Factors Affecting Wheat Protein Premiums

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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 Kansas Hard Red Winter wheat protein. Results were mixed. Own-district protein level was not economically significant; however, an increase in other Kansas district's protein level and the North Dakota Hard Red Spring protein level may have a slight economic impact on own-district protein premium. The results of this study indicate that new varieties of wheat developed that increase protein content without loss of yield and that are regional specific can impact the price or wheat in other areas.

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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. Providing this information will allow producers and agribusinesses to better assess the economic viability of marketing strategies based on quality. 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.

Numerous previous studies have investigated the impact of wheat quality differentials on price and have noted the relative importance or 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 affected 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 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 parameters is to properly specify the characteristic demand model (fiststage 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 Hard Red Winter wheat protein. Using these estimated values, a demand model of wheat protein will be estimated to determine the impact of demand shifters for predetermined values of Hard Red Winter wheat protein premiums.

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 of "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 attained. 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 was constructed to graphically depict this situation. According to Rosen, some may inappropriately interpret the dashed line drawn through 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 suggested a two-step procedure to estimate characteristic supply and demand equations. First, traditional hedonic modeling was used to estimate marginal implicit values. Next, marginal implicit prices computed from the estimates became endogenous variables in the second-stage simultaneous estimation of structural supply and demand equations. Assume the price of a good can be specified as p(z), where z is some vector of *i* characteristics of the good. A series of marginal implicit values for characteristic *i*, $\partial p(z)/\partial z_i = P_i(z)$, can be computed using traditional first-stage hedonic estimation. These derived marginal implicit prices are then used in the second stage to estimate:

(1) $$P_i(z) = F_i(Z_i, \ldots, Z_n, Y_1) \quad \text{(demand)}$$

(2) $$P_i(z) = G_i(Z_i, \ldots, Z_n, Y_2) \quad \text{(supply)},$$

where F_i and G_i 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 showed that first-stage hedonic modeling overlooks changing marginal implicit values for different levels of characteristics because only consumer behavior was considered, while producer behavior was overlooked. His rationalization was 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).

Mendelsohn (1987) contradicted the findings of Rosen in that the simple linear model approach for the estimation of structural equations was sufficient. He suggested that by virtue of his earlier research (1984) the bias in structural demand coefficients may be corrected with two-stage least squares. Mendelsohn refuted earlier assumptions of an exogenous supply schedule as a solution to identification problems of demand functions. He suggested single-market data was acceptable if the proper nonlinear functional form was modeled in the first-stage hedonic analysis. Mendelsohn stated that when marginal implicit prices are held constant, a first-stage analysis will capture all marketing and production effects, e.g., structural demand variables. Coefficients estimated using nonlinear functional form allow for a non-constant marginal implicit price gradient. Thus, a nonlinear functional form will never capture all structural effects in first-stage hedonic estimates while allowing for the estimation of structural demand estimates in second stage analysis. Mendelsohn cautioned that linear models of second-stage coefficients were consistent only if a proper nonlinear first-stage functional form was chosen. He suggested the use of multi-markets to avoid inconsistencies. He stated, "The multiple markets allow estimation of price effects to be independent of demand- or supply-shift effects" (p. 90).

Also in 1987 Epple commented on the earlier works of Rosen. Epple concluded that the technique for correction of estimation error was through collection of multiple location data sets. He stated, "The form of the demand and supply functions depends on the tastes of consumers with a given set of characteristics or on the technology of producers . . . Therefore, the parameters of these demand and supply functions should not vary across markets." (p. 66). Epple suggested allowing supply to be exogenous in the second-stage estimation model.

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 allows 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 do not follow the Rosen approach explicitly in obtaining first-stage parameter estimates, their procedure alleviated the necessary condition of non-linear functional form introduced by Mendelsohn and Epple. Using a linear functional form they estimated coefficients based on yearly observations, by region. This procedure produced multiple data points for each characteristic's marginal implicit value. 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 equations.

