Factors Affecting Wheat Proteins Premiums

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This study used the Rosen methodology of deriving a marginal implicit price series of a characteristic from traditional first-stage hedonic modeling and then using this series to estimate a demand model for the characteristic wheat protein. This procedure was applied to Kansas Hard Red Winter and North Dakota Hard Red Spring wheat. Estimated flexibilities indicate an elastic demand for both Hard Red Winter and Hard Red Spring wheat protein. Also, cross-price flexibilities for wheat protein indicate that an increase in the demand for protein in one region has a significant impact on the value of the other regions' wheat crop.

keywords: wheat protein, hedonic modeling, characteristic demand modeling

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As the wheat industry evolves toward a quality based marketing system, there are many questions to be answered regarding the value of certain wheat characteristics. More importantly, factors affecting the change in the value of wheat quality characteristics need to be determined. Considerable previous research has investigated the marginal implicit value of wheat characteristics through hedonic modeling, e.g., Larue; Espinosa and Goodwin; Parcell and Stiegert; and Veeman. However, no previous research has attempted to identify wheat characteristic demand elasticities or factors shifting the characteristic demand curve. The objective of this research is to build on previous characteristic demand research to determine factors affecting the value of one wheat quality characteristic, protein. This study estimates the demand elasticity and factors shifting the demand curve for one wheat characteristic, protein, for Hard Red Winter (HRW) and Hard Red Spring (HRS) wheat.

Previous studies have investigated the impact of wheat quality differentials on price and have noted the relative importance of protein in contributing to price relative to other characteristics (e.g., Espinosa and Goodwin; Parcell and Stiegert; and Veeman). Only Parcell and Stiegert analyzed how demand factors effected the marginal implicit price of protein. Parcell and Stiegert developed a characteristic demand model that accounted for both intraregional (between the same wheat class) and interregional (between wheat classes) competition for protein and test weight. Their characteristic demand model was motivated by Rosen's theoretical development for identifying characteristic demand parameters affecting characteristic value (second-stage analysis).

Rosen's work has been previously applied to the determination of housing characteristics (e.g., Diamond and Smith; Harrison and Rubinfeld; Palmquist; and Witte, Sumka, and Erekson) and for agricultural commodities to cotton (e.g., Bowman and Ethridge; and Chiou, Chen, and Capps). However, the concepts developed by Rosen have not been explicitly extended to wheat. As suggested by Epple and carried out by Parcell and Stiegert, the first step in obtaining unbiased characteristic demand parameter estimates is to properly specify the characteristic demand model (fist-stage analysis) for determination of the marginal implicit pricing schedule to be used in the second-stage analysis.

This research builds on the work of Parcell and Stiegert by modifying and extending the characteristic demand model they developed to obtain a marginal implicit price series for HRW and HRS wheat protein. Using these estimated values, an inverse demand model of wheat protein is estimated to determine the impact of demand shifters on HRW and HRS wheat protein values.

Understanding factors affecting wheat protein premiums is important for producers and agribusinesses as the wheat marking system moves toward more of a quality based pricing system. This information will help producers make better production decisions and producers and elevators better formulate and assess marketing strategies involving quality based marketing. This study is a step toward determining the economics of these decisions.

Review of Methodology and Application

Rosen's (1974) theoretical analysis titled, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," provided the theoretical foundation for the estimation procedures of structural supply and demand equations for product characteristics. Rosen developed a simple one characteristic model and showed how equilibrium in the market for this characteristic was obtained. Rosen postulated that the marginal implicit pricing schedule for a characteristic is a series of equilibrium between supply of and demand for the characteristic over time or between markets. Figure 1 graphically depicts this situation. According to Rosen, some may inappropriately interpret the dashed line in Figure 1, drawn through the equilibrium points representing the marginal implicit values estimated from the standard hedonic pricing equation, as the demand function for that characteristic. However, Rosen argued that those points are just a sequence of supply and demand equilibrium that shift due to changes in exogenous supply and demand factors.

