gluten, which includes gliadin and gives dough its tough elastic quality. Protein is a desirable component of hard wheat used in the production of yeast breads and hard rolls and thus should be positively related to the price of wheat where the wheat is used for making yeast breads and hard rolls and similar products (General Accounting Office [1987]). That protein is perceived to be a very important determinant of the wheat price was highlighted in November 1987 during a Joint Hearing before the Subcommittee on Agricultural Production and Stabilization of Prices of the Committee on Agriculture, Nutrition, and Forestry of the United States Senate and the Subcommittee on Wheat, Soybeans, and Feed Grains of the Committee on Agriculture of the United States House of Representatives. During those hearings, the impact of the FGIS protein measurement on wheat prices was discussed. It was repeatedly suggested that the protein content of wheat was an extremely important factor (e.g., Wilson [1987]) or the only important factor (e.g., Kelly [1987]) in determining the price of hard red winter and hard red spring wheat for export.

Dockage consists of non-millable or poorly millable material that yields little useable flour. Consequently, it should be inversely related to the price of wheat. However, because allowance for dockage is typically made at the point of delivery (it is subtracted from the shipment quantity), it has been argued (Lin and Leath [1993] and Mercier [1989]) that it is unlikely that its effect on price will be appreciable. Whether this is correct, however, is an empirical question that will be addressed.

Heat damage (in percent), frost damage (in percent), and mold damage (in percent) all adversely affect flour yield and hence should be inversely related to the price of wheat. The presence of aflatoxin^5^ is undesirable (highly undesirable in some Asian countries (Mercier [1993])) affecting the look and taste of flour and, in some instances, the health of the consumer when consumed in a sufficient concentration. It should be inversely related to the price of wheat.

A higher falling number (measured in seconds) indicates a lower degree of starch damage and, since starch damage is an undesirable property, a higher falling number should be positively related to price.

The presence of insects is undesirable and can raise the cost of wheat to the buyer since an excess amount of insect parts in wheat will require additional cleaning via an aspirator (Hyberg, et al. [1993]). Thus, the presence of insects should be inversely related to the price of wheat. The use of fumigants is designed to destroy pests infesting wheat and thereby increase

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^3^ Sprout damage to wheat kernels increases alpha-amylase activity in the flour which retards the ability of the flour to thicken which is important in most baked goods.

^4^ Also known as dwarf bunt. A wheat fungal disease (Telletia Controversa Kuhn) which infects wheat.

^5^ Aflatoxin is a toxic substance produced by fungus, especially Aspergillus flavus (University of Illinois [1980]).
There should, consequently, be a positive relationship between the price of wheat and the use of fumigants. The implicit presumption is that there are no residual fumigants on the wheat. If there are, food safety issues become of concern and thus residual fumigants can adversely affect the price of wheat. Currently, however, there are no measurements of fumigant residuals on wheat and they are not considered to be an official criterion.

While it would be desirable to consider the impact on price of each of the nongrade determining characteristics included in the official criteria that the FGIS has the capability of measuring, data in the sample were not consistently collected for heat damage, mold damage, smut, and kernel hardness. Hence, these variables are deleted from consideration in the estimation.

Data

In estimating the implicit prices associated with the characteristics of a good, all of the characteristics potentially valued by the market should be considered in the specification. In the current instance, however, all of the characteristics that might be important in determining the price of wheat, as noted previously, are not available. This arises because the data that are used in the estimation were collected by the FGIS and represent transactions prices (FOB) for specific shiplots together with information on grade determining characteristics and official criteria for each of those shiplots. On the one hand, this presents some potential problems in specifying the price relationship (i.e., a specification problem is present (Theil [1957])). On the other hand, it is a substantial improvement over most other studies attempting to measure the implicit prices associated with a grain's characteristics because it uses actual transactions prices and the associated physical and intrinsic characteristics instead of some sort of average values for the various variables. Thus, for example, in studying the price of Kansas wheat, Espinosa and Goodwin [1991] use seasonal averages of the price of wheat and wheat characteristics for nine crop-reporting districts in Kansas. Young and Mercier [1993], Veeman [1987] and Larue [1991] use annual averages of the price of wheat and its characteristics. It has been shown that the use of averages is not appropriate in the estimation of implicit price relationships (Brown and Rosen [1982], Griliches [1964], and Triplett 1986)). Aggregation tends to obfuscate the measurement of the impact of physical and intrinsic characteristics on the price of the good.

