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Competition for U.S. Hard Wheat Characteristics

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Discounts and premiums for wheat quality factors at a specific location can be affected by the quality of wheat at other locations. We estimate the effects of protein and test weight levels of Kansas hard red winter and North Dakota dark northern spring wheat on the protein and test weight premiums of each other. Additionally, we determine the effect on premiums of protein and test weight and discounts of shrunken/broken and damaged kernels at different locations within each region from changes in wheat qualities at other locations within the same region. Results indicate that spatial competition was important for protein and test weight, both between the two wheat regions and within the same region.

Key words: characteristic demand, hedonics, spatial competition, wheat

Introduction

Hard red winter (HRW) wheat and dark northern spring (DNS) wheat have different milling and baking characteristics, yet are grown to meet similar end-use demands. These wheat classes are blended regularly to achieve the desired mix of characteristics. Most HRW wheat is grown in the southern Great Plains, while DNS wheat is grown exclusively in the northern Great Plains. Since these wheat classes are substitutes in milling and baking, the wheat markets of each region are not isolated. Price differentials between wheat classes are determined by transportation factors, explicit premiums and discounts based on grading factors, and implicit premiums and discounts. Implicit price adjustments occur when all wheat in a region receives a high or low price due to quality characteristics. Quality factors such as protein are too costly to measure for individual lots. Since protein is partly determined by weather, most wheat in an area will have similar protein.[1]

For simplicity, we use the term "interregional" to describe spatial competition between wheat classes (HRW and DNS), and the term "intraregional" to describe spatial competition within the principal growing region for each individual wheat class. The purpose of this study is to test the significance of inter- and intraregional levels of wheat quality in determining the marginal value (i.e., price) of wheat characteristics. Our theory expands on the standard Ladd and Martin framework by modeling price as being determined by aggregate characteristic levels as well as local characteristic levels. Past

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[1] Information about wheat quality is obtained from samples taken at harvest from most growing regions in the United States.

studies estimating marginal values for wheat characteristics generally have viewed wheat classes in isolation (Espinosa and Goodwin; Ahmadi-Esfahani and Stanmore) or have estimated a common marginal value for each wheat characteristic from a group of wheat classes (Larue; Veeman). The equations estimated here are local demand equations since they account for intra- and interregional supplies of characteristics.

Since the early 1970s, wheat marketing has evolved from a simple system which recognized a small set of grade qualities to the current system in which prices are determined in a complex system that reflects the value of wheat characteristics that reduce milling costs or meet specific end uses. Espinosa and Goodwin identified these relationships in a straightforward hedonic framework using data for a single class of wheat. Larue showed that wheats sold internationally maintained different marginal values for characteristics based on their end uses. Stiegert and Blanc linked end-use demand for baking qualities with the way heterogeneous wheat protein is priced on international markets. Although each of these studies have contributed in significant ways to the overall understanding of the wheat marketing system, no study has modeled cross-regional competition for wheat characteristics. The idea of a market, and therefore a competition, for product characteristics is not new. Rosen's classic article, now over two decades old, established the theoretical groundwork for identifying characteristic demand parameters. The model for our study was motivated by the theoretical framework of Rosen.

Wheat varieties are developed primarily by university agricultural experiment stations funded in part by producer checkoff programs. These agencies attempt to release varieties with valuable end-use characteristics, while maintaining high yield potential. Quality and yield are often substitutes in the breeding decision. Knowing the value of characteristics is necessary to make optimal choices between quality and yield. Additionally, grain elevators and transportation systems are not fully equipped to identity-preserve wheat quality. Changing the grain handling sector to preserve identity will be costly and will require new capital investments. To assess the viability of such change, a reasonable estimate of the benefits from various segregation strategies is needed.

Conceptual Model

Wheat millers and international buyers sample wheat in all production regions, and thus know the quality of wheat being produced in a region in a given year (Eustace). Competition for these characteristics implies that some locations receive implicit premiums and others receive discounts based on the relative scarcity or abundance of characteristics. Following Ladd and Martin, the price paid (r_i) for a bushel of wheat (\$/bushel) in the ith location is:

(1) $$r_i = \sum_j T_j \partial x_j / \partial v_i,$$

where j refers to wheat characteristics, T_j is the marginal implicit price for the jth characteristic, x_j is the total quantity of characteristic j available in the ith location, and v_i is the quantity of wheat available in the ith location.

Equation (1) states that the price paid for a bushel of wheat in the ith location equals the sum of values of the marginal yields of the bushel's characteristics ($T_j \partial x_j / \partial v_i$).

