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Japanese Demand for Wheat Protein Quantity and Quality

Kyle Stiegert and Jean-Pierre Blanc

Ladd and Martin's hedonic pricing model is extended to include the interactive effect of noncontracted characteristics on the value of contracted characteristics. Marginal values of wheat protein in the Japanese import market are estimated using the interactive effects of noncontracted dough/flour characteristics typically proxied by protein. Protein value is linked positively to farinograph stability, a prime factor in blending different flours. Three high protein wheats maintained about the same marginal value of protein. The marginal value for the two low protein wheats appear more end-use dependant. They varied in a \$2.00/ton range depending on protein absorption, stability, and extensibility.

Key words: dough characteristics, flour characteristics, hedonics, Japan, wheat protein

Introduction

Wheat is a heterogeneous good. Prices of wheat are determined partly by physical grading characteristics and other contract specifications, which help to meet necessary quality and quantity requirements of intermediate (millers) and end-use (bakers) processors. Grading specifications, such as the percentage of damaged kernels or test weight, provide information about physical wheat quality (soundness characteristics). Grading information is important to wheat millers because it helps them assess the costs, time, and flour yield that can be expected from processing the wheat they purchase. Contracts also specify moisture maximums to ensure the wheat does not spoil or mold.

Millers also need to produce flours that meet high-volume baking specifications for downstream customers. For hard wheats, minimum protein percentages typically are specified, because protein is a good proxy of how wheat will perform in the baking of yeast breads and hard rolls. However, the correlation between higher protein and superior end-use quality also depends on the *quality* of the protein. As we discuss below, protein quality is defined by the relative proportion of two classes of gluten proteins, which can vary across wheat classes and varieties and with growing conditions and producer practices. As a result, the marginal value of wheat protein should reflect its heterogeneous nature.

Since the early 1970s, quality in the export market for wheat has become increasingly more important. Wilson (1989) indicated that "prior to 1973/74, price differentials in international [wheat] markets were relatively small ... Since then, price differentials

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[prices received by exporters] have increased in nearly all [import] markets . . . ” (p. 76). These price differentials reflect importers’ growing interest in wheat characteristics. Changes in international trade law and privatization of state trading agencies in many import markets are likely to intensify the quality dimension of international wheat marketing.¹

A rich literature has emerged regarding quality in international demand for wheat. Blanc provides an up-to-date survey of this material in which four strands of work are identified. The first has looked at the demand for wheat by export origin [recent examples include articles by Wilson (1994) and by Wilson and Gallagher]. These and other studies show that country of origin is important in determining global wheat prices, but leaves open the question of why these differences exist.

A second strand of work has focused on the implicit demand for wheat quality characteristics (Veeman; Wilson 1989; Uri, Hyberg, Mercier, and Lyford; Larue; Ahmadi-Esfahani and Stanmore; Wilson and Preszler 1992, 1993). Although results are somewhat different for each of these studies, wheat protein (and wheat flour protein) emerged as a common and important characteristic in determining international wheat prices. The Larue study showed that the marginal value of protein varies with time and by wheat class. Wilson (1989) agreed that protein value varies with time and showed that it also will vary for different points of origin and destinations. The two papers by Wilson and Preszler suggested that specific importers will look for different wheat quality characteristics and that the quality of indigenous wheats partially determine the residual needs for imported quality. They identify several end-use characteristics as important in affecting the import levels of different wheat classes.

A third strand has addressed the question of exporter reputation about quality in international markets (Larue and Lapan; Pick et al.). Larue showed how the current U.S. marketing system, comprising many trade representatives, can lead rationally to the marketing of lower-quality wheat. It is based on the so-called “free rider” problem. If one firm pays to market a cleaner wheat, all other firms costlessly improve their position through improved national reputation, so it is optimal to wait for a competitor to build a quality-based wheat marketing system. The result is that firms do not work to improve in quality dimensions. Pick et al. completed a survey analysis of international wheat buyers. The results indicated that the reputation of wheat quality is significantly lower for the U.S. than for other suppliers.

