AE 88008 August 1988

Differentiation and Implicit Prices in Export Wheat Markets*

William W. Wilson
Paul Gallagher**

Abstract

This paper measures the extent and characteristics of differentiation in the international wheat market. Results indicate that the degree of differentiation has increased in the last 15 years. A hedonic price function is specified and estimated to examine the nature of the implicit prices and their changes through time.

*Paper presented at the American Agricultural Economics Association Meetings, Knoxville, TN, August 1988.

**William W. Wilson and Paul Gallagher are associate professors, Department of Agricultural Economics, North Dakota State University and Iowa State University respectively.

Differentiation and Implicit Prices
in Export Wheat Markets

As the intensity of competition in wheat trade has increased, so has differentiation according to important quality characteristics. Competition in which quality is variable performs much the same function as price competition (Abbott). Providing a superior (inferior) product at equal prices is simply an inverted way of decreasing (increasing) prices. Nearly all previous studies on wheat competition recognize the potential importance of differentiation across exporters but most empirical studies ultimately assume homogeneity. Generally, product differentiation is a supply-side phenomena and preceeds the marketing function (Ireland p. 5). One way in which to capture the nature of differentiation is through examination of prices for wheats of different characteristics. The purpose of this paper is to measure the extent and characteristics of differentiation in the international wheat market. One empirical measure simply demonstrates that the degree of differentiation in international wheat markets has increased in the past 15 years. A hedonic price function is specified and estimated using pooled data to examine the nature of implied values, and their changes through time.

Quality of wheat cannot be expressed in terms of a single property, but depends on several milling, processing, and physical dough and baking characteristics. Wheats are normally categorized according to kernel hardness, growing habit, and bran color. Protein level and type are highly correlated with hardness so that hard (medium-hard, soft) wheats are high (medium, low) in protein content and have the kind of proteins important to breadmaking quality. Whether wheat is sown in the winter or spring identifies its habit. Wheats are also categorized by bran color, either red or white. Various types of wheat are produced around the world based on conduciveness of the climate for cultivation or particular wheat types. Environmental factors including rainfall, temperatures, soils, available nutrients and topography influence and cause wide variety in wheat characteristics such as protein content, test weight, and kernel size. Classes of wheat, rather than being synonymous with types of wheat, are defined by official grading standards of exporting countries. There are many differences in quality between wheats produced and exported in the international market. In general, these can be categorized as indigenous and extraneous differences. Color, protein level and quality, strength and hardness are all indigenous characteristics. Some of these may be unique to each country, and most are a product of environmental conditions and breeding programs.[1]

Empirical Model and Data Sources

The general theory of hedonic analysis of prices stems from the original theoretical work of Lancaster and Rosen. Empirical analysis, especially in the case of agricultural products, follow the work of Ladd as well as Ladd and Martin, and Ladd and Suavannunt. The logic of hedonic analysis of wheat prices is that productive inputs, such as different classes and origins of wheat are demanded by processors because of the particular characteristics they embody.[2] Thus, imbedded

---

[1]For elaboration on these topics see: Canada Grains Council; Patterson and Allen; Pomeranz; Zeleny; and Wilson, Gallagher, and Reipe.

[2]The theory of hedonic price analysis is not presented here. Extensive development is contained in the citations and, in particular, Wilson.

in the price of wheat in international markets are implicit values of particular quality characteristics. The general empirical specification results in a functional relationship between prices and quality characteristics. In this study, as discussed below, pooled time series and cross-sectional data are used. Thus the general specification is:

$$P_{it} = P_t \, (X_{it}, U_{it}) \qquad (1)$$

$$i = 1, 2, \ldots N$$

Where P_{it} is the price of wheat type i in time t; X_{it} is a vector of quality characteristics in a unit of the i^{th} wheat in time t; and U_{it} is a random disturbance term. The implicit value of each characteristic is $\partial P_{it}/\partial X_{it}$ and can be interpreted as the value implied in the price of a unit increase in that characteristic.