Following convention, $\partial x_j / \partial v_i = x_{ji}$ is a constant, which implies a fixed proportion of characteristic x_j in input v_i. Equation (1) can be respecified as:

$$r_i = \sum_{j=1}^{m} T_j x_{ji}. \tag{2}$$

The marginal implicit values (T_j) need not be constant. Ladd and Martin show that if (2) is derived from a functional form that is quadratic for a characteristic, then the marginal yield depends on the characteristic level at each observation. Numerous previous studies of demand for livestock characteristics have shown that marginal values changed as the level of the characteristic changed (e.g, Bailey, Peterson, and Brorsen; Faminow and Gum; Parcell, Schroeder, and Hiner). However, previous studies investigating agricultural commodities have not considered the effects of spatial competition for characteristics on marginal implicit prices. That is, how does a change in the level of a characteristic in one wheat-producing region affect the value of that characteristic in another wheat-producing region? For example, suppose the Kansas wheat price (r_1) depends only on protein in both Kansas HRW wheat (x_{11}) and North Dakota DNS wheat (x_{12}). Equation (2) for the price of a bushel of wheat in Kansas could be specified in a manner similar to a quadratic functional form for one characteristic:

$$r_1 = \beta_1 x_{11} + \beta_2 (x_{11} \cdot x_{12}) = x_{11}(\beta_1 + \beta_2 x_{12}), \tag{3}$$

where βs are estimated parameters, $(\beta_1 + \beta_2 x_{12})$ is the marginal implicit price of protein in Kansas and varies as the level of protein in North Dakota changes.

Empirical Model

Interregional effects refer to the impact of wheat quality in Kansas on prices in North Dakota, and vice versa. The intraregional effects refer to the impact on price in one district from changes in wheat quality in districts within the same region. The value of characteristics at a particular location is determined by the aggregate supply and demand for characteristics. An important issue is deciding which characteristics form an interregional competition and which characteristics are most likely to form an intraregional competition. This is a difficult distinction that has no clear theoretical basis. Our decision criteria involved the degree of endogeneity that the marketing system has in varying the levels of characteristics at various points of delivery. Protein levels and test weight generally cannot be varied in the marketing system. When the crop in one region is deficient in supplying an adequate volume of wheat with high protein or test weight, the only other source will be the other region. Therefore, we modeled these characteristics both interregionally and intraregionally. Because levels of shrunken and broken kernels and total damaged kernels can be controlled at country and terminal elevators through cleaning and screening, these characteristics are not anticipated to determine prices across regions. However, they could be a factor in explaining price within each region because farmers have far less ability to control these characteristics, and elevators are likely to pay higher prices for wheat with lower handling costs.

The characteristic demand equations to be estimated are:

$$(4)\qquad KWH_{it} = \alpha + \sum_{a=1}^{8} \beta_a KD_{ita} + \beta_9 KPT_{it} + \beta_{10} KPTOD_{it} + \beta_{11} KPTOR_t + \beta_{12} KTW_{it} + \beta_{13} KTWOD_{it} + \beta_{14} KTWOR_t + \beta_{15} KSB_{it} + \beta_{16} KSBOD_{it} + \beta_{17} KDK_{it} + \beta_{18} KDKOD_{it} + \epsilon_{it}$$

and

$$(5)\qquad NWH_{it} = \alpha + \sum_{a=1}^{8} \beta_a ND_{ita} + \beta_9 NPT_{it} + \beta_{10} NPTOD_{it} + \beta_{11} NPTOR_t + \beta_{12} NTW_{it} + \beta_{13} NTWOD_{it} + \beta_{14} NTWOR_t + \beta_{15} NSB_{it} + \beta_{16} NSBOD_{it} + \beta_{17} NDK_{it} + \beta_{18} NDKOD_{it} + \epsilon_{it}.$$

Definitions of variables are presented in table 1. The subscript i refers to the ith reporting district in either Kansas or North Dakota ($i = 1, \ldots, 9$), and the subscript t refers to time period ($t = 1, \ldots, 20$). All variables for Kansas begin with the letter K, and all variables for North Dakota begin with the letter N. Each equation contains eight binary terms to capture differences in transportation costs to major demand points (east central Kansas and southeast North Dakota are the respective defaults). Districts farther from terminal locations are expected to receive a lower price because of increased transportation costs. The next three terms in each equation are the district protein average (*_PT*), the interaction of district average and the average of all other districts within each region (*_PTOD*), and the interaction of district average protein with the annual protein level in the other region (*_PTOR*). A similar structure is in place for the next pair of terms which refer to test weight (*_TW*, *_TWOD*, and *_TWOR*). The next group of terms, shrunken and broken kernels (*_SB*, *_SBOD*) and damaged kernels (*_DK*, *_DKOD*), follows a similar pattern, where *_SBOD*, and *_DKOD* represent the average of shrunken and broken and damaged kernels in all other districts within each region.

Increases in the level of protein and test weight in one region would be expected to decrease price in the other region. Similarly, increases in the level of protein and test weight in other districts within each region would be expected to decrease price in that district. The effects of an increase in the level of shrunken and broken and damaged kernels in other districts within each region are uncertain.

Wheat protein was expected to be related positively to price. Protein is the most critical component sought by millers, and is a predictor of how well the flour will bake (Stiegert and Blanc). The effect of test weight on price also was expected to be positive. Higher test weights typically are interpreted to mean high quality kernels that reduce milling costs and increase flour yields and flour purity. An increase in the level of shrunken/broken kernels and/or damaged kernels is expected to reduce price.