A fourth strand of research has examined the feasibility of providing cleaner wheat to international markets (Hyberg et al.; Mercier; Lin and Leath; Johnson and Wilson 1993, 1995). Although results are mixed, cleaning wheat for specific, quality-conscious markets can be economically feasible.

The purpose of the research presented in this article is to estimate the marginal value of wheat protein for Japanese imports. To accomplish this, the theory of input characteristic demand is extended to consider the effect of noncontracted characteristics on determining the marginal value of contracted characteristics. In doing so, we can make

¹ The agreement on agriculture as part of the Uruguay round of GATT is currently being phased in through the year 2001. To comply with the agreement, individual countries must reduce aggregate domestic support to agriculture by at least 20%, shift nontariff barriers to tariff equivalents, and then reduce them by at least 36%, and reduce export subsidy expenditures by at least 36% (Anania). Abbot indicates that dispute settlement structure for WTO violations has shifted from a “flexible process of political bargaining” to a “hard law” structure which depends relatively on a fixed set of rules. Changes as a result of GATT make the use of government export subsidies in price and export market-share competition less viable.

definitive statements about which end-use characteristics are important in defining the value of protein in quality-conscious markets.

This research contributes to an understanding of international wheat markets in several meaningful ways. Japan is the world's largest importer of wheat and is the largest annual importer of U.S. wheat. Japan has advocated for higher wheat quality in international markets (Frey; U.S. Wheat Associates; Caplan and Webb). Caplan and Webb report that Japanese millers "were generally more dissatisfied with the quality of U.S. wheat, compared with Canada and Australia" (p.26). Our research addresses these issues. In addition, the research sheds light on the unanswered questions raised by Blanc's first strand of research about why country of origin is important in determining international wheat prices, and it extends the second strand of work by modeling the unique relationship between end-use characteristics and the value of percent protein levels. Specifically, we show how differing end-use characteristics shift the value of protein for wheats from different origins and by wheat class.

Conceptual Framework

Ladd and Martin extend the Lancaster characteristic demand model to derive the theory of characteristic demand for firm inputs. The underlying assumption is that inputs are useful in a production process because of the characteristics they possess. Therefore, the amount of various intrinsic characteristics that describe the input determine its contribution to the production process. Total output depends on the sum of all characteristics provided by all inputs.

The conceptual framework of this paper begins with a production function for a single-product firm using m inputs containing n characteristics given by:

$$(1) \quad q = F(c, x),$$

where q is quantity of output, F is the production function, c is vector with p elements of contracted quality specifications, and x is an $n-p$ vector of characteristics that are not contracted. Each contracted characteristic is specified in relation to the amount contained in the m inputs according to:

$$(2) \quad c_j = C_j(v_1, v_2, \dots, v_m, c_{j1}, c_{j2}, \dots, c_{jm}), \quad j = 1, 2, \dots, p;$$

where v_i is the quantity of input i , and c_{ji} is the quantity of characteristic j contained in each unit of v_i . Some noncontracted qualities enter the model just as in (2) [simply replace c with x in (2)]. Other contracted qualities can be proxies for noncontracted qualities. For example, wheat protein levels are considered a proxy for various dough/bread characteristics, which may be impractical to specify in wheat contracts. The relationship between these qualities is given by:

$$(3) \quad x_{ki} = f(c_{ji}),$$

where x_{ki} is the amount of noncontracted characteristic k contained in input v_i . Let $q < p$ contracted characteristics be proxies for $s < (n-p)$ noncontracted characteristics. These noncontracted characteristics do not directly explain price; but rather, they explain partially the marginal value of the q contracted characteristics which in turn explains price

in the hedonic model. The $(n-p)-s$ noncontracted characteristics directly explain price. The production function is rewritten as:

$$(4) \quad q = G(v, c, x: x_{ki} = f(c_{ji}) \quad i = 1, 2, \dots, m; j = 1, 2, \dots, q; k = 1, 2, \dots, s),$$

where v is the vector of m inputs, c is a $m \times p$ matrix of the p contracted characteristics in each of the m inputs, and x is a $m \times (n-p)$ matrix of the $n-p$ noncontracted characteristics in each input. The amount of the first q noncontracted characteristics each input contains depends on the amount of the first s contracted characteristics each input contains. The profit equation for the firm is

$$(5) \quad \Pi = p_w G(\cdot) - \sum_{i=1}^m r_i v_i,$$

where p_w is the price of the output, and the r s are input prices. To maximize profits, the first-order condition of (5) with respect to v_i is set to zero and rearranged to give:

$$(6) \quad r_i = p_w \sum_{j=1}^p (\partial G / \partial c_j) (\partial c_j / \partial v_i) + p_w \sum_{h=1}^{n-p-s} (\partial G / \partial x_h) (\partial x_h / \partial v_i) \\ + p_w \sum_{k=1}^s \sum_{d=1}^q (\partial G / \partial x_k) (\partial x_k / \partial c_d) (\partial c_d / \partial v_i).$$

In (6), the items in the first two terms ($p_w \partial G / \partial c_j = \beta_j$ for $j=1, 2, \dots, p$ and $p_w \partial G / \partial x_h = \alpha_h$ for $h=1, 2, \dots, n-p-s$) describe the marginal relationships between the input price and the characteristics. For the contracted characteristics that do not proxy noncontracted characteristics (c_j for $j=q+1, q+2, \dots, p$) and all the noncontracted characteristics in the second term of (6), this marginal relationship has a traditional hedonic interpretation: that being one of a constant marginal price. The last item in both of the first two terms are interpreted as the amount of each characteristic in each unit of input (c_{ji} , x_{hi}). The remaining contracted characteristics (c_j for $j=1, 2, \dots, q$) do not have constant marginal prices, but interact with the first s noncontracted characteristics in the last term. Before interpreting the last term, however, one other substitution becomes necessary. The middle item in the last term represents the relationship between a noncontracted characteristic, x_k , and the contracted one, c_d . Assuming there exists a linear relationship between these characteristics, then we can write

$$(7) \quad \frac{\partial x_k}{\partial c_d} = \lambda \frac{\partial x_k}{\partial v_i},$$

where λ is a conversion constant. The marginal relationship between the noncontracted characteristic, k , on the contracted characteristic is $p_w (\partial G / \partial x_k) \lambda x_{ki} = \alpha_k x_{ki}$. The first-order condition can now be rewritten as:

$$(8) \quad r_i = \sum_{j=1}^p \beta_j c_{ji} + \sum_{h=1}^{n-p-s} \alpha_h x_{hi} + \sum_{k=1}^s \sum_{d=1}^q \alpha_k x_{ki} c_{di}.$$

Note that the last term represents a linear series of interaction terms between the contracted characteristics that act as proxies for noncontracted characteristics. The hedonic price equation for the first q contracted characteristics is then written

$$(9) \quad \frac{\partial r_i}{\partial c_{di}} = \beta_d + \sum_{k=1}^s \alpha_k x_{ki}.$$

The standard errors of the hedonic price equation given in (9) are calculated at each marginal value using the following standard variance equation:

$$(10) \quad \left[\frac{\partial r_i}{\partial c_{di}} \right]_{s.e.} = [y' Ay]^{0.5},$$

where y is the gradient vector of (9), and A is the variance-covariance matrix of the parameter estimates in (9).