Empirical 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 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, a farmer does not have the technology or the storage capacity to change the level of protein produced or withhold the supply of protein from the market through storage. Therefore, for this analysis the supply of protein is assumed exogenous.

The protein price series used to estimate the inverse demand equation for protein in the current study was derived in an earlier analysis by Parcell and Stiegert. Parcell and Stiegert jointly estimated characteristic demand models for Hard Red Winter (HRW) wheat and Hard Red Spring (HRS) wheat using panel data for each of the nine crop reporting districts in Kansas and North Dakota. They specified the demand model such that price of wheat type for a specific district in a particular year was a function of district dummy variables, own-characteristics of protein, test weight, shrunken and broken kernel, and damaged kernel, interaction terms for intra-regional characteristics protein, test weight, shrunken and broken kernels, and damaged kernels; and inter-regional characteristics for protein and test weight. For only protein and disregarding other variables due to paper length limitations, the impact protein has on wheat price was specified by Parcell and Stiegert as:[1]

(3) $$\text{Price of wheat}_{it} = f\,(\text{protein level}_{it}\,,\ \text{protein level}_{it} \times \text{intraregional protein level}_{t},\ \text{protein level}_{it} \times \text{interregional protein level}_{t})$$

where *i* equals one of the nine crop reporting districts in Kansas and t refers to year that ranged from 1974 to 1996. Intraregional protein refers to the production weighted average protein level in the other eight districts in Kansas and interregional protein refers to the protein level for North

[1]See Parcell and Stiegert for a complete description of the empirical model and procedures.

Dakota. Following from Rosen's methodology, the protein values (dependent variable) used for second-stage analysis in the current study were derived as:

$$(4)\quad \frac{\partial wheat\ price_{it}}{\partial protein\ level_{it}} = \beta_1 + \beta_2\ intrargional\ protein\ level + \beta_3\ interregional\ protein\ level,$$

where β_is are estimated coefficients that refer to the variables specified equation 1. For a detailed description of the procedures used to derive the dependent variable vector series used in the this study see Parcell and Stiegert. Figure 2 graphically depicts the relationship between protein premium and protein level (marginal implicit pricing schedule). This relationship nicely traces out a downward sloping demand curve. However, following from Rosen, it is assumed that each point indicated in figure 2 represents an equilibrium point between supply of and demand for HRW wheat 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.

The inverse demand model estimated for HRW wheat protein premium (PTP_{it}) in Kansas district *i* in year *t* was:

$$(5)\quad PTP_{it} = \alpha + \beta_1 PT_{it} + \beta_2 PTPROD_{it} + \beta_3 PTOD_{it} + \beta_4 PTODPROD_{it} + \beta_5 PTOR_t + \beta_6 PTORPROD_t + \beta_7 CASH_t + \epsilon_t$$

Variable definitions are presented in table 1. The inverse demand model specified in equation 5 states that Kansas HRW protein premium is a function of the district average protein level (*PT*), an interaction term between district protein level and district wheat production (*PTPROD*), the production weighted average protein level in all other districts in Kansas (*PTOD*), an interaction term between other district's protein level and other district's wheat production (*PTODPROD*), the average protein level in North Dakota (*PTOR*), an interaction term between North Dakota protein level and North Dakota wheat production (*PTORPROD*), and HRW regional cash price.

Following convention, own-district protein level is expected to be negatively correlated with protein premium. The interaction term between district protein content and district production was included to account for the quantity of protein produced in the district. The overall impact on protein premium from an increase in own-district protein level is expected to be negative. Similarly, the overall impact on protein premium from an increase in other district's protein level, and North Dakota protein level is expected to be negative as these two factors are substitutes for protein produced in a specific district. The regional average cash price was included to empirically examine how implicit protein premiums are effected by a change in the cash price. There is no *a priori* expectation for this variable.