The value of all wheat quality characteristics will involve interaction terms. Interaction terms for protein and test weight included the other region's level of protein and test weight and the other district's production-weighted level of protein and test weight. For shrunken and broken and damaged kernels, the interaction term was the production-weighted intraregional level of this characteristic. For example, the marginal value of HRW protein is calculated as:

Table 1. Definitions of Variables Employed in Empirical Models

Variables	Definitions
KWH_{it}, NWH_{it}	District price deflated by regional average price (\$/bu.) in district i (i = 1, 2, ..., 9), and time period t (t = 1, 2, ..., 23)
KD_{it}, ND_{it}	Binary (0, 1) terms for each district
KPT_{it}, NPT_{it}	District protein (%/bu.)
$KPTOD_{it}$, $NPTOD_{it}$	Interaction terms: District protein × the production-weighted average of protein for all other districts in the region (%/bu.)
$KPTOR_t$, $NPTOR_t$	Interaction terms: District protein × the other region's annual average base protein (%/bu.)
KTW_{it}, NTW_{it}	District test weight (lbs./bu.)
$KTWOD_{it}$, $NTWOD_{it}$	Interaction terms: District test weight × the production-weighted average of test weight for all other districts in the region (%/bu.)
$KTWOR_t$, $NTWOR_t$	Interaction terms: District test weight × the other region's annual average base test weight (lbs./bu.)
KSB_{it}, NSB_{it}	District shrunken/broken kernels (%/bu.)
$KSBOD_{it}$, $NSBOD_{it}$	Interaction terms: District shrunken/broken kernels × the production-weighted average of shrunken/broken kernels for all other districts in the region (%/bu.)
KDK_{it}, NDK_{it}	District damaged kernels (%/bu.)
$KDKOD_{it}$, $NDKOD_{it}$	Interaction terms: District damaged kernels × the production-weighted average of damaged kernels for all other districts in the region (%/bu.)

$$\text{(6)} \qquad \frac{\partial KWH_{it}}{\partial KPT_{it}} = \beta_9 + \beta_{10} KPTOD_{it} + \beta_{11} KPTOR_t,$$

where $KPTOD_{it}$ represents the level of protein in all other districts within Kansas, and $KPTOR_t$ represents the annual average protein of North Dakota DNS wheat. Because the marginal value of each characteristic involves more than one parameter estimate, a standard t-statistic was calculated using the marginal value over the standard error at each data point. Following the example of protein in equation (6), standard errors for each marginal value can be calculated using the following expression for the variance:

$$\text{(7)} \qquad \begin{aligned} \operatorname{Var}\left[\frac{\partial KWH_{it}}{\partial KPT_{it}}\right] = {} & \operatorname{Var}(\beta_9) + KPOD_{it}^2 \cdot \operatorname{Var}(\beta_{10}) + KPTOR_t^2 \cdot \operatorname{Var}(\beta_{11}) \\ & + 2 \cdot KPTOD_{it} \cdot \operatorname{Cov}(\beta_9, \beta_{10}) + 2 \cdot KPTOR_t \cdot \operatorname{Cov}(\beta_9, \beta_{11}) \\ & + 2 \cdot KPTOD_{it} \cdot KPTOR_t \cdot \operatorname{Cov}(\beta_{10}, \beta_{11}). \end{aligned}$$

Computations similar to (6) and (7) were performed for the other characteristics. The statistical significance of individual parameters does not imply that the marginal values of each characteristic will be significant at each data point. Therefore, the focus was on marginal values and not on individual parameter estimates.

Data

Summary statistics of the data are reported in table 2. Price and quality data represent annual district averages for Kansas HRW wheat and North Dakota DNS wheat. Though aggregation reduces variability, annual averages represent the most readily available data. Price data for 1974–96 were collected for all nine Kansas crop reporting districts from various issues of *Kansas Farm Facts* (Kansas State Board of Agriculture). Similar price data were collected for the nine crop reporting districts in North Dakota (North Dakota State Agricultural Statistical Service). For both Kansas and North Dakota, the cash price series represent annual average prices from the point of first sale received by producers, for all grades and qualities, to either a terminal or a local elevator. These prices are net of government payments, allowances for unredeemed loans, and purchases by the government. Additionally, these prices do not include any explicit discounts and premiums paid to producers for quality adjustments.[2] The dependent-variable price series was deflated by the U.S. annual prices received for HRW and DNS wheat. Deflating by an aggregate price allows for the adjustment of the exogenous supply and demand shocks which may have occurred over time (Espinosa and Goodwin). The average annual cash price series for HRW wheat is a Kansas City price for a 13% protein and 60-pound bushel, and the cash price series for DNS wheat is a Minneapolis price for a 13% protein and 58-pound bushel (U.S. Department of Agriculture).

Quality data for Kansas HRW wheat were collected from the *Kansas Wheat Quality Report* series (Kansas State Board of Agriculture). Similarly, quality data for North Dakota DNS wheat were collected from the *Regional Hard Red Spring Wheat Quality Report* series (North Dakota State University). Three of the characteristics (test weight, shrunken/broken kernels, and damaged kernels) are official U.S. grading parameters.