Rosen showed that first-stage hedonic modeling overlooks changing marginal implicit values for different levels of characteristics because only consumer behavior is considered, while producer behavior is overlooked. He rationalized that supply of characteristics and demand for characteristics at any given characteristic level creates the marginal implicit value schedule for a characteristic. Rosen concluded, "In fact, those [estimated first-stage hedonic price-characteristics] observations were described by a joint-envelope function and cannot by themselves identify the structure of consumer preferences and producer technologies that generate them" (p. 54).

Rosen suggested a two-step procedure to estimate characteristic supply and demand equations. First, traditional hedonic modeling is used to estimate marginal implicit values. Next, marginal implicit prices computed from the estimates become endogenous variables in the second-stage simultaneous estimation of structural supply and demand equations. Assume the price of good *k* can be specified as $p_k(z)$, where *z* is a 1 x *i* vector of characteristics of good *k*. The hedonic function for good *k* is a regression of the form (Lucas and Brorsen, Grant, and Rister):

(1) $$p_k = p(z_{k1}, \ldots, z_{ki}; u_k),$$

where u_k is a white noise, normally distributed, error vector. A series of marginal implicit values for characteristic *i*,

(2) $$\partial p_k(z)/\partial z_{ki} = P_{ki}(z),$$

can be computed from estimation of (1) and used as a price vector for characteristic *i* in the second-stage supply and demand equations to be estimated:

(3) $$P_{ki}(z) = F_{ki}(z_i, Y_1) \quad \text{(demand)}$$

(4) $$P_{ki}(z) = G_{ki}(z_i, Y_2) \quad \text{(supply)},$$

where F_{ki} and G_{ki} represent functions of demand for z_i and the supply of z_i, respectively, and Y_1 and Y_2 represent a vector or exogenous shift variables of demand and supply. Rosen suggested estimating the specified structural supply and demand equations specified in equations (3) and (4) independently using Ordinary Least Squares.

Bowman and Ethridge were the first to apply second-stage hedonic analysis to an agricultural commodity. They examined U.S. regional cotton characteristic data for the cropping years 1976-1977 to 1986-1987 to evaluate the structural demand and supply of individual characteristics. All observed prices and quality characteristics were evaluated relative to a base set of quality attributes and a base price. This procedure allowed for the capture of overall market movements. Cotton characteristics evaluated included trash content, color, length of fiber, low micronaire, high micronaire, and strength.

Although Bowman and Ethridge did not follow the Rosen approach explicitly in obtaining first-stage parameter estimates, their procedure alleviated the necessary condition of non-linear functional form suggested by Mendelsohn (1984b, 1987) and Epple. Using a linear functional form they estimated coefficients based on yearly observations. This procedure produced multiple data points for each characteristic's marginal implicit value, by region. Thus, a non-constant marginal implicit value schedule was derived for each characteristic. Estimated marginal implicit values were then used as dependent variables in the estimation of structural demand and supply equations.

Chiou et al. estimated first and second-stage hedonic models to evaluate the economic benefits of biotechnology on cotton. In the first stage Chiou et al. estimated four separate models, for four different locations, for different cotton characteristics. Similar to Bowman and Ethridge, Chiou et al. computed the marginal implicit prices across the different locations so that it was not necessary to specify the impact of a change in quality on price using a nonlinear functional form. The series' of marginal implicit prices for staple and strength estimates from the first stage model were used in the second stage estimation of characteristic supply and demand equations for cotton staple and strength.

Using what has been learned from previous characteristic demand research, we apply Rosen's theoretical model to one wheat characteristic, protein, to estimate the demand flexibility for HRW and HRS wheat and determine to what extent factors shift the demand for this characteristic. The following section describes the first and second-stage empirical models used to derive our results.

Empirical Model

Empirical studies explaining the impact of commodity quality attributes on commodity price are now over 70 years old, e.g., Waugh (1929). Court (1939) first introduced the word "hedonic" to the literature in describing the impact of automobile characteristics on price paid by consumers.[1] The theoretical underpinnings of linking consumer theory to characteristic demand models is credited to Lancaster. However, Ladd and Martin's methodological link of characteristic demand analysis and neoclassical firm theory contributed significantly to the use of hedonic

[1] Court credited Alexander Sachs with first suggesting the term "hedonic." And, Court, referring to the shortened term hedonic from hedonism, stated (p. 107) , "Hedonic price comparisons are those which recognize the potential contribution of any commodity, a motor car in this instance, to the welfare and happiness of its purchasers and the community."

modeling in the agricultural economics literature. Ladd and Martin showed the price of an input good equals the sum of the implicit value of the input's characteristics and demand for the input is affected by the quantity of the input's characteristics.