The individual transactions for which the data were collected by the FGIS occurred over the period January 1990 through December 1991. A sample of 1141 wheat shipments was taken representing five different kinds of wheat including hard red winter wheat, hard red spring wheat, durum, soft white wheat, and soft red winter wheat. The wheat was shipped to 63 countries. None of the shipments was made under any of the U.S. federal government export programs (e.g., PL-480, GSM-102, GSM-103, or the export enhancement program (see Ackerman and Smith [1990] for a discussion of the programs)). Three grades - U.S. number 1, U.S. number 2, and U.S. number 3 - are represented in the sample and the wheat is shipped from four different locations - the West Coast, the East Coast, the East Gulf Coast, and the Great Lakes.

Estimation Considerations

Functional Form

An important empirical issue deals with the choice of the appropriate functional form for the implicit price function. In the theoretical discussion above, the equation for the price of wheat (relationship (2)) was assumed to be linear. This was based on a number of implicit assumptions including a constant implicit value of individual wheat characteristics. The accuracy of this linearity assumption needs to be verified.

Economic theory in general places few restrictions on the form of the implicit price function. If the goal is to measure implicit prices of the characteristics of a good, the form of the price function that should be used is the one that most accurately estimates implicit characteristic prices.
Errors in the measurement of the implicit prices of quality characteristics may bias the valuation of the good in question (Cropper, et al. [1988]). To carefully scrutinize the form of the price function, a number of studies, including those by Craig, et al. [1991], Cropper, et al. [1988], and Rasmussen and Zuehlke [1990], have recommended the use of linear and/or quadratic Box-Cox forms.

The general Box-Cox form is given as

\[ G(P,\lambda) = \alpha + \delta' G(X,\phi) + 0.5 G(X,\phi)' \beta G(X,\phi) + \epsilon \]

where \( G(P,\lambda) \) denotes the Box-Cox transformation of the selling price of wheat \( P \) with parameter \( \lambda \) and \( G(X,\phi) \) denotes the vector of Box-Cox transformations of a vector of \( k \) explanatory variables \( X \) with parameter \( \phi \). The scalar parameter \( \alpha \) is the intercept of the price function, \( \delta \) is a vector of coefficients for the \( k \) linear terms, and \( \beta \) is a \( k \times k \) symmetric matrix of coefficients for the squared and cross-product terms.

Use of the Box-Cox transformation provides considerable flexibility in the functional representation of the variables and includes the linear, logarithmic, and reciprocal values as special cases. The Lagrange Multiplier test is an appropriate way to check for the appropriate transformation and is the one that will be employed here (Davidson and MacKinnon [1985] and Godfrey [1988]).

**Data Grouping**

Another concern has to do with grouping the data across all types of wheat. Given that flours from different types of wheat (e.g., hard red winter wheat versus soft white wheat) are typically used for different purposes, the market valuation of quality characteristics can be better understood by considering the different categories of wheat independently since different factors will be driving the markets for the different processed wheats. In the sample data, there are a sufficient number of observations for three categories of wheat to permit estimation and obtain robust estimates. These three categories include hard red winter wheat, hard red spring wheat, and soft white wheat.