There are two groups of quality variables which are implied in international wheat prices. The first group varies within and/or between countries. Variables included are protein, which is a continuous variable, the hardness and growth habit (spring/winter) which are noncontinuous and treated as binary variables. Those in the second group are constant through time within a country and/or between classes. These include color and grade factors such as impurities, test weight, moisture, etc., all of which are constant. Prices may vary due to country of origin reflecting the cumulative effects of a country's entire production/marketing system including the grading system, breeding programs, port availability, shipment reliability, cargo consistency, and credit availability. This second group of variables, due to their constancy, are reflected by binary variables for a particular country.

The specific model presented here incorporates several features to accommodate the data used. First, pooled data were used consisting of both time series and cross-sectional (cross classes and countries). To account for the temporal variability in prices the International Wheat Council (IWC) wheat price index was included in the model. All other variables were included to explain cross-sectional variability. Second, the growth habit category spring is highly related to hardness and color. For example, all spring planted wheats are hard and red, whereas some winter wheats are soft and white. To avoid potential multicollinearity, models were estimated and presented including both categories individually as well as combined. Third, from a demand perspective protein generally only has implicit value for hard wheats (Zeleny). Thus, the implicit value of protein was constrained to hard wheats. Additionally, review of wheat prices by protein level in U.S. domestic markets suggests that the implicit value of protein varies through time. Rather than to constrain the implicit value of protein to be equal across years, protein was introduced as an interaction term with a binary variable for individual years, and hardness as discussed above. Thus, the implicit value of protein was restricted to hard wheat but was allowed to vary between years.

Separate models were estimated for two export locations in the U.S. and two international destinations. This precludes implicit differences associated with location which would vary through time in response to relative ocean rates. The general model for estimation is:

$$P_{it} = \gamma_0 + \gamma_1 \, IWC_t + \delta_1 \, Spring_{it} + \delta_2 \, Country_{it} + \delta_3 Hard_{it} + \sum_{YR=73}^{85} \beta_{YR} \, (PRO_{it} \cdot Hard_{it}) + U_{it} \qquad (2)$$

Variables are defined as: P_{it} is the price of wheat from origin/class i in time t; IWC_t is the International Wheat Price Index; $Spring_{it}$ is 0 if a spring planted wheat and 1 if; $Country_{it}$ (used only in models at international destinations) in the case of Rotterdam is 0 if U.S. origin, 1 if Canada origin. Two country variables were included in the case of Japan with the default value being Australia; $hard_{it}$ is 0 if the wheat is soft and 1 if hard; PRO_{it} is the protein level of the i^{th} wheat; and U_{it} is a random error term. The estimated parameters δ_1 and δ_2 represent the marginal implict value (or implied premiums or discounts) associated with spring and country, respectively. The implicit value of protein level is allowed to vary by year, as represented by β_{YR} (YR = 73, . . . 85), and applies only to hard wheats. Similarly the implicit value of hardness depends on the protein level and varies by year. Formally, the implicit value of hardness is: $\delta_3 + \beta_{YR} \cdot PRO_{it}$.

In temporal hedonic price analysis it is important to use price data from one consistent source to preclude introduction of differences due to measurement. It is also necessary to use price data for specific locations to eliminate differences which would be implied due to relative transport cost if using different locations. For these reasons the price data used in this study were taken from various issues of World Wheat Statistics (International Wheat Council). Separate models were estimated for two FOB export locations in the U.S., FOB Gulf and FOB Pacific, and two international destinations, CIF Rotterdam and CIF Japan. Separate models were estimated for each market from 1972/73 to 1985/86 market years (beginning July of each year). Information on quality was taken from Wheats of the World (Canada Grains Council), Canadian International Grain Institute, and unpublished data from the International Wheat Council ("Analysis of Trends in Demand For, and Trade In, Different Qualities of Wheat" -- CL 103/7 Restricted). Protein was adjusted to a constant 12 percent moisture basis using either specified or traditional levels of moisture for each class/origin. Due to the relative high moisture of Canadian Wheat, this imputes a larger negative effect on their protein level, but the transformation results in more accurate measures of protein content.