Parcell and Stiegert expanded on the standard Ladd and Martin framework by modeling price as being determined by aggregate characteristic levels as well as local characteristic levels. Parcell and Stiegert estimated a characteristic demand model for Hard Red Winter (HRW) and Hard Red Spring (HRS) wheat. The first-stage hedonic model developed by Parcell and Stiegert is used in the present study to obtain a protein price series for use in the estimation of structural demand equations for protein. The characteristic demand equations estimated by Parcell and Stiegert were:

$$
\begin{aligned}
KWH_{it} = \alpha + \sum_{a=1}^{8} \beta_a KD_{ita} &+ \beta_9 KPT_{it} + \beta_{10} KPTOD_{it} + \beta_{11} KPTOR_t + \beta_{12} KTW_{it} \\
&+ \beta_{13} KTWOD_{it} + \beta_{14} KTWOR_{it} + \beta_{15} KSB_{it} \\
&+ \beta_{16} KSBOD_{it} + \beta_{17} KDK_{it} + \beta_{18} KDKOD_{it} + \varepsilon_{it}.
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
NWH_{it} = \alpha + \sum_{a=1}^{8} \beta_a ND_{ita} &+ \beta_9 NPT_{it} + \beta_{10} NPTOD_{it} + \beta_{11} NPTOR_t + \beta_{12} NTW_{it} \\
&+ \beta_{13} NTWOD_{it} + \beta_{14} NTWOR_{it} + \beta_{15} NSB_{it} \\
&+ \beta_{16} NSBOD_{it} + \beta_{17} NDK_{it} + \beta_{18} NDKOD_{it} + \varepsilon_{it}.
\end{aligned} \tag{6}
$$

Variable definitions are presented in table 1. The subscript i refers to the ith reporting district in either Kansas or North Dakota (i=1, ..., 9), and subscript t refers to time period (t=1, ..., 23; 1974-1996). 207 observations were used in the estimation of (5) and (6), i.e., data were pooled. All variables for Kansas begin with the letter *K* and all variables for North Dakota begin with the letter *N*. Because the interest of this study is on protein, discussion of other wheat quality characteristics is forgone. For a detailed description of the variables used in equations (5) and (6) see Parcell and Stiegert. Three terms of interest 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*).

Mendelsohn (1984a, 1984b) and Lang and Kahn are among the many researchers who have suggested the need for a non-linear functional form in first-stage hedonic analysis when estimating second-stage characteristic demand equations from first-stage marginal implicit values. Mendelsohn (1984b, 1987) and Kahn and Lang suggested a non-linear functional form must be used in the first-stage estimation so that the marginal implicit price changes as the level of characteristic changes. If equations (5) and (6) are estimated using a linear functional form, the marginal implicit values will be constant and independent of the quantity of characteristic

(Witte, Sumka, and Erekson). Because the value of the protein characteristic in the current study involves interaction terms, i.e., non-linear specification in protein, the marginal value of HRW protein, for example, is calculated as:

$$\frac{\partial KWH_{it}}{\partial KPT_{it}} = \beta_9 + \beta_{10} KPTD_{it} + \beta_{11} KPTR_t = KPTP_{it} , \tag{7}$$

where $KPTD_{it}$ represents the level of protein in all other districts within Kansas and $KPTR_t$ represents the annual average protein of North Dakota HRS wheat. Because the value of the protein characteristic involves interaction terms, the marginal implicit pricing schedule for the protein characteristic derived using (7) is now a 207 x 1 vector or protein prices ($KPTP_{it}$) that changes as the level of own and competing region characteristic levels change. The price gradient is used as the dependent variable series in the estimation of a protein structural demand equation in the second-stage hedonic analysis. Furthermore, Brown and Rosen stated,". . . marginal "prices" constructed only from quantities do not in themselves add any information to that already provided by observations on quantities" (p. 767). Thus, by modeling protein in the first-stage analysis as a function of exogenous factors, own district protein quantity need not be treated as an endogenous variable in the second stage.