**Nature of the Data**

Estimation of empirical relationships which combine cross section (the data cover 63 countries) and time series data (the data cover the period January 1990 through December 1991) frequently present unique estimation problems. For example, differences can exist among cross-sectional units (countries in the current analysis). The problem of serial correlation (first order or, perhaps, higher orders given that the shiplot data being used cover 24 months) might also be present in the time series structure of the data. Frequently used estimation techniques such as pooled cross section and time series estimation techniques (see, e.g., Judge, et al. [1985]) are not appropriate here because there are many missing observations for various country/month paired combinations. Still, it is necessary to make allowance for possible effects common to individual countries represented in the cross section but not captured by the other variables used in the estimation. This can arise because individual countries sometimes have special purchase arrangements or have unique requirements that are not reflected in the quality characteristics of the wheat.\(^8\)

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\(^7\) The Box-Cox transformation for a variable \( w \) is given as

\[ w(\gamma) = \begin{cases} (w^\gamma - 1)/\gamma & \text{for } \gamma \neq 0 \\ \log(w) & \text{for } \gamma = 0. \end{cases} \]

This transformation is well defined for all \( w > 0 \) and it is continuous.

\(^8\) For example, in China, Ghana, and Indonesia, wheat purchases are made by government traders while in Italy, South Korea, and Venezuela, private traders make all wheat purchases. In Japan, the government makes the purchases and there is a price support system while in the Philippines, private traders make all purchases and there is a 10 percent value added tariff. The specifics of these purchasing arrangements and a broad discussion of their implications for the price of wheat is found in Mercier [1993].
Additionally, any dynamic effects associated with the time series must be captured. The dynamics can take the following form. Over the period January 1990 through December 1991 covered by the data, one sees relative changes in the price of wheat due to fluctuation in quality characteristics between ships. Additionally, however, one might observe variations in the absolute price of wheat due to changes in the underlying market conditions for wheat (Griliches [1971]). Whether this is the case is an empirical issue that needs to examined.

Other Considerations

There remain a few other considerations before turning to the estimation results. One has to do with heteroscedasticity. In the current analysis, this problem would occur if the regression results for, say, larger ships indicate a larger variation in the error term on the wheat price equations than one observes for smaller ships. For the data being used here, White’s [1980] test for heteroscedasticity was performed on the price equation for each of the three categories of wheat. The test statistic is distributed as chi-squared. The computed value of the test statistic for the hard red winter wheat equation is 34.92, while for the hard red spring wheat equation it is 30.09, and for the soft white wheat equation it is 19.85. The critical value at the 5 percent level and 104 degrees of freedom is 125.04. In each instance the tabulated value is less than the critical value so that the null hypothesis of homoscedasticity can not be rejected for any of the wheat price equations.

There are a couple of other factors besides physical and intrinsic characteristics and the country of destination and the temporal considerations that might impact the price of wheat. For example, the location from which the wheat is shipped and the grade of the wheat are potentially important in explaining variations in the price of wheat. Preliminary analyses did not show the origin of the shipment to have any statistically identifiable impact on explaining variation in the price of wheat across ships probably because the price variable is net of any transportation charges. Second, the grade variation, as noted above, is reflected in such things as the moisture content of the wheat, and the percentage of shrunken and broken kernels. Consequently, a variable to account for the grade of a ships was not included in the final wheat price specification.

Finally, it is not uncommon in empirical work to find that the results are very much influenced by a subset of the total number of observations used in the estimation. As a check on the possibility that coefficient estimates were inordinately influenced by a subset of the total number of observations used in the estimation, the empirical analysis was subjected to the regression diagnostics of Belsley, Kuh and Welsch [1980].

The fact that a subset of the data can have a disproportionate influence on the estimated parameters is of concern because it is quite possible that coefficient estimates in the model are generated primarily by this subset of the data rather than by all of the data equally. Belsley, Kuh and Welsch identify four diagnostic techniques to help in isolating influential data points: RSTUDENT, HAT DIAGONAL, COVRATIO, and DFFITS. Each of these diagnostics is employed here.