For each of the markets described above the data were pooled across types of wheat and through time. Thus the resulting model for estimation is a covariance model with binary variables included to account for cross-sectional discrete effects. Each model was estimated using ordinary least squares (OLS). In addition, selected models were estimated using Park's method which corrects for both heteroskedasticity and autocorrelated error terms, common problems with pooled data. This method assumes first-order autocorrelation with contemporaneous correlation between cross-sections.

Results

As a prelude to the hedonic analysis an alternative measure of product differentiation is derived. Greenway provides three general measures of product differentiation including advertising intensity, the Hufbauer Index, and hedonic models. The former is not applicable in the case of international wheat, however, the other two are. The Hufbauer index is defined as: $H = \sigma_i/M_i$. Where σ_i is the standard deviation across wheat types, and M_i is the mean. H was calculated at different points of time at several markets, FOB Gulf, CIF Japan, and CIF Rotterdam. Different time periods were used to demonstrate the change through time, and to accommodate for missing values (any missing price data would severely restrict the deviation of H). Results are shown in Table 1. The results suggest that in general the degree of product differentiation is similar at each of the markets. Also, of particular importance is that the degree of product differentiation has increased substantially between the early 1970s and 1980s.

The hedonic model developed above is used to test hypothesis about the existence of product differentiation in the international wheat market, and to assess implicit values associated with certain quality characteristics. The results are presented in Tables 2 and 3 for the different markets. In each case several models are presented depending on the inclusion of hard and/or spring. In general within this section, only results of the models including both winter and spring are discussed along with those models estimated using Park's method where appropriate. Due to missing price data at the U.S. Gulf prior to 1975/76, models using the Park's method were estimated only for more recent years, and not at all in the case of the Rotterdam market.

The coefficient for spring varies across markets and is significant in each with the exception of the Pacific FOB market. The value of the coefficient indicates the value of spring relative to winter wheat. For example, in Japan the implicit value for spring wheat, holding all other characteristics constant, is $4.15/MT. These results suggest that from a demand perspective there are important differences between wheats with different growing habits which are reflected in the implicit values.

The country of origin variables in the CIF markets are generally significant suggesting that important differences in value are perceived across importers. Of particular interest is the substantial premium for

Canadian origin wheats relative to the U.S. origin wheats in the Rotterdam market, and relative to Australian wheat in the Japanese market. The implicit premiums over U.S. wheat in Rotterdam are about \$14/MT, and about \$9/MT over Australian wheat in the Japanese market. Factors which may contribute to the differences in implicit values could include the various national pecularities in production/marketing systems. The implicit value of the U.S. wheat at Rotterdam is negative compared to Canada. In the Japanese CIF market all signs for U.S. origin are negative, but the t-values indicate lack of significance when using Park's method.

The implicit value of hard versus soft wheat is difficult to interpret because it varies by year and protein level. At the 13 percent protein level, the implicit value of hard versus soft at the U.S. Gulf was \$8.96/MT, \$17.15/MT, and \$6.36/MT in 1973/74, 1982/83, and 1985/86 respectively. The same derivation at the Rotterdam market resulted in an implicit premium for hard wheat of \$5.45/MT in 1973/74, which increased to \$15.59/MT in 1982/83.

The implicit value of protein varies by year and only applies to hard wheat, thus the coefficients (β_{yr}) can be interpreted directly. In Japan, for example, the implicit value of a 1 percent unit of protein increased from \$.57/MT in 1974/75 to \$1.96/MT in 1983/84. At the U.S. Gulf the implicit value increased from \$.69/MT in 1973/74 to \$1.31/MT in 1975/76. In general, significant implicit premiums for protein were observed in each market except for Rotterdam (Models 2 and 3). This exception may be due to the limited trading of Hard Red Winter resulting in protein premiums being implied in the spring variable. The implicit values for protein vary through time, and the results indicate there is a general upward trend, suggestive of a structural shift in the value of protein. Beginning in in about 1979/80 to recent, the implicit values of protein have increased substantially in each of the U.S. markets, and in the Japanese CIF markets.