To measure the intraregional availability of each characteristic, a production-weighted average of each characteristic for each district exclusive of the own district was computed. For example, the average level of HRW shrunken/broken kernels outside of Kansas district 1 is the production-weighted average of shrunken/broken kernels in Kansas districts 2–9. Production data were collected from various issues of *Kansas Farm Facts* (Kansas State Board of Agriculture). Similar procedures were followed for North Dakota DNS wheat (North Dakota State Agricultural Statistical Service). The other region's protein and test weight levels refer to the annual state averages recorded in North Dakota for use in (4) and the annual state averages in Kansas for use in (5).

Econometric Issues

When using pooled cross-sectional and time-series data, cross-sectional heteroskedasticity and time-series autocorrelation are typical concerns. The null of homoskedasticity was tested versus the alternative of groupwise heteroskedasticity using the Lagrange multiplier test (Greene). The calculated test statistics were 397 and 384 for Kansas and North Dakota, respectively. The 1% critical value for the χ^2 distribution with eight degrees of freedom was 20; thus the null hypothesis of equal variances

[2] Explicit discounts and premiums are subtractions or additions, respectively, to the original payment based on deviations from U.S. grading standards.

Table 2. Summary Statistics of Selected Wheat Characteristics, 1974–96

Characteristic	Average	Std. Dev.	Minimum	Maximum
KANSAS:				
District Price ($/bu.)	3.31	0.42	2.13	4.82
Regional Price ($/bu.)	3.96	0.45	2.81	5.69
Protein (%/bu.)	12.03	0.58	10.60	14.80
▸ Production weighted (%/bu.)	12.02	0.52	10.31	13.75
▸ State average protein (%/bu.)	12.06	0.40	11.20	13.40
Test Weight (lbs./bu.)	60.13	1.60	56.70	62.90
▸ Production weighted (lbs./bu.)	60.14	0.89	56.87	61.73
▸ State average test weight (lbs./bu.)	59.48	1.53	56.70	61.60
Shrunken/Broken Kernels (%/bu.)	2.09	0.33	0.90	4.00
▸ Production weighted (%/bu.)	2.15	0.17	1.37	3.17
Damaged Kernels (%/bu.)	0.41	0.17	0.00	2.60
▸ Production weighted (%/bu.)	0.33	0.04	0.08	1.28
NORTH DAKOTA:				
District Price ($/bu.)	3.44	0.39	2.07	4.80
Regional Price ($/bu.)	3.95	0.45	2.83	5.64
Protein (%/bu.)	14.34	0.62	12.60	17.20
▸ Production weighted (%/bu.)	14.24	0.30	13.43	16.40
▸ State average protein (%/bu.)	14.76	0.78	13.80	16.50
Test Weight (lbs./bu.)	59.80	1.39	56.10	62.60
▸ Production weighted (lbs./bu.)	59.74	0.79	57.85	61.42
▸ State average test weight (lbs./bu.)	59.68	0.64	57.90	61.20
Shrunken/Broken Kernels (%/bu.)	1.47	0.18	0.18	3.20
▸ Production weighted (%/bu.)	1.50	0.23	0.71	3.21
Damaged Kernels (%/bu.)	0.45	0.53	0.00	4.80
▸ Production weighted (%/bu.)	0.56	0.29	0.00	1.91

between crop reporting districts in both Kansas and North Dakota was rejected. A modified version of the Breusch-Godfrey test for autocorrelation was used because of the use of panel data (Wu and Brorsen). The test statistics were 3.62 and 0.017 for Kansas and North Dakota, respectively. The 1% critical value for the χ^2 distribution with one degree of freedom was 2.71, and so the null hypothesis of no autocorrelation in Kansas was rejected but failed to be rejected for North Dakota. Data were corrected for heteroskedasticity and autocorrelation in Kansas and for heteroskedasticity in North Dakota with the following data transformations.

Following Kmenta, heteroskedasticity was corrected for by first individually estimating (4) and (5) using ordinary least squares (OLS). For simplicity, r_{it} refers to the dependent variable, x_{it} refers to explanatory variables, v_{it} refers to the error terms, and subscripts i and t are as defined previously. Using the error terms (v_{it}), a separate error variance (τ_i^2) for each district in each region was derived according to:

$$\tau_i^2 = \sum_{t=1}^{23} v_{it}^2/23, \tag{8}$$

where $i = 1, \ldots, 9$ for both Kansas and North Dakota. Then the τ_i were used to transform both the dependent and independent variables according to:

$$(9) \qquad r^*_{it} = r_{it}/\tau_i, \qquad x^*_{it} = x_{it}/\tau_i.$$

These data were used in correcting for autocorrelation, as outlined below.