Preliminary Analyses

Preliminary analyses were undertaken to examine which variables are multicollinear, to determine the appropriate functional form to use, and to search for any data irregularities. In the case of multicollinearity, the objective is to minimize the impact of multicollinearity while at the same time to maintain the integrity of the functional specification. For the grade determining factors and official criteria for which data are collected by the FGIS, there is a general absence of any relatively strong collinearity (e.g., where the correlations equal or exceed 0.6) with the other explanatory variables. Thus, for example, while a priori one might expect test weight and moisture content to be relatively highly correlated, for the three different types of wheat being considered the correlation never exceeds 0.29.
with one exception.\textsuperscript{10,11} Similarly, linear combinations of the quality characteristics did not exhibit strong collinearities with one or more of the other quality characteristics. Finally, use of the variance decomposition collinearity diagnostic of Belsley, Kuh, and Welsch \citeyear{BEL90} never results in a computed value in excess of 0.26 for the variable combinations considered. The exception is the relationship between the presence of insects and the use of fumigants. In this case, the correlation between the presence of insects and the use of fumigants for each of the wheat types exceeds 0.75 and the variance decomposition diagnostic exceeds 0.80.\textsuperscript{12} Nevertheless, the estimation is carried out without adjustments for any potential impact of collinearity among the quality characteristics variables (e.g., eliminating the insect presence variable or the fumigant use variable). This decision is made in order to maintain the integrity of the specification. Its effect is explored below.

Next, a Lagrange Multiplier test was utilized to determine the appropriate functional form for the price equation of the three types of wheat being considered here. The test statistic is distributed as chi-square with the number of degrees of freedom equal to the number of restrictions (Engle \citeyear{ENG84}). The null hypothesis for each is that the transformation parameters $\lambda$ and $\phi$ are equal to one. The value of the test statistic for hard red winter wheat is 3.01, for hard red spring, it is 2.94, and for soft white, it is 2.89. In each instance the value is below the 5 percent critical value of 5.99 (for two degrees of freedom) indicating that the null hypothesis cannot be rejected. That is, the relationship between the price of each type of wheat being considered and its characteristics is linear. Subsequent reported empirical results will therefore be based on this.

Also, preliminary analyses did not generally show the quadratic terms of the Box-Cox transformation to be statistically significant. Thus, a zero restrictions likelihood ratio test was applied to the matrix of coefficients $\beta$. The null hypothesis was that each element of the matrix is equal to zero. There are eleven quality characteristics used in the analysis including test weight per bushel, WGT, the percentage of foreign material, FM, the percentage of shrunken and broken kernels, SBK, percentage dockage, DOCK, moisture content, MOIS, protein content, PROT, frost damage, FD, the presence of aflatoxin, AFLOT, falling number, FNUM, presence of insects, INSECT, and the use of a fumigant to control for the presence of insects, FUM. Therefore, the matrix of coefficients $\beta$ is $11 \times 11$. The value of the test statistic (which is distributed as chi-squared with the number of degrees of freedom equal to the number of restrictions which, in this instance, is equal to the number of elements in the matrix $\beta$ (121)) for hard red winter is equal to 41.09, for hard red spring is equal to 39.20, and for soft white is equal to 20.07. The critical value at the 5 percent level for each test is 146.57. Consequently, the null hypothesis of zero restrictions is accepted for each type of wheat indicating that a linear specification with no quadratic and no cross-product terms is adequate.

The implications of this finding of the appropriateness of a linear relationship are straightforward. The results are consistent with the assumptions delineated above that the yields of the wheat quality characteristics are constant across wheat purchasers and that the marginal implicit values of individual wheat characteristics over the period of study are constant.

**Empirical Results**

A linear function for the export price of three different types of wheat was estimated. The price is measured in dollars per metric ton. A total of 159 observations were used in estimating the hard red winter wheat price equation, a total of 195 observations were used in estimating the hard red spring wheat price equation, and a total of 70 observations were used in estimating the soft white wheat price equation. The data, as noted previously, are a mix of cross section and time series observations. Descriptive statistics for the

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\textsuperscript{10} For hard red winter wheat it was 0.29, for hard red spring wheat it was 0.22, and for soft white wheat it was 0.09.

\textsuperscript{11} This result, upon closer examination is not surprising. The FGIS in measuring the weight of wheat adjusts for a constant 12 percent moisture content (Hill \citeyear{HIL90}).