Summary

In the period prior to 1973/74, price differences in international markets were relatively small, likely reflecting the supply/demand situation and the lack of need to distinguish between different classes of wheat. Since then price differentials have increased dramatically in nearly all markets reflecting the increased differentiation in the international market. Notable increases have occurred in prices for stronger wheats relative to all other classes. Implicit values of certain quality characteristics are of interest because all other effects are held constant. There are several specific results of interest. First, it appears that there is an implied value for spring planted wheats relative to winter, even while holding other factors (e.g., protein content, etc.) constant. Second, there are substantial implicit premiums for CWRS, or discounts for U.S. wheats. Third, the implicit premiums for hard wheats over soft have been diminishing in recent years. Fourth, the implied value of protein varies through time but has been gradually increasing in the past decade.

TABLE 1. HUFBAUER INDEXES IN THE INTERNATIONAL WHEAT MARKET

	1970/71	1972/73	1981/82	1985/86
FOB Gulf	.04	--	--	.09
CIF Rotterdam	.04	--	.08	--
CIF Japan	--	.03	--	.08

TABLE 2. HEDONIC MODELS OF U.S. FOB EXPORT PRICES

Variable	U.S. Gulf Model 1	2	3	4	Pacific Model 1	2	3	4
Intercept	10.73*	23.88*	10.75*	-7.27	6.26*	33.97*	16.56*	14.44
	(10.87)	(2.21)	(1.30)	(.47)	(0.81)	(2.58)	(1.70)	(1.58)
IWC	0.82*	0.74*	0.82*	0.95*	0.89*	0.72*	0.83*	0.84*
	(20.90)	(10.63)	(15.50)	(10.02)	(17.60)	(8.65)	(13.48)	(14.58)
Spring	10.96	--	10.95*	14.82*	16.17*	--	14.91*	1.31
	(6.04)	--	(6.00)	(5.63)	(5.84)	--	(5.34)	(0.21)
Hard	--	-5.46	-0.01	9.73*	--	-17.42*	9.17	0.00
	--	(0.96)	(0.83)	(2.97)	--	(2.25)	(1.63)	(0.00)
Protein 73	0.69*	1.68*	.69	--	0.22	2.71*	1.09	1.30*
	(2.22)	(2.53)	(1.32)	--	(0.48)	(3.02)	(1.58)	(2.15)
74	1.19*	2.10*	1.19*	--	0.84*	3.17*	1.66*	2.42*
	(4.06)	(3.39)	(2.46)	--	(1.92)	(3.73)	(2.53)	(4.19)
75	1.30*	2.11*	1.31*	0.33*	0.86*	2.96*	1.60*	2.28*
	(4.76)	(3.76)	(3.00)	(2.53)	(2.06)	(3.74)	(2.63)	(4.54)
76	0.60*	1.14*	0.61*	0.04	0.25	1.81*	0.80	1.22*
	(2.23)	(2.44)	(1.71)	(0.01)	(0.61)	(2.57)	(1.53)	(3.46)
77	0.50*	1.03*	0.50	-0.11	0.05	1.61*	0.60	0.85*
	(1.85)	(2.22)	(1.42)	(-0.27)	(0.12)	(2.28)	(1.13)	(2.45)
78	0.70*	1.40*	0.71	-0.21	0.06	1.96*	0.73	1.01*
	(2.69)	(2.72)	(1.77)	(0.91)	(0.15)	(2.61)	(1.28)	(2.37)
79	1.32*	2.23*	1.32*	0.04	0.58	2.89*	1.37*	1.42*
	(4.55)	(3.62)	(2.76)	(0.69)	(1.32)	(3.41)	(2.13)	(2.50)
80	1.34*	2.34*	1.33*	-0.10	0.96*	3.47*	1.85*	2.12*
	(4.29)	(3.49)	(2.56)	(0.87)	(2.11)	(3.85)	(2.65)	(3.30)
81	1.56*	2.42*	1.56*	0.37*	0.67	2.90*	1.45*	1.66*
	(5.49)	(4.09)	(3.37)	(4.65)	(1.56)	(3.52)	(2.28)	(3.00)
82	1.32*	2.14*	1.32*	0.18	0.61	2.75*	1.37*	1.73*
	(4.76)	(3.75)	(2.98)	(1.50)	(1.45)	(3.43)	(2.22)	(3.35)
83	1.27*	2.09*	1.27*	0.12	0.54	2.67*	1.30*	1.71*
	(4.61)	(3.68)	(2.89)	(0.90)	(1.31)	(3.35)	(2.12)	(3.35)
84	1.01*	1.77*	1.00*	-0.06	0.62	2.64*	1.33*	1.48*
	(3.72)	(3.26)	(2.39)	(-0.35)	(1.49)	(3.41)	(2.24)	(3.08)
85	0.49*	1.21*	6.49	-0.47*	0.24	2.18*	0.92	1.35*
	(1.84)	(2.31)	(1.21)	(-2.15)	(0.58)	(2.88)	(1.60)	(3.01)
Adj. R^2	0.96	0.93	0.96		0.95	0.90	0.95	
Estimation	OLS	OLS	OLS	Parks[1]	OLS	OLS	OLS	Parks[2]