Following Kmenta, autocorrelation was corrected for in the Kansas data by first performing OLS on the transformed data from (9) and then using the residuals (v^*_{it}) to estimate ρ_i as:

$$(10) \qquad \hat{\rho}_i = \sum_{t=1}^{22} v^*_{it} \cdot v^*_{it-1} \Big/ \sum_{t=1}^{22} (v^*_{it})^2,$$

where $i = 1, 2, \ldots, 9$. The $\hat{\rho}_i$ were used to transform data from (9) as follows:

$$(11) \qquad r^{**}_{i1} = \sqrt{1 - \hat{\rho}_i^2} \cdot r^*_{i1}, \qquad r^{**}_{it} = r^*_{it} - \hat{\rho}_i r^*_{it-1}, \qquad \text{for } t = 2, 3, \ldots, 23;$$

$$x^{**}_{i1} = \sqrt{1 - \hat{\rho}_i^2} \cdot x^*_{i1}, \qquad x^{**}_{it} = x^*_{it} - \hat{\rho}_i x^*_{it-1}, \qquad \text{for } t = 2, 3, \ldots, 23.$$

Using the transformed data from (11), we tested for contemporaneous correlation due to the competitive bidding for wheat characteristics between regions. The Lagrange multiplier statistic (Breusch and Pagan) was used to test the null hypothesis of no contemporaneous correlation between the two-equation system. The test statistic was computed to be 0.485, and the 10% critical value for the χ^2 distribution with one degree of freedom was 2.71. We failed to reject the null hypothesis of no contemporaneous correlation; however, following theory that competition exists for characteristics in the HRW and DNS growing regions, we estimated the two-equation model using Zellner's seemingly unrelated regression (SUR) technique.[3] The SUR system, corrected for heteroskedasticity and autocorrelation, was estimated using data from (11) in SHAZAM 7.0 (White et al.). The null hypothesis of normally distributed error terms could not be rejected at the 1% level of confidence with the Jarque-Bera test (table 3).

Results

The econometric estimates of (4) and (5) are reported in table 3. The two-equation model explained 99% of the variation in wheat prices. Most coefficients were significant at the 0.05 level, but results focus on the significance of marginal values and not individual parameter estimates. Positive parameter estimates indicate a premium relative to a base bushel of wheat, and negative parameter estimates indicate a discount relative to a base bushel of wheat.

Estimated coefficients for district dummy variables in Kansas and North Dakota reflect premiums and discounts relative to the district not included. Because the district not included is closest to the principal terminal market (i.e., east central is closest to Kansas City for HRW wheat, and southeast is closest to Minneapolis for DNS wheat), the parameter estimates are approximations of transport costs from each district. As shown in table 3, those districts farthest from the base price location generally received the largest discounts. For Kansas, the central districts had discounts from 0.22 to 0.25

[3] No loss of asymptotic efficiency occurs in estimating the model using the SUR technique.

Table 3. Hedonic Regression Equations for Regional Wheat Prices, 1974–96

HARD RED WINTER WHEAT			DARK NORTHERN SPRING WHEAT		
Characteristic	Marginal Value ($/bu.)	t-Statis.	Characteristic	Marginal Value ($/bu.)	t-Statis.
Protein:					
District	0.218	12.88**	District	0.169	6.08**
Other district's X district	-0.006	6.00**	Other district's X district	-0.002	1.45
Other region's X district	-0.004	5.38**	Other region's X district	-0.007	7.42**
Significant data points [a]	100%		Significant data points [a]	100%	
90% confidence interval [b]	[0.065–0.105]		90% confidence interval [b]	[0.046–0.074]	
Test Weight:					
District	-0.069	4.84**	District	0.098	6.19**
Other district's X district	-0.0001	0.42	Other district's X district	-0.001	6.44**
Other region's X district	0.002	11.71**	Other region's X district	0.0001	0.78
Significant data points [a]	100%		Significant data points [a]	100%	
Shrunken/Broken Kernels:					
District	0.044	1.82*	District	-0.018	0.54
Other district's X district	-0.012	1.27	Other district's X district	0.006	0.45
Significant data points [a]	0%		Significant data points [a]	0%	
Damaged Kernels:					
District	-0.008	0.28	District	0.007	0.31
Other district's X district	0.254	2.96**	Other district's X district	-0.002	1.45
Significant data points [a]	0%		Significant data points [a]	32%	
District Dummy Variables:					
Northwest	-0.155	2.99**	Northwest	-0.243	3.41**
North Central	-0.240	3.89**	North Central	-0.148	3.71**
Northeast	0.124	1.97*	Northeast	-0.082	2.20**
West Central	-0.183	3.66**	West Central	-0.159	4.24**
Central	-0.250	3.51**	Central	-0.061	1.34
Southwest	-0.347	4.78**	East Central	-0.011	0.13
South Central	-0.215	3.42**	Southwest	0.129	1.80*
Southeast	-0.052	1.04	South Central	-0.111	1.63
Constant:	-2.598	2.90**		0.456	0.82
System R^2	0.998				
Jarque-Bera normality test: $\chi^2_{2,0.01}$ critical value = 9.21	3.85			7.82	

Note: Single and double asterisks (*) denote coefficients significantly different from zero at the 0.05 and 0.01 levels, respectively.
[a] Significant data points refers to the percentage of data points that are statistically significant and of the expected sign.
[b] Confidence intervals calculated using Chebychev's inequality: $[P(|X - \mu| < g\sigma) > 1 - 1/g^2]$, where $g = \sqrt{10}$.