The extension of the Ladd and Martin hedonic framework presented in this article imposes a physical linkage between the contracted characteristics and the noncontracted characteristics they proxy. If there is no known relationship between these characteristics, then the conversion constant in (7) is zero, and the term is meaningless. Therefore, building quadratic or other functional forms without regard to known institutional factors is a suspicious and ad hoc hedonic method. When such a physical linkage exists, the marginal value of a contracted characteristic will adjust through time or across sections as noncontracted characteristics vary in quantity. The theory of structural hedonics developed by Rosen implies that nonconstant marginal price gradients will arise only when product characteristics cannot be unbundled. Taken at face value, the ability to blend different wheats, therefore, would negate the need to consider nonconstant marginal prices. However, Rosen's model is built on the premise that individual consumers demand intrinsic characteristic sets supplied to the market free of any exogenous constraints. In any crop year, however, a limited supply of different wheats is available to meet specific quality constraints. Suppose high-protein wheats are in short supply. To ration the relative supply differences, higher marginal values for high-protein wheat are likely to emerge relative to those for low-protein wheat, which implies a nonconstant marginal pricing structure. Nonconstant marginal prices for protein emerge not only from rationing of different wheats, but also because protein is *heterogeneous*. Therefore, as the protein quality varies, so too should its marginal value in the processing and/or pricing of various end-use products.

Data Requirements and Empirical Procedures

The hedonic model described above is used to estimate marginal implicit values of characteristics using wheat import data for Japan. Each shipment of wheat into Japan is tested for physical, milling, and baking qualities by the Japanese Food Agency (JFA) and the Japanese Wheat Flour Institute (JWFI) and reported in the JFA *Quality Survey of Imported Wheat Cargoes*. Because protein was measured at observed moisture contents before 1988 and at different moisture levels for each country of origin after 1988, each protein data point was adjusted to a dry matter basis. Japan releases for research purposes volume-weighted financial year (FY) averages of all quality tests performed. The financial year is from 1 April to 31 March. Because these purchases typically are tendered six to eight weeks in advance, all price data are based on a February to January year (two-month lag from the Japanese FY). Hereafter, these price series are referred to simply as financial year data.

Wheat Prices

The dependent variable (P_j) is the ratio of the price per ton of an imported wheat class and a world wheat price index:

$$(11) \quad P_j = \frac{CF_{zt}}{PBAR_t},$$

where CF_{zt} is the landed price in U.S. dollars per ton for wheat class z in financial year t .² The denominator ($PBAR_t$) is an index of the world wheat price used to deflate each price series to a common year (1992=100) and to adjust for year-to-year quality changes and supply and demand shocks in the world wheat market.³ These data are available from the International Wheat Council. Deflating prices in this way follows conventional practices used in other wheat marketing studies (for example, Ahmadi-Esfahani and Stanmore; Espinosa and Goodwin; Wilson 1989).

Wheat Characteristics

Japan imports several types of hard, soft, and durum wheats. Because of the different end uses for and the resulting demand for protein and other quality factors in soft wheats and durum wheat, we consider only hard wheat. Japan buys Canadian western red spring (CWRS), grade 1, 13.5% and 12.5%; U.S. dark northern spring (DNS), grade 2 or better; U.S. hard red winter (HRW), grade 2 or better, 13%, 11.5%, and ordinary protein (10.5%); Australian standard white (ASW); and Australian prime hard. Because Japan only bought and tested for quality 12.5% CWRS and Australian prime hard in a few of the study years, we confined our analysis to CWRS 13.5%, DNS, HRW 13%, HRW ordinary, and ASW wheats.

All incoming shipments are inspected for specific grading characteristics and also for protein and ash. Because of tight contract specifications, standard grading characteristics such as dockage vary little from year to year and, therefore, are not suitable as explanatory variables.⁴ Other than test weight, these grading characteristics do differ by country of origin, which probably explains part of the observed price premiums and discounts in world wheat prices. Our results are considered in light of these factors.