Second-stage hedonic model

Using Rosen's concept that the marginal implicit pricing equation is a dynamic equilibrium of supply and demand factors, the current study proposes an empirical model to estimate the impact of characteristic demand factors for HRW and HRS wheat protein premiums. Whereas Mendelsohn suggested that supply need not be exogenous, he was not considering agricultural commodities but rather goods, such as houses, for which the supply of specific characteristics could be created or withheld from the market. However, farmers have limited ability to change the level of protein produced or withhold the supply of protein from the market through storage.[2] Therefore, for this analysis the supply of HRW and HRS protein is assumed exogenous.

Following from Rosen's methodology, the protein prices (dependent variable) used for second-stage estimation of the protein inverse demand model are the marginal implicit prices calculated using (7). Figure 2 graphically depicts the relationship between protein premium and protein level for HRW protein (marginal implicit pricing schedule). This relationship nicely traces out a downward sloping demand curve. However, as suggested by Rosen, it is assumed

[2] In the Northern Plains it is sometimes common to apply nitrogen post emergence to increase protein content; however, it is difficult to quantify this impact because it is difficult to distinguish between the time when the nitrogen is applied because timing is crucial to increasing protein content.

that each point indicated in figure 2 represents an equilibrium point between supply of and demand for HRW wheat protein, e.g., not the demand curve for protein. Assuming supply exogenous, it is then possible to specify an inverse demand model to quantify the impact on protein price caused by changes in demand shifters.

Following the work of Stiegert and Balzar, the inverse demand models estimated for HRW and HRS wheat protein price (*_PTP*$_{it}$) in Kansas or North Dakota district *i* in year *t* were:

(8) $$KPTP_{it} = \gamma_0 + \gamma_1 KPT_{it} + \gamma_2 KPTORRATIO + \gamma_3 KPRODRATIO_t + \gamma_4 QGLUTEN_t + \varepsilon_t^K$$

(9) $$NPTP_{it} = \phi + \phi_1 NPT_{it} + \phi_2 NPTORRATIO + \phi_3 NPRODRATIO_t + \phi_4 QGLUTEN_t + \varepsilon_t^{ND}$$

Variable definitions are given in table 1. The inverse demand models specified in equations (8)and (9) state that Kansas HRW and North Dakota HRS protein premium is a function the district average protein level (*_PT*), the average other region's protein relative to the average own regions's protein (*_PTORRATIO*), the ratio of annual wheat production in own region to other region (*_PRODRATIO*), and quantity of gluten in the U.S. (*QGLUTEN*).

Following convention, own-district protein level is expected to be negatively correlated with protein value. The ratio of other region's protein to own region's protein is included to account for cross-regional effects. As this ratio increases it is expected that the own region protein price will decrease. The production ratio is expected to capture relative changes in protein availability associated with blending of wheat types. An increase in this variable should indicate an overall increase in protein quantity relative to the other region and decrease own region's protein value. As demand for gluten – a product derived from processing wheat protein – the value of protein is expected in decrease, *ceteris paribus*.

Data

Summary statistics of the data for first-stage hedonic estimation are reported in table 2, and summary statistics of the data for protein structural demand estimation (second-stage) are reported in table 3. Data were annual, by location, from 1974 to 1996. See Parcell and Stiegert for a detailed description of data used for estimation of the HRW and HRS wheat characteristic demand models described by equations (5) and (6). The average annual cash price series for HRW wheat is a Kansas City price for a 13% protein and 60 lb. bushel, and the cash price series for DNS wheat is a Minneapolis price for a 13% protein and 58 lb. bushel (*Wheat Situation and Outlook*).

Quality data for Kansas HRW wheat were collected from the *Kansas Wheat Quality* report series (Kansas Agricultural Statistics Service). Similarly, quality data for North Dakota DNS wheat were collected from the *Regional Hard Red Spring Wheat Quality Reports* (North Dakota State University). Production data were collected from various issues of *Kansas Farm Facts* (Kansas State Board of Agriculture) and through the 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 and the annual state averages in Kansas for use in. Gluten data was obtained from Hesser.