$/bushel and the western districts had discounts from 0.16 to 0.35 $/bushel. For North Dakota, the northwest district had a discount of 0.24 $/bushel, and both the north central and west central districts had a discount of about 0.15 $/bushel.

The marginal value of protein will vary for each wheat class as levels of protein in the other wheat class change. Each marginal value of protein was calculated using (6), and the standard errors were calculated using (7). All observations for Kansas were significantly different from zero at the 10% level and of the right sign. The mean and standard deviations of the Kansas protein marginal values were 0.085 $/bushel and 0.0064 $/bushel, respectively. Using this information in Chebychev's inequality, a 90% confidence interval was estimated to be 0.065 to 0.105 $/bushel. Figure 1 shows the plot of the change in the average district's marginal value of HRW wheat protein from a change in both the level of protein in the other districts in Kansas and from a change in the

Table 4. Estimated Marginal Values of Wheat Protein from Current and Previous Studies

Study	Study Period	Wheat Class [a]	Market	Protein Premium ($/MT) [b]
U.S. Domestic:				
▸ Current study	1974–96	DNS, HRW	Kansas	2.50–3.75
▸ Current study	1974–96	DNS, HRW	North Dakota	1.94–3.67
▸ Espinosa & Goodwin	1974–87	APH, DNS, HRW	Kansas	2.08
U.S. Export Terminals:				
▸ Uri et al.	1990–91	HRW	U.S. Gulf	5.64
▸ Uri et al.	1990–91	DNS	U.S. Gulf	14.14
▸ Wilson	1973–86	DNS, HRW	U.S. Pacific	8.18
World Export Terminals:				
▸ Ahmadi-Esfahani & Stanmore	1977–91	APH	Australian export	8.80
▸ Veeman	1976–84	ASW, CWRS, DNS, HRW	Export (1970s)	4.37
▸ Veeman	1976–84	ASW, CWRS, DNS, HRW	Export (1980s)	5.29
▸ Larue	1980–88	APH, CWRS, DNS, HRW	Export	5.49
Import Terminals:				
▸ Stiegert & Blanc	1984–92	ASW, CWRS, DNS, HRW	Japan import	3.00–6.00
▸ Wilson	1973–86	CWRS, DNS, HRW	Rotterdam import	7.15

[a] Wheat classes are defined as follows: APH = Australian prime hard, ASW = Australian standard white, CWRS = Canadian western red spring, DNS = U.S. dark northern spring, and HRW = U.S. hard red winter.
[b] Converted to a dry matter equivalent.

level of protein in North Dakota. Before 1988, protein values remained in the 0.08 to 0.0925 $/bushel range. In 1988, protein values shifted down by about 0.01 $/bushel in response to much higher average protein levels in North Dakota. In 1996, however, protein values shifted up by 0.01 $/bushel in response to much lower average protein levels in North Dakota. This demonstrates that the level of protein in one region can affect the value of protein in the other region.

Figure 2 displays the plot of estimated marginal values of protein for North Dakota DNS wheat. The graph demonstrates how highly varied the protein levels are in the southern Great Plains and the effect of this in determining the value of protein in North Dakota. All of the 207 observations for North Dakota were significantly different from zero at the 10% level and of the right sign. The mean and standard deviation of the North Dakota protein marginal values were 0.060 $/bushel and 0.0045 $/bushel, respectively. The estimated 90% confidence interval using Chebychev's inequality was 0.046 to 0.074 $/bushel (table 3).

Findings are consistent with previous research estimating the marginal value of protein (table 4). Additionally, Bale and Ryan found that the ratios of DNS/HRW wheat prices in Portland and in Minneapolis from 1965–75 were related negatively to the average protein content in HRW wheat. They also found that the average protein content of Kansas wheat was related negatively to the ratio of DNS/HRW wheat prices in Minneapolis.

Three grading characteristics were analyzed in our model: test weight, shrunken and broken kernels, and total damaged kernels. Blending between HRW and DNS wheat classes occurs because millers seek optimal test weight to reduce processing costs. For