\textsuperscript{12} For hard red winter wheat the correlation was 0.79, for hard red spring wheat it was 0.82, and for soft white wheat it was 0.75. For hard red winter wheat, the variance decomposition diagnostic was 0.86, for hard red spring wheat it was 0.91, and for soft white wheat it was 0.80.
samples of the three wheat types are presented in Table 1. Because the time period is relatively short, no attempt is made to correct for a changing price level (inflation). This means that the implicit values of the wheat quality characteristics are in current dollar terms. The units on the explanatory variables are as previously indicated.

To make allowance for possible effects common to individual countries represented in the cross section but not captured by the other variables used in the estimation, country specific qualitative variables (defined to equal one if the shipment was destined for a specific country and zero otherwise) are introduced and a zero restrictions test (Judge, et al. [1985]) employed to assess whether such factors have a measurable effect on the price of wheat sold to a country. If there was no indicated effect, the country variable was dropped from the final specification. The assumption is implicit that a varying intercept term captures any differences among the countries in the analysis and that each country shares common estimates of the implicit values of the wheat quality characteristics.

To account for variations in the absolute price of wheat due to changes in the underlying market conditions for wheat and in the absence of a better measure, qualitative variables are introduced for each month and defined to equal one if the shipment occurred in that month and zero otherwise. A zero restrictions test is used to determine whether there was any measurable change in the underlying market conditions for a given month. If there was none, the variable was dropped from the estimated relationship.

Next, because heteroscedasticity is not a problem in the data, correction to account for its impact is not necessary.

The price equations for the three different types of wheat were estimated via ordinary least squares using the grade determining factor and official criteria quality characteristics collected by the FGIS. Regression diagnostics indicated some data outliers. Using the hypothesized price relationship for each type of wheat discussed previously, the regression diagnostics were computed. The regression diagnostics - RSTUDENT, HAT DIAGONAL, COVRATIO, and DFFITS - indicated some outliers. That is, there are some observations for each type of wheat that are beyond the cutoff points. To mitigate the impact of data outliers on the coefficient estimates, the outliers can either be omitted from the sample which results in throwing away potentially useful information or making some allowance for them. The latter option is selected. A qualitative variable is introduced and defined to equal one for each observation that is judged to be an outlier and zero otherwise indicating a shift in the price function but no change in the slope for the deviant obser-
vation. For hard red winter wheat, there were 11 outliers, for hard red spring wheat, there were 9 outliers, and for soft white wheat, there were four outliers.

Table 2 reports the estimated coefficients with the exception of the coefficient estimates on the variables introduced to account for the data outliers. There is no apparent consistency among the outliers (e.g., they do not all occur in the same months nor do they all deal with shipments to one country or one region of the world). Reporting the estimates adds little useful information. They are available, however, upon request. The standard errors of the estimates are in parentheses.

The results are revealing. At least 85 percent of the variation in the price of wheat for export for the three different types of wheat is explained by the included variables. Additionally, the null hypothesis that all of the coefficient estimates for each wheat price equation individually are simultaneously zero (as indicated by the computed F-statistic) is rejected at the 5 percent level or better.

Just two of the FGIS grade determining factors - the test weight and the percentage of shrunk and broken kernels - are consistently statistically significant (at the 5 percent level) in explaining the export price for the three different types of wheat considered. Moreover, both of these factors have the expected impact on the price - positive in the case of test weight and negative in the case of the percentage of shrunk and broken kernels. The other grade determining factors considered including moisture content and the percentage of foreign material do not, on average, have a measurable (statistically identifiable) impact on the export price of wheat.

These results are useful in the context of the debate in the early 1990s about treating shrunked and broken kernels and foreign material as one grade factor or two. Clearly, the market values information about shrunk and broken kernels but not about foreign material. Consequently, the two factors should be considered separately in order to facilitate the efficient transmission of information in the market. These results are also useful in addressing another concern. In 1991 a proposal was made by the FGIS to reduce the limits on foreign material by 50 percent in order to expand exports. There is no evidence from the estimation results that a change in the percentage of foreign material will impact the price of wheat for any of the wheat classes considered. This means that absent any price effects, there would be no change in the quantity of wheat exported. Thus, the empirical verification desired by farmers and grain exporters of the beneficial effects of reducing the limits on foreign material in wheat is not provided by these results.