Ash is a quality variable defined as the inorganic remains after incinerating a specific amount of wheat. It is reported as a percentage of original weight and looked upon as a measure of the quality of wheat kernels and a predictor of flour quality and perhaps flour yield (Bequette). Basically, ash provides a rough estimate of how well the floury endosperm can be separated from undesirable bran. Wheat kernels that are plump and uniform likely will have lower ash quantities and produce higher flour yields. Ash is expected to be related negatively to price.

² CF_{zt} is the price for a commodity or good delivered to its final or agreed upon destination; this price reflects cost of cargo, transportation, and freight.

³ The International Wheat Council wheat price index comprises five hard wheats from the U.S., Canada, and Australia, and two soft wheats from the U.S. There is not a world *hard* wheat price index to replace the price index we chose. Constructing an accurate price series for the Japanese financial year would require monthly price and trade data by class which is not available. Because hard wheats compose a large percentage of the wheat traded globally, any bias caused by soft wheat prices is likely to be small. Espinosa and Goodwin tested a variety of deflators for a hedonic analysis of Kansas wheat quality and reported "nearly identical results" (p. 76) for each one.

⁴ These characteristics include sprout damage, dockage, falling number, test weight, and shrunken and broken kernels, and moisture.

Protein is of importance in this study because it represents the one primary characteristic that best describes end-use performance. Protein is a proxy measure of two groups of proteins in the gluten complex: gliadins and glutenins. Hoseney provides a simple and useful description of their differences. Gliadins constitute a large but homogeneous group of proteins and provide cohesiveness to dough. Isolated, these proteins are sticky and very stretchy and offer almost no resistance to extension. Glutenins are a group of proteins that are rubbery and tough and give dough its strength to resist extension. Together, gluten proteins give dough its viscoelastic property necessary in baking processes.

Hoseney points out that the growing environment has little effect on the relative proportions of these gluten proteins in a wheat kernel. They are determined primarily by the genetics associated with different wheat varieties. On the other hand, the total amount of protein in a wheat kernel is highly dependent on regional growing conditions and to a lesser extent on a wheat's genotype. The point to be made here is that the quantity and quality of protein (as described by the relative proportion of gliadins and glutenins) are dictated partly by weather and farming practices and partly by wheat variety choice and wheat class.

Flour and Dough Characteristics

Flour characteristic data are also collected for each shipment of wheat into Japan. Five flour characteristics are used in this study: color, farinograph absorption, farinograph stability, extensograph resistance, and extensograph extensibility (the ratio of extensograph resistance to extensograph extensibility, called the proportional number, is also used in the analysis). Flour color is an indicator of bran contamination from the milling process, which is linked closely to kernel quality and flour yield (Bequette). Poor flour color can indicate poor grain development and can also be inappropriate for many end-use products. It is measured along a light reflectance scale using a spectrophotometer. Unlike some other color measuring devices, such as the Kent-Jones and Martin measure, high light reflectance on the spectrophotometer refers to the highest quality wheat. Therefore, we expect a positive relationship between color and price. Color is not associated to protein, so it enters the model as a direct, noncontracted variable.

The remaining three characteristics used in this study are measures of dough quality. They are sensitive to the relative proportions of gliadins and glutenins that make up the gluten proteins. In other words, these dough quality measures provide information about wheat protein quality.

Farinograph stability is defined formally as the time interval in which the dough remains at or above the farinograph measure of 500 Brabender units (BU). A longer stability period indicates a stronger tolerance to mixing and greater flexibility in blending operations. The JWFI uses a surrogate measure of dough stability described as weakening degree.⁵ This measures the distance in BU between 500 BU and the farinograph curve 12 minutes after it begins to decline. Pyler describes this as a minute drop test. Higher weakening degree numbers indicate lower dough stability; therefore, we expect a negative relationship to price.

⁵ Japan also performs a valorimeter measure of stability. Although the results were similar in our analysis using this measure for stability, weakening degree was presented because standard errors on other parameter estimates were a little smaller.