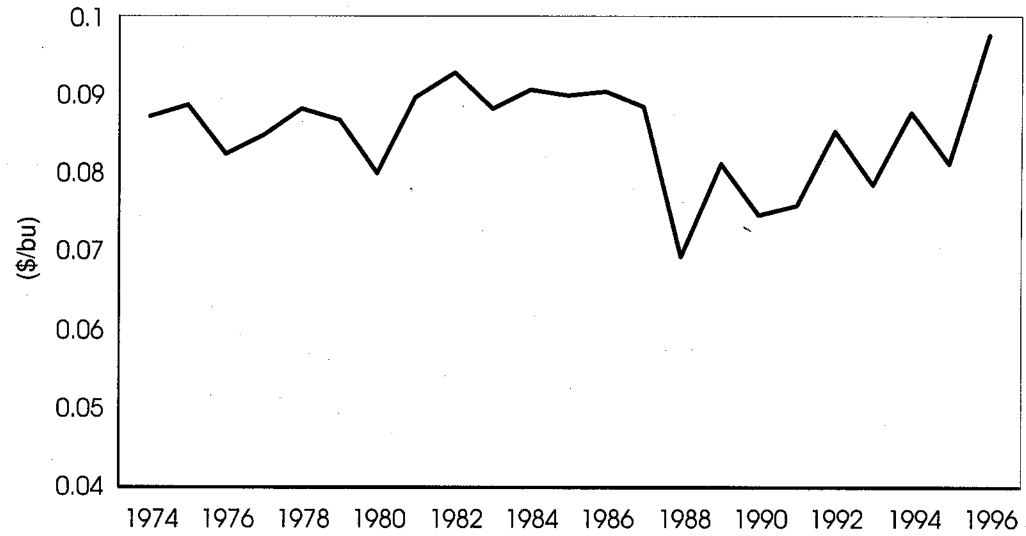

Figure 1. Marginal value of HRW wheat protein, 1974–96

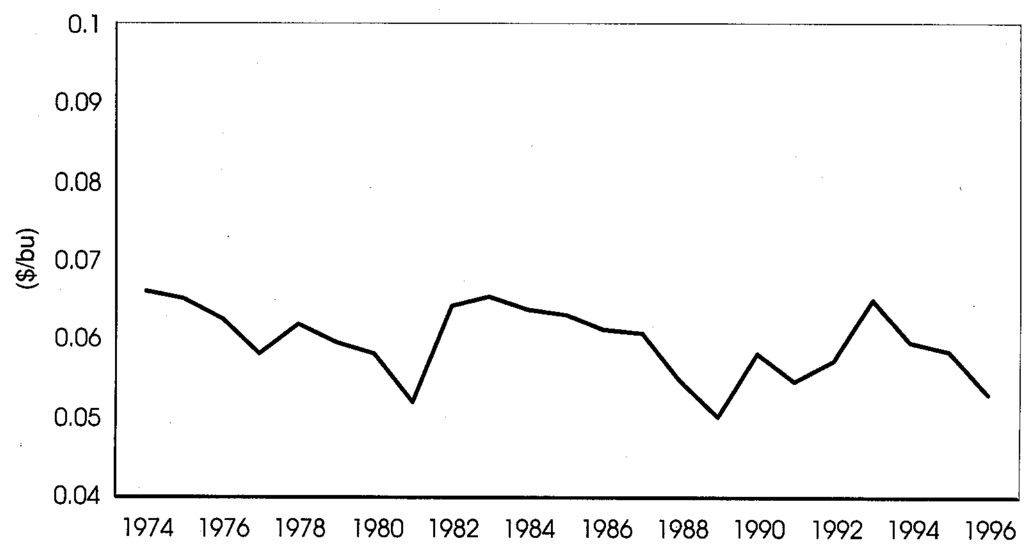

Figure 2. Marginal value of DNS wheat protein, 1974–96

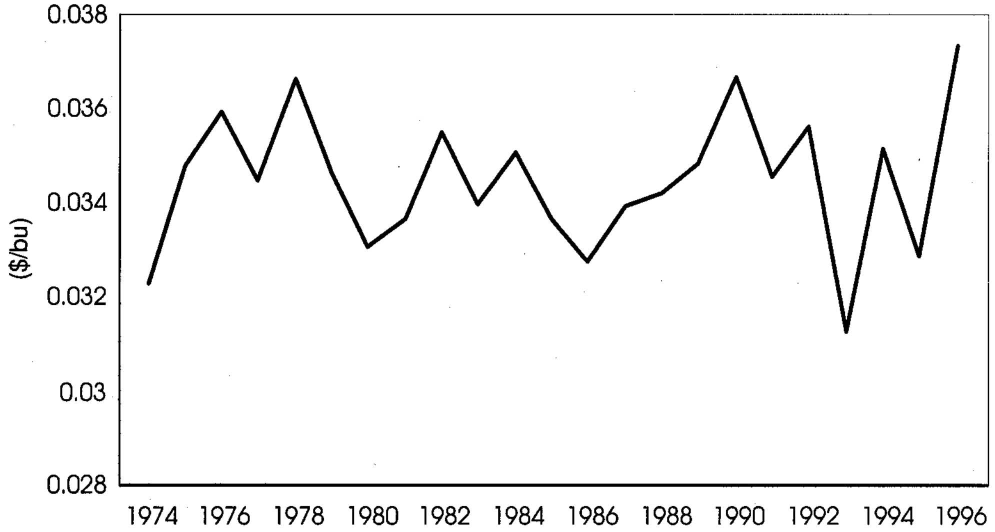

Figure 3. Marginal value of HRW wheat test weight, 1974–96

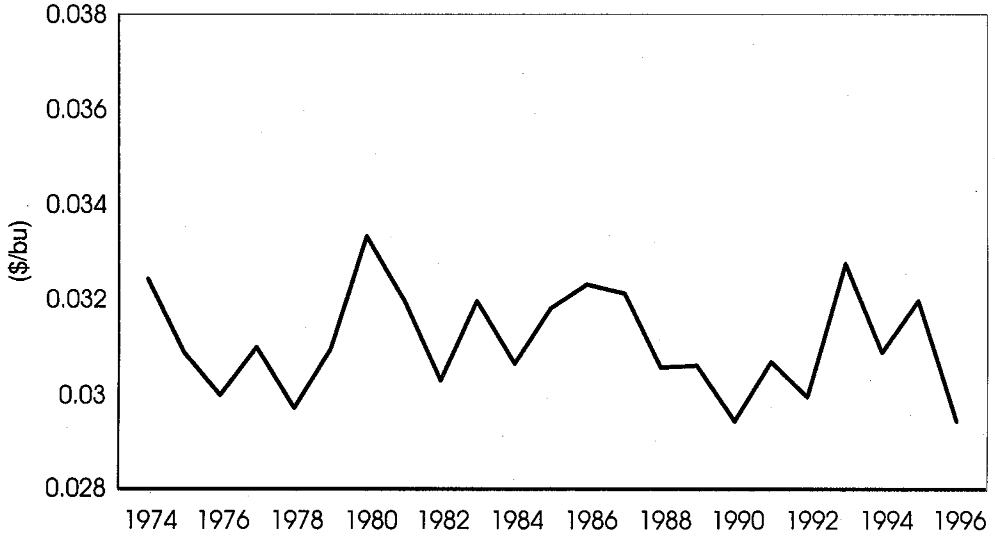

Figure 4. Marginal value of DNS wheat test weight, 1974–96

Kansas and North Dakota, all marginal values of test weight at each data point were significant at the 10% level and of the correct sign. However, the variability was minimal with a range of 0.031 $/bushel to 0.037 $/bushel for Kansas (figure 3) and 0.029 $/bushel to 0.034 $/bushel for North Dakota (figure 4).

Espinosa and Goodwin used a dummy variable approach to model the grading system and found that test weight of Kansas HRW wheat below the grade level of 60 pounds was docked about 0.11 $/bushel. This is certainly different than the result for Kansas in this analysis, but mainly because of the model structure. Almost all (two standard deviations—see table 2) of the test weight data were in the range of 57 to 63 pounds/bushel, so most of the test weight premiums and discounts from 60 pounds would be in the range of −0.093 $/bushel to 0.093 $/bushel based on a test-weight marginal value of 0.031 $/bushel.

Studies of the international market found test weight to be an important characteristic in export markets. Uri et al. reported marginal values at the Gulf of 0.13 $/bushel for HRW test weight and 0.20 $/bushel for DNS test weight. These higher values at the Gulf may be due partly to the ability of a shipping firm to spread fixed costs over more tons of wheat when kernel density is higher. Ahmadi-Esfahani and Stanmore found that the thousand kernel weight measure significantly explained price, whereas Larue did not find test weight to be significant.

None of the marginal values for Kansas or North Dakota shrunken/broken kernels were statistically significant and of the right sign. Additionally, none of the marginal values for Kansas damaged kernels were statistically significant and of the right sign, and 32% of the marginal values for North Dakota damaged kernels were statistically significant and of the right sign. Espinosa and Goodwin estimated the marginal value of damaged kernels to be about $0.03 per 1% increase in damaged kernels. Although damaged kernels can be removed in the premilling stages, fewer damaged kernels may indicate a crop with uniform kernel quality, which is a highly desirable trait in domestic milling and in export markets (Stephens).