Results

The first- and second-stage data were corrected for autocorrelation and heteroskedasticity following procedures outlined by Parcell and Steigert. The first-stage characteristic demand models were estimated as a systems of equation in *SHAZAM* 9.0. The second-stage protein demand models were estimated using the *pool* command in SHAZAM 9.0.

First-stage hedonic model results, reported by Parcell and Stiegert, for Kansas HRW wheat and North Dakota HRS wheat are reported in table 3. See Parcell and Stiegert for a full discussion of the estimation results of first-stage hedonic modeling. The marginal implicit price schedule for protein was calculated from first-stage parameter estimates following from equation 7. The derived protein premium gradients were used as dependent variables in the structural demand equations. Model results from the structural demand models for HRW and HRS wheat protein premiums specified in (8) and (9) are listed in table 4. All variables were statistically significant at the 0.01 level. The chosen explanatory variables explained over 69% and 66% of the variability in HRW and HRS protein values, respectively.

As expected, an increase in own-district protein level decreased protein premium. The impact of a one-percentage point increase in own-district protein level would decrease HRW (HRS) protein premium by \$0.0034/bushel (\$0.0022/bushel). Also, of specific interest is the cross-region protein impact. For HRW wheat, a one-percentage point increase in the ratio of HRS wheat protein to HRW wheat protein decreased the value of HRW protein by \$0.042/bushel. For HRS wheat, a one-percentage point increase in the ratio of HRW wheat protein to HRS wheat protein decreased the value of HRS protein by \$0.056/bushel. This is an important finding because it indicates that there significant implications to the other region due an increase in protein level in the other region. Furthermore, the HRS protein value is more responsive to protein changes in the HRW wheat crop than HRW protein value to protein changes in the HRS wheat crop.

Using the reported mean value of protein premium and protein content, flexibilities were computed and used for simulation analysis (table 5). Computed flexibilities, at the mean, were -0.478 and -0.575 for HRW and HRS protein, respectively. Because the demand curves are elastic – the lower bound of the elasticity of demand is the reciprocal of the flexibility – a change in the quantity demanded will lead to a less than proportionate change in protein price. Thus, an increase in quantity demanded, assuming supply exogenous, will have a positive net effect on the value of the wheat crop in each region. Table 5 is used to show the impact of a 10% increase in quantity demanded for HRW and HRS protein. That is, creating new products that utilize more protein will have a positive impact on the value of wheat. For instance, increasing the quantity demand of HRW wheat protein has an effect of increasing the overall value of HRW wheat crop by 2.96%. Yet, this increase in HRW protein quantity demanded would decrease the value of the HRS wheat crop through a substitution affect.

As expected, an increase in ratio of own region's production to other region's production decreased the protein value for in both the HRW and HRS protein premium models. However, the negative impact on HRW protein premium was almost twice that of the impact on HRS protein premium. Yet, for both HRW and HRS protein value the impact was relatively small. Protein is a substitute for the relatively more expensive gluten in the baking process. An increase in the quantity of domestic gluten had a negative impact on protein value, but this impact was sufficiently small.

Conclusions

This study used Rosen's methodology of deriving a marginal implicit price series from traditional hedonic modeling and then using this series in to then estimate a demand model. This procedure was applied to Hard Red Winter and Hard Red Spring wheat protein. Using protein premiums computed from a previous study by Parcell and Stiegert, the current study estimated a demand model to quantify factors shifting the demand for protein premium. Results were mixed. Most coefficients were statistically significant, and simulation of how intrinsic protein premiums might respond to a change in quantity demanded for an average Kansas or North Dakota farmer indicated that the economic impact of these factors is large enough to matter, assuming the increase in quantity demanded for wheat protein is large enough. Furthermore, we find the impact on the other regions' protein value to be negatively impacted by an increase in demand for own regions' protein content.

Our analysis indicates the demand for HRW and HRS wheat is elastic, around two in absolute value. This indicates that technologies to increase wheat protein on the production side will have a positive impact on farm profitability, assuming an inelastic supply curve for wheat.

The research we presented is a first attempt at assessing the factors affecting the characteristic demand for a wheat characteristic, protein. While we employ an established theoretical methodology for arriving at our results, a limitation of this study is that we use aggregated data.