In terms of the quantitative impact of test weight on the price of wheat for export, shiplots of all three types of wheat are comparably affected by variations in test weight. Thus, for example, an higher test weight is associated with a higher price for the wheat and this higher price across the different types of wheat is approximately the same since there is no statistically significant difference in the coefficient estimate on the variable WGT in the price equation for the different wheat types.

Does the market value any of the factors making up the official criteria for which the FGIS collects data but which do not serve to determine the official grade of the wheat exported? For the protein characteristic, as expected a higher content yields a higher price for all three types of wheat considered. The quantitative magnitudes of this for hard red winter wheat and hard red spring wheat are approximately equal (based on a test of the equality of coefficient estimates on the PROT variable) while the impact of a higher protein content on the price of hard red winter wheat and hard red spring wheat is more than twice that for soft white wheat. This result is somewhat of an anomaly and difficult to explain although the result is consistent with the estimate by Wilson [1989]. While a slightly higher price might be expected given the desirability of hard wheat varieties for their various characteristics which have not been reflected in the other variables used in the estimation, it is difficult to explain why the effect is so much larger. One possible explanation is that relatively high protein wheat is used for blending with lower protein, domestically produced wheat to produce flour with the requisite protein level.

Of the other official criteria variables, the presence of aflatoxin, the presence of insects, and

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<td>2.61 (1.77)</td>
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\[ R^2 = 0.89 \quad 0.89 \quad 0.85 \]
\[ F = F(28,130) = 19.52 \quad F(27,163) = 23.56 \quad F(13,56) = 12.91 \]
\[ \text{RMSE} = 6.78 \quad 8.68 \quad 8.25 \]

where:
- \( P \) = the price of wheat,
- \( \text{COU6} \) = Belize,
- \( \text{WGT} \) = test weight per bushel,
- \( \text{JAN0} \) = January 1990,
- \( \text{COU9} \) = Canada,
- \( \text{MOIS} \) = the moisture content,
- \( \text{FEB0} \) = February 1990,
- \( \text{COU11} \) = Taiwan,
- \( \text{FM} \) = the percentage of foreign material,
- \( \text{MAR0} \) = March 1990,
- \( \text{COU12} \) = Columbia,
- \( \text{SBK} \) = the percentage of shrunken and broken kernels,
- \( \text{APRO} \) = April 1990,
- \( \text{COU14} \) = Cyprus,
- \( \text{PROT} \) = the protein content in percent,
- \( \text{MAY0} \) = May 1990,
- \( \text{COU22} \) = Guatemala,
- \( \text{DOCK} \) = the percentage dockage,
- \( \text{JUN0} \) = June 1990,
- \( \text{COU25} \) = Honduras,
- \( \text{FD} \) = frost damage in percent,
- \( \text{JUL0} \) = July 1990,
- \( \text{COU34} \) = Korea,
- \( \text{AFLAT} \) = the presence of aflatoxin,
- \( \text{AUG0} \) = August 1990,
- \( \text{COU35} \) = Kuwait,
- \( \text{FNUM} \) = the falling number,
- \( \text{SEP0} \) = September 1990,
- \( \text{COU39} \) = Mexico,
- \( \text{INSECT} \) = the presence of insects, and
- \( \text{DECO} \) = December 1990,
- \( \text{COU55} \) = Suriname,
- \( \text{FUM} \) = whether a fumigant was applied to control for the presence of insects.
- \( \text{JANI} \) = January 1991,
- \( \text{FEB1} \) = February 1991
- \( \text{JUL1} \) = July 1991, and
- \( \text{AUG1} \) = August 1991.
the falling number all, on average, affect the export price of wheat in the anticipated fashion. Thus, for example, a one second higher falling number leads to between a $0.13 and $0.19 higher wheat price per ton depending on the type of wheat. Moreover, the coefficient estimates of the respective variables across the various types of wheat (when considered in conjunction with their respective standard errors) are statistically identical. The percentage of dockage, the amount of frost damage, and the use of fumigants have no identifiable impact. The absence of any indication of a statistically identifiable effect of the use of fumigants on the price of wheat while coincidentally the finding that the presence of insects does have a statistically identifiable effect is related to the collinearity problem noted previously. While the coefficient estimates on the presence of insects for the various types of wheat is fairly robust with or without the fumigant use variable included in the specification, the coefficient estimates on the use of fumigants variable for the various wheat types in statistically significantly different from zero at the 5 percent level for both hard red winter wheat and hard red spring wheat when the presence of insects variable is deleted from the specification.\textsuperscript{13}