Data and Results

Summary statistics of data used in the estimation of factors affecting wheat protein premiums are listed in table 2. There were a total of 207 observations (9 districts over 23 years). Data used for this analysis was collected from various issues of *Kansas Farm Facts* and *Kansas Wheat Quality* published by the Kansas State Board of Agriculture and various issues of *Wheat Situation and Outlook Report* published by USDA.

Model results from the inverse demand model for HRW wheat protein premium specified in equation 5 are listed in table 3. The demand model was estimated using *SHAZAM* 8.0, and the model was estimated using a logarithmic functional form. Therefore, parameter estimates refer to percentage changes in protein premium from a given one percentage change in the explanatory variable. All but two of the variables were statistically significant at the 0.05 level or higher. The chosen explanatory variables explained over 99% of the variability in protein premium.

As expected, an increase in own-district protein level decreased protein premium. However, the interaction term was not statistically significant. The overall impact of an increase in own-district protein level on protein premium was calculated by evaluating the two variables simultaneously at the means, *ceteris paribus*. The calculated impact of a 10% increase in own-district protein level decreased the protein premium by 0.20%/bushel. Using the reported mean value of protein premium reported in the summary statistics table, this would amount to approximately a $0.002/bushel reduction in protein premium per bushel. For a producer who harvested 2000 acres at a yield of 35/bushel/acre, this would amount to a $140 ($0.07/acre) reduction in gross revenue. Thus, this impact would not be considered economically significant.

As expected, an increase in other district's and North Dakota protein level had a statistically significant negative impact on protein premium. To evaluate the economic impact on protein premium the interaction term must be include as well. The calculated impact of a 10% increase in other district's HRW and North Dakota HRS protein level decreased the protein premium by 8.6% and 9.5%, respectively. Using the reported mean protein premium, this would amount to a $0.007/bushel and $0.008/bushel reduction in protein premium per bushel. For a producer who harvested 2000 acres at a yield of 35/bushel/acre, this would amount to a $490 ($0.25/acre) and $560 ($0.28/acre) reduction in gross revenue. Arguably, these impacts could be considered to be economically significant. For instance, for the average district the overall economic impact ranges from $285,000 to $326,000 decrease in gross revenue (reduction in premium multiplied by average district production).

A 10% increase in the regional cash price decreased protein premium by 0.09%. The coefficient was statistically significant. This result suggests that as the cash price of HRW wheat increases the protein premium would fall. Because there is an inverse relationship between protein level and yield and a higher price could be associated with a short-crop year, it may that higher prices are positively correlated with higher protein levels across the region.

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 Kansas Hard Red Winter 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, but simulation of how chosen factors might affect an average Kansas farmer indicated that the economic impact of these factors is questionable. Specifically, own-district protein level was not economically significant; however, an increase in other Kansas district's protein level and the North Dakota Hard Red Spring protein level may have a slight economic impact on own-district protein premium.

The results of this study indicate that new varieties of wheat developed that increase protein content without loss of yield and that are regional specific can impact the price or wheat in other areas. Any cost-benefit analysis evaluating the impact of introducing new wheat varieties should consider this. Future research will add additional variables to the protein demand model specified in this study. Industry structure variables and import/export variables will be evaluated.

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Table 1. Description of Variables Employed in Second-Stage Hedonic Model of Wheat Protein Premiums

Variable	Definition
PTP_{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 ($/bushel).
PT_{it}	Protein level in district *i* at time *t* (%)
$PTPROD_{it}$	Interaction term between wheat production (bushels) and protein level (%) in district *i* at time *t*
$PTOD_{it}$	Production weighted protein level in all other districts except *i* at time *t* (%)
$PTODPROD_{it}$	Interaction term between Kansas wheat production (bushels) and protein level (%) in all other districts except *i* at time *t*
$PTOR_t$	Protein level in North Dakota at time *t* (%)
$PTORPROD_t$	Interaction term between North Dakota wheat production (bushels) and protein level (%) in North Dakota at time *t*
$CASH_t$	Regional cash price paid for Hard Red Winter Wheat at time t ($/bushel)