t-ratios in parentheses.
*Indicates significance at the 10 percent level.

[1]Rho = .35, .74, .69, .48 for I = 1, 2, 3, and 4, respectively.
[2]Rho = .21, .05, .22 for I = 1, 2, and 3, respectively.

TABLE 3. HEDONIC MODELS OF IMPORT PRICES CIF ROTTERDAM AND JAPAN

Variable	Rotterdam 1	Rotterdam 2	Rotterdam 3	Japan 1	Japan 2	Japan 3	Japan 4
Intercept	-12.53	-17.50	-23.85	-19.28	-12.37*	-15.96*	-18.43*
	(1.23)	(1.14)	(1.57)	(3.08)	(1.46)	(1.89)	(2.70)
IWC	1.06	1.08*	1.13*	1.23*	1.18	1.22*	1.24*
	(14.08)	(10.95)	(11.46)	(30.33)	(21.77)	(22.79)	(28.97)
Spring	6.80*	--	7.09*	7.49*	--	7.26*	4.15*
	(1.88)	--	(1.95)	(2.91)	--	(2.78)	(1.86)
Hard	--	6.32	7.53	--	-4.84	-2.86	-0.70
	--	(0.81)	(0.99)	--	(0.96)	(20.59)	--
Canada	14.60*	18.38*	14.47*	8.11*	14.62*	8.34*	9.45*
	(3.87)	(5.56)	(3.83)	(2.29)	(5.08)	(2.33)	(4.48)
U.S.	--	--	--	-4.28*	-2.61	-4.10*	-1.78
	--	--	--	(2.91)	(-1.33)	(2.09)	(0.79)
Protein 73	0.54	0.26	-0.16	0.39	1.00*	0.64	0.29
	(1.00)	(0.81)	(0.18)	(1.17)	(1.80)	(1.18)	(0.91)
74	0.54	0.29	-0.10	0.49	1.06*	0.74	0.57*
	(1.07)	(0.30)	(0.13)	(1.57)	(2.04)	(1.43)	(7.06)
75	1.34*	1.12	0.79	0.62	1.12*	0.83*	0.69*
	(2.94)	(0.35)	(1.10)	(2.05)	(2.36)	(1.78)	(3.09)
76	1.00*	0.86	0.66	0.79*	1.14*	0.93*	0.89*
	(2.34)	(1.57)	(1.20)	(2.57)	(2.80)	(2.35)	(8.51)
77	0.99*	0.86	0.65	0.23	0.59	0.38	0.30*
	(2.32)	(1.55)	(1.19)	(0.76)	(1.44)	(0.96)	(3.83)
78	0.68	0.50	0.21	0.37	0.81*	0.56	0.43*
	(1.59)	(1.54)	(0.33)	(1.23)	(1.83)	(1.27)	(2.37)
79	1.55*	1.31	0.92	1.35*	1.91*	1.58*	1.40*
	(3.14)	(0.77)	(1.15)	(4.25)	(3.68)	(3.10)	(5.02)
80	1.86*	1.59	1.16	1.55*	2.17*	1.81*	1.50*
	(3.47)	(1.62)	(1.31)	(4.64)	(3.88)	(3.29)	(4.67)
81	1.61*	1.38*	1.02	1.70*	2.24*	1.93*	1.71*
	(3.38)	(1.79)	(1.32)	(5.48)	(4.47)	(3.90)	(6.67)
82	1.16*	1.00	0.62	2.07*	2.58*	2.28*	2.07*
	(2.34)	(1.36)	(0.84)	(6.77)	(5.33)	(4.79)	(8.84)
83	1.58*	1.54*	1.04	2.04*	2.55*	2.26*	1.96*
	(2.69)	(1.97)	(1.32)	(6.70)	(5.29)	(4.75)	(8.44)
84	1.12*	1.09	0.61	1.23*	1.72*	1.43*	1.18*
	(1.93)	(1.44)	(0.80)	(4.11)	(3.69)	(3.14)	(5.63)
85	--	--	--	1.59*	2.04*	1.78*	1.51*
	--	--	--	(5.31)	(4.54)	(4.01)	(7.96)
Adj. R	0.94	0.94	0.94	0.96	0.96	0.96	--
Estimation	OLS	OLS	OLS	OLS	OLS	OLS	Parks[1]