Conclusions

Wheat breeding programs, production practices, and marketing programs all recognize the importance of delivering wheat with high quality characteristics. Several previous studies have demonstrated that wheat buyers pay for certain quality characteristics, particularly protein. The purpose of this research was to estimate the marginal value of wheat-grading characteristics and wheat protein in a spatially competitive framework. The model was motivated by Rosen's notion that the marginal pricing schedule of characteristics differs over time and location. A characteristic demand system was structured to include interaction terms to capture shifts in the marginal value of each characteristic as the supply of those characteristics changes between wheat classes and within the same wheat class. Protein and test weight were evaluated in an intra- and interregional framework because of their use in blending, and shrunken/broken and damaged kernels were evaluated intraregionally because they are determinants of differences in transportation costs. This study found that the marginal values of protein in Kansas HRW and North Dakota DNS were affected by the level of protein in other districts within the same region and by the level in the other region.

Discounts for test weight and for shrunken/broken kernels were not affected by the quality of wheat in other locations. These factors can affect processing costs and flour yield, and apparently their effects are unaffected by blending.

The results for protein are very significant in several ways. First, wheat breeding programs should recognize that high protein varieties, when adopted, shift the supply of protein and lower its marginal value. One critical area of future research is determining estimated elasticities of wheat protein supply and demand. Such information could help in understanding the risks and rewards of releasing and adopting high protein wheat. The conventional notion that increasing protein is a way to add value to a wheat crop is not quite that simple. As this research demonstrates, value is determined not only by demand, but also by a characteristic's relative scarcity. It is important to note that producers need wheat varieties that give them a competitive advantage over producers in other regions. Because several years are required to breed a variety for specific traits, the obvious strategy is to provide producers with many choices, so that they can respond to the market prices for wheat quality and wheat quantity.

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