Flour absorption is an important measure of baking yields and costs and is somewhat end-use dependent. The test measures how much water is added in a standard farinograph mix to reach optimum dough consistency (500 BU). Finney shows that absorption is highly variable in climate-controlled test plots for different varieties of hard winter wheat. Thus, it may be an important factor in determining which wheat class to purchase year to year given varied weather patterns. For bread baking, high absorption is desirable because it gives lower mix time and higher loaf volume. Caplan and Webb report that Japan buys wheat for bread making based on the absorption characteristic. For Japanese style noodles, lower water absorption is preferred.⁶ The absorption level is a function of not only protein content but also starch damage, which varies according to growing conditions and variety.

Extensogram resistance, extensogram extension, and ratio of these measures (proportional number) are an important measure of dough quality and their interpretation is also end-use specific. Dough is shaped into a cylindrical form and stretched using a hook. The extensogram measures the *resistance* to extension and length of the stretched dough (i.e., *extension*) until it ruptures. Because of requirements in end-use texture and baking performance, Chinese noodle producers will look for high proportional numbers. Although bread bakers look for a wheat or for wheats that are strong as predicted by a high proportional number, wheat can be too strong causing dough to become bucky. Hosenev points out that bucky doughs produce poor quality breads. Producers of Japanese noodles look for wheats with low proportional numbers.

Empirical Procedures

The estimating model is specified following the conceptual framework of (8):

$$(12) \quad P = \gamma_0 + \left(\sum_{i=1}^n \gamma_i BIN_i \right) + (\beta_1 ASH + \beta_2 COLOR + \beta_3 PROT) \\ + (\alpha_1 STAB * PROT + \alpha_2 PROPEN * PROT + \alpha_3 ABS * PROT) + \epsilon,$$

where γ_0 is the intercept term, and ϵ is the error term with the usual properties. Financial data from 1984 to 1992 for five cross sections (45 data points) of imported wheat classes were used in the analysis. All models were estimated in SHAZAM 7.0 using the Parks generalized least squares (GLS) procedure, which assumes cross-sectional heteroskedasticity (with cross-sectional independence) and timewise first-order autocorrelation within each cross section. Because OLS violations of this nature are common in panel data analysis, the Parks procedure has become a fairly conventional estimation approach (for example, Wilson 1989; Veeman; Espinosa and Goodwin). For each model, a statistical test for normality and a Buse R^2 goodness-of-fit measure are reported.⁷ Finally, two nested-hypothesis tests were calculated to examine the question of model selection.

The first model was estimated using only the binary variables (*BIN*) that appear as the first set of terms in (12). We introduce binary variables for Canada (*CWRS*) and Australia

⁶ Throughout the paper, Japanese style noodles refer to a group of salt noodles, which include the "udon" noodle. These noodles are dried in the final processing stage and can have poor texture (i.e., mushy) if too much absorption takes place during rehydration for consumption.

⁷ The dependent variable total sum of squares for the Buse R^2 is calculated using means weighted according to the GLS error covariance structure estimated by the model (SHAZAM). It is the standard goodness-of-fit measure reported by SHAZAM in GLS procedures.

Table 1. Means of the Dependent Variable and of the Wheat Characteristics Used in Constructing Independent Variables by Wheat Classification: 1984–92

Variable	Canadian Western Red Spring	Dark Northern Spring	Hard Red Winter 13.0%	Hard Red Winter Ordinary	Australian Standard White
Dependent variable	204.02	185.46	179.46	169.43	167.62
Protein ^a	16.189	15.861	14.714	12.672	11.099
Ash	1.556	1.567	1.506	1.503	1.272
Color	79.85	79.23	78.92	79.6	81.23
Stability	41.444	33.222	32.889	53.333	71.000
Proportional number	2.611	2.978	3.433	3.933	3.200
Resistance	551.56	636.44	659.33	661.89	511.67
Extension	212.89	213.56	193.78	169.00	161.44
Absorption	62.667	61.156	58.922	58.000	58.089

^a Reported protein means have been adjusted to a dry matter basis.