t-ratio in parentheses.
*Indicates significance at the 10 percent level.

[1]Rho = -.24, .13, .37, .08, .54, .58, and .25 for I = 1, 2, ... 7, respectively.

References

Abbot, L. Quality and Competition. New York: Columbia University Press, 1955.

Canada Grains Council. Wheat of the World. Winnipeg: Canada Grains Council.

Greenway, D. "The Measurement of Produce Differentiation in Empirical Studies by Trade Flows," in Kierzkowski, 1984.

Grennes, T., P. Johnson, and M. Thursby. The Economics of World Grain Trade. New York: Praeger Publishers, 1978.

Hufbauer, G.C. "The Impact of National Characteristics and Technology on the Commodity Composition of Trade in Manufactured Goods," ed. R. Vernon. Technology Factor of International Trade. New York: NBER.

International Wheat Council. World Wheat Statistics, Annual Issues. London: International Wheat Council, 1960-85.

Ireland, N. "Product Competition and Nonprice Competition." England: Basil Blackwell, 1987.

Kierzkowski, H., ed. Monopolistic Competition and International Trade. Oxford: Clarendan Press, 1984.

Ladd, G.W. and M.B. Martin. "Prices and Demands for Input Characteristics." Amer. J. Agr. Econ. 58(1976):21-30.

Ladd, G.W. "Research on Product Characteristics: Models, Applications, and Measures." Agr. and Home Econ. Exp. Sta., Research Bulletin 584, Iowa State University, 1978.

Ladd, G.D. and JV. Suavannunt. "A Model of Consumer Goods Characteristics." Amer. J. Agr. Econ. 58(1976):540-610.

Lancaster, K. Consumer Demand. New York: Columbia University Press, 1971.

Oleson, B.T. "Price Determination and Market Share Formation in the International Wheat Market," Ph.D. thesis, University of Minnesota, 1979.

Parks, R.W. "Efficient Estimation of a System of Regression Equation When Disturbances are Both Serially and Contemporaneously Correlated," J. Amer. Stat. Assn. 61(1967):500-507.

Patterson, F.L., and R.E. Allen. "Soft Wheat Breeding in the United States," Soft Wheat: Production, Breeding, Milling, and Uses. St. Paul: Amer. Assn. Cereal Chem., Inc., 1981.

Pomeranz, Y., ed. Wheat Chemistry and Technology, 2nd ed. St. Paul: Amer. Assn. Cereal Chem., 1978.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." J. Polit. Econ. 82(1974):34-35.

Wilson, W. "Hedonic Prices in the Malting Barley Market," Western J. of Agri. Econ., 9(1984):1, 29-40.

Wilson, W., P. Gallagher, and J. Reipe. "Analysis of Demand for Wheat Quality Characteristics," Office of Technology Assessment, U.S. Congress (forthcoming).

Zeleny, Lawrence. "Criteria of Wheat Quality," Wheat Chemistry and Technology, Chapter 2, ed. Y. Pomeranz, 2nd ed. St. Paul: Amer. Assn. Cereal Chem., 1978.

sds