Table 2. Summary Statistics of Variables used in Second-Stage Hedonic Model of Wheat Protein Premiums

Variable	Average	S.D.	Minimum	Maximum
Protein premium ($/bushel)	0.085	0.006	0.068	0.098
District protein level (%)	12.03	0.762	10.60	14.80
District production (bushels)	40846000	24092000	4578000	104190000
Other district's protein level (%)	12.021	0.719	10.31	13.75
Kansas production (bushels)	367610000	69615000	213600000	472000000
North Dakota protein level (%)	14.757	0.885	13.80	16.50
North Dakota production (bushels)	202320000	69067000	70500000	382200000
HRW regional cash price ($/bushel)	3.958	0.669	2.810	5.690

Table 3. Estimated Coefficients for Double-Log Demand Equation for Hard Red Winter Wheat Protein, 1974-1996, where the Dependent Variable is the value of Protein ($/bushel).

Characteristic	Parameter estimate	t-stat	*p*-valu
Own district protein level	-0.0216***	2.634	0.009
Interaction term between own district protein level and production	0.0003	0.471	0.638
Other district's protein level[a]	-0.7830***	29.310	0.000
Interaction term between other district's protein level and other district's production	-0.0015	1.321	0.188
Other region's protein[b]	-0.8204***	65.780	0.000
Interaction term between other region's protein level and other region's production	0.0014**	2.821	0.005
Hard Red Winter wheat regional cash price	-0.009***	3.371	0.001
Constant	1.7510***	58.410	0.000
R-squared	0.994		
Number of Observations	207		

Note: Double and triple asterisks (*) denote coefficients significantly different from zero at the 0.05 and 0.01 levels, respectively.

[a] Other district's refers to the production weighted average for all other districts than the district being evaluated (nine districts for Kansas).

[b] Other region's refers to the average for North Dakota

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

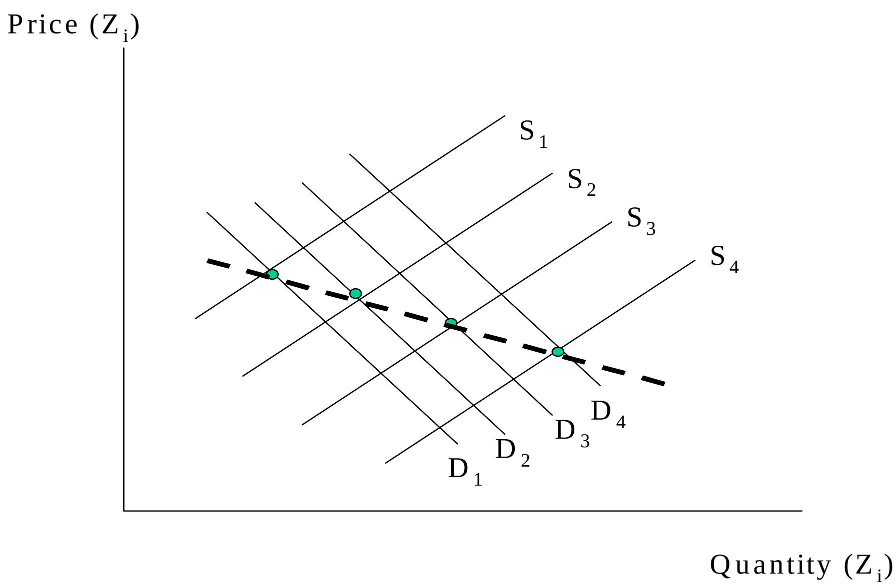

Figure 2. Estimated Protein Marginal Implicit Pricing Schedule from First-Stage Hedonic Pricing Equation Reported by Parcell and Stiegert.