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Table 1. Description of Variables Employed in Empirical Models

Variable name	Definition
	First-Stage
KWH_{it}, NWH_{it}	District price deflated by regional average price ($/bushel) in district i (i=1, 2, ..., 9) and time period t (t=1, 2, ..., 23)
KD_{it}, ND_{it}	Binary (0 or 1) terms for each district
KPT_{it}, NPT_{it}	District protein (%/bu)
$KPTOD_{it,}$ $NPTOD_{it}$	Interaction terms: district protein times the production-weighted average of protein for all other districts in the region (%/bu)
$KPTOR_{t}$, $NPTOR_{t}$	Interaction terms: district protein times 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 times the production-weighted average of test weight for all other districts in the region (%/bu)
$KTWOR_{t}$, $NTWOR_{t}$	Interaction terms: district test weight times 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 times 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 times the production-weighted damaged kernels for all other districts in the region (%/bu).
	Second-Stage
$KPTP_{it}$, $NPTP_{it}$	Protein premium in district i (i = 1, . . ., 9) at time t (t= 1974, . . ., 1996) estimated from first-stage hedonic model reported in Parcell and Stiegert ($/bu).
$KPROD_{t,}$ $NDPROD_{t}$	Ratio of own region's total production of protein (production multiplied by average protein content in the region) to other region's total production of protein in year t.
$KPRODRATIO_{t}$, $NDPRODRATIO_{t}$	Ratio of other region's protein level to own region's protein level in year t.
$Qgluten_{t}$	Domestic gluten production plus gluten imports (000 tons) in year t.

Table 2. Summary Statistics of Selected Wheat Characteristics (1974-1996).

Characteristic	Average	S.D.	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 (lb/bu)	60.13	1.60	56.70	62.90
Production weighted (lb/bu)	60.14	0.89	56.87	61.73
State average test weight (lb/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
Production (000 bushels)	367610	69615	213600	472000
Protein premium ($/bushel)	0.085	0.006	0.068	0.098
North Dakota				
District price ($/bu)	3.44	0.39	2.07	4.80
Regional price ($/bu)	3.95	0.45	2.83	5.64
Protein (%/bu)	14.34	0.62	12.60	17.20
Production weighted (%/bu)	14.24	0.30	13.43	16.40
State average protein (%/bu)	14.76	0.78	13.80	16.50
Test weight (lb/bu)	59.80	1.39	56.10	62.60
Production weighted (lb/bu)	59.74	0.79	57.85	61.42
State average test weight (lb/bu)	59.68	0.64	57.90	61.20
Shrunken/broken kernels (%/bu)	1.47	0.18	0.18	3.20
Production weighted (%/bu)	1.50	0.23	0.71	3.21
Damaged kernels (%/bu)	0.45	0.53	0.00	4.80
Production weighted (%/bu)	0.56	0.29	0.00	1.91
Production (000 bushels)	202320	69067	70500	382200
Protein premium ($/bushel)	0.058	0.005	0.047	0.066
Aggregate				
Gluten (000 ton)	17.76	7.08	7.85	30.75

Table 3. First-Stage Hedonic Regression Equations for Regional Wheat Prices: 1974-1996

Hard Red Winter			Dark Northern Spring		
Characteristic	Marginal Value	t-stat[a]	Characteristic	Marginal Value	t-stat
		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**
		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
		Shrunken and Broken Kernel			
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
		Damaged Kernel			
District	-0.008	0.28	Damaged kernel	0.007	0.31
Other district's X district	0.254	2.96**	Other district's	-0.002	1.45
		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**	Constant	0.456	0.82
System R-squared	0.998				

[a] Two asterisks and one asterisk denote coefficients significantly different from zero at the 0.01 level and 0.05 level, respectively.

Table 4. Second-Stage Structural Demand Equations for Regional Protein Prices: 1974-1996, (Dependent Variable is Protein Premium for the Respective Wheat Variety).