The statistically significant coefficient estimates on the monthly variables suggests that the markets for each of the three different types of wheat considered including hard red winter wheat, hard red spring wheat, and soft white wheat did change over the period of study although this change was somewhat random -- there are increases and decreases indicated by the positive as well as negative signs on the coefficients-- and did not occur uniformly between months. That is, the market(s) did not always change from one month to the next and the magnitude of the changes indicated by the sizes of the estimated coefficients on the monthly variables are statistically different for many of the months. Additionally, while changes in the markets for hard red winter wheat and hard red spring wheat tend to emulate one another, the market for soft white wheat exhibits a much different pattern of variation indicating that, among other things, soft white wheat is a different commodity -- used for different purposes -- than are hard red winter wheat and hard red spring wheat as the previous discussion suggests.

In terms of discounts or premiums paid by specific countries for wheat, no uniform pattern emerges. That is, for example, countries in a specific region of the world (e.g., South America or the Middle East) were not more or less likely to pay a premium as countries in another region of the world even though the wheat is frequently used for different purposes (Lin and Leath [1993]).

A Comparison

How do the results obtained here compare with those obtained by others with regard to the export price of wheat? While it is not the purpose to make an exhaustive comparison, it is useful to point out a few similarities and differences. Wilson [1989], using annual data covering the period 1972 through 1987 for four countries, finds that, for the variables that his study and the current study have in common, in general protein content is significant in explaining variations in the export price of wheat. Veeman [1987] using annual average data on prices and some quality characteristics for wheat exported from Canada, Australia, and the United States over the period 1976 through 1984 finds protein content to be a significant factor in explaining variation in the price of wheat across countries as well as temporal variations in the price of wheat which is indicative of changing market conditions over the period of study. Finally, Larue [1991] using annual average data covering the period 1976 through 1984 on prices and quality characteristics of wheat exported from Australia, Canada, and the United States finds the protein content of wheat to be a statistically significant price determining factor. Unlike most other studies, however, Larue in-
cludes a variable for test weight but this turns out not to be a statistically significant price determining characteristic contrary to the results obtained here.

Conclusion

This study set out to examine whether grade determining and official criteria factors identified by the FGIS affect the price of wheat for export and, in turn, the competitiveness of United States wheat exports. Using shiplot data on the transactions price for hard red winter wheat, hard red spring wheat, and soft white wheat and the associated quality characteristics covering the period January 1990 through December 1991 and exported to 63 countries, the results suggest that the test weight, the percentage of shrunken and broken kernels, the protein content, the presence of aflatoxin, the presence of insects, and the falling number are characteristics consistently valued by the market.

These results have important implications for the collection and reporting of information on wheat quality characteristics. There is no apparent market failure associated with information on the percentage of foreign material, the percentage of dockage, and the percentage of frost damage since the market, on average, does not use this information.

Should the grade determining factors used as quality characteristics that are reported but not used by the market in valuing wheat be replaced by some or all of the official criteria that can be collected when requested? Clearly, some of the official criteria are valued by the market. Whether such a change should be undertaken in order to aid the market in operating more efficiently would necessarily involve weighing the costs associated with revising the FGIS system of grades and standards to better reflect characteristics valued by the market versus the benefits of this sort of action. Such an analysis is properly the subject of a future study.

References


Note that the estimated coefficients are averages and, as such, should not be used to infer that no countries that import wheat use these measures. As Hyberg, et al. [1993] make clear from anecdotal evidence, there are some countries that value this information. It is just that in the aggregate, the market does not use this information.