Hard Red Winter Protein			Dark Northern Spring Protein		
Characteristic	Parameter Estimate	*t-stat.*	Characteristic	Parameter Estimate	*s.e.*
Own-quantity district protein	-0.34E-02 (***)	8.76	Own-quantity district protein	-0.22E-02 (***)	9.82
Ratio of HRS protein level to HRW protein level	-0.042 (***)	11.98	Ratio of HRW protein level to HRS protein level	-0.056 (***)	14.59
Ratio of HRW wheat production to HRS wheat production.	-0.37E-02	11.90	Ratio of HRS wheat production to HRW wheat production.	-0.19E-02	2.05
Gluten quantity	-0.98E-04 (***)	7.82	Gluten quantity	-0.27E-04 (***)	2.11
Constant	0.193 (***)	25.73	Constant	0.141 (***)	29.07
R-*squared*	0.691		R-*squared*	0.663	
No. of observations	207		No. of observations	207	

Note: Three asterisks (***) denote coefficients significantly different from zero at the 0.01 level.

Table 5. Simulation Analysis of 10% increase in Quantity Demanded of HRW and HRS Wheat Value.

	Kansas - HRW	**North Dakota - HRS**
Per bushel	$0.0982	$0.0798
Per acre	$3.437	$2.794
Per 2000 acre farm	$6,873	$5,588
State	$36.5 million	$29.7 million
Entire Region	$153.961 million (2.96%)	$125.18 million (3.50%)
Regional impact from 10% increase in own regions' protein level on value other region's wheat	$8.14 million (0.16%)	$7.17 million (0.20%)

Values for own region represent summation of change in value from a change in quantity demanded of protein and a price adjustment due to change in quantity demanded. Cross-regional effects represent change in overall value of own region's protein. Values in parenthesis indicate % of overall crop value.

Figure 1. Hedonic Pricing Equation Derived via Equilibrium between Supply of and Demand for Quality factor Z_i.

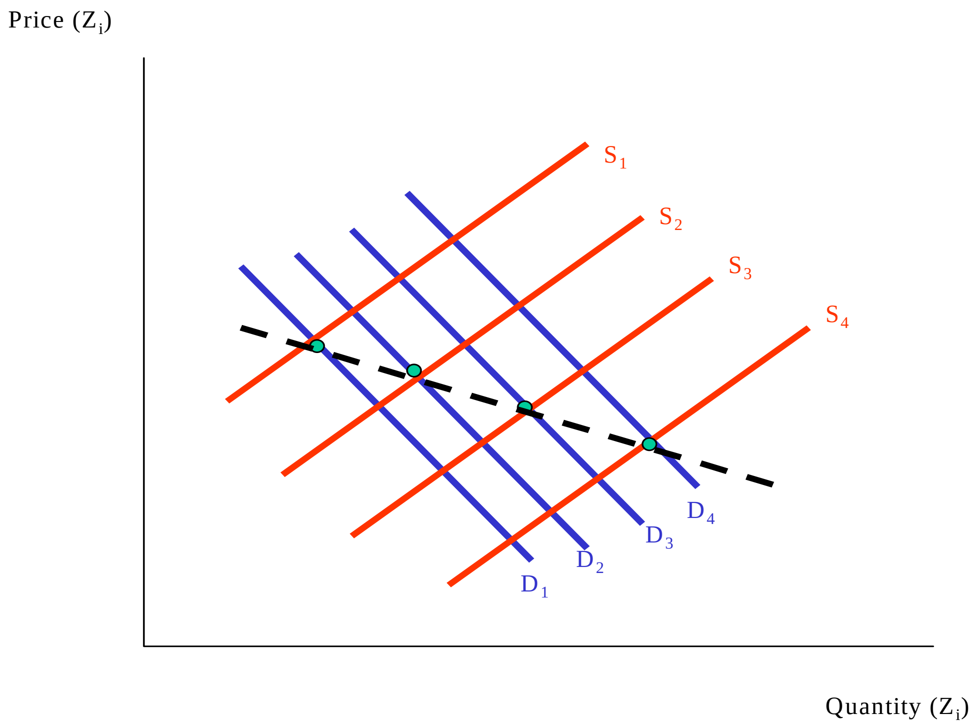

Figure 2. Estimated HRW Protein Marginal Implicit Pricing Schedule from First-Stage Hedonic Pricing Equation Reported by Parcell and Stiegert.