(ASW), 13% hard red winter (*HRW13*), and hard red winter ordinary (*HRWORD*). Model 2 contains the same binary terms as Model 1 and appends the middle terms that appear in (12). These middle terms include noncontracted flour color, ash, and contracted protein. Model 3 is estimated by appending to Model 2 the three protein quality factors [last set of terms in (12)]. Finally, a fourth model was run that separated the terms in the proportional number ratio.⁸

Results and Discussion

Table 1 presents the means of the dependent variable and the wheat characteristics used in constructing the independent variables. We refer to this table throughout the discussion or our results.

Table 2 presents the results of the analysis. Standard errors appear in parentheses below each parameter estimate. The first regression (Model 1) tests the hypothesis that individual wheat classes are not significant in determining prices. To avoid perfect multicollinearity, a binary term was not included for U.S. dark northern spring (DNS). Therefore, each parameter is in reference to DNS wheat prices. *CWRS* maintains a \$18.75/ton premium over DNS, whereas *ASW* and *HRWORD* ordinary are priced about \$17.00 below DNS. Using the Wald chi-squared test, we tested the hypothesis that wheat classes jointly do not determine price. The hypothesis was soundly rejected. The Buse R^2 indicates that Model 1 explained roughly half of total price variability. The Jarque-Bera test failed to reject the null hypothesis that the errors are normally distributed.

Model 2 maintains the dummy variable structure of Model 1 but also considers the effects of flour color, ash, and wheat protein (protein in dry matter equivalent terms). The dummy variables are now interpreted as mean deviations from DNS prices after

⁸ Four other regressions were performed but not reported in this article. One version was like Model 1, but considered a different binary variable structure in which high protein wheats were grouped. The protein binary term was barely significant. A second regression used this binary variable structure to replace the binary structure in Model 2 of this study. The protein binary term was not significant. The third and fourth models (not presented) contained one and two protein quality terms, respectively, that were analyzed in moving toward Model 3 (i.e., a stepwise approach).

Table 2. Characteristics Demand Results, Japanese Wheat Imports: 1984–92

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	184.91*** (3.518)	-551.50*** (90.96)	-596.32*** (81.87)	-629.27*** (86.06)
Canadian Western Red Spring (CWRS)	18.715*** (4.622)	9.722*** (2.432)	14.611*** (3.122)	8.678** (4.413)
Australian Standard White (ASW)	-17.032** (7.686)	8.354 (11.50)	-3.820 (10.39)	-9.297 (12.97)
Hard Red Winter 13% (HRWB)	-5.438 (4.954)	6.958* (3.756)	3.397 (5.025)	1.232 (5.062)
Hard Red Winter Ordinary (HRWORD)	-17.737** (8.000)	13.282* (7.274)	11.465** (5.834)	6.097 (7.758)
Ash (ASH)		-30.219* (20.13)	-13.108 (20.84)	-7.722 (21.98)
Color (COLOR)		7.774*** (0.987)	9.07*** (0.9287)	9.14*** (0.995)
Protein (PROT)		10.63*** (2.17)	23.515*** (5.756)	23.511*** (7.521)
Stability × Protein (STAB*PROT)			-0.038*** (0.013)	-0.038*** (0.013)
Extensibility × Protein (EXT*PROT)			-1.15*** (0.293)	
Resistance × Protein (RES*PROT)				-0.008*** (0.002)
Extension × Protein (EXT*PROT)				-0.001 (0.013)
Absorption × Protein (ABS*PROT)			-0.222*** (0.084)	-0.172** (0.084)
Buse R^2	0.53	0.87	0.93	0.92
Jarque-Bera normality test $\chi^2_{2,0.05}$ critical value = 5.99	2.08	4.73	4.80	3.96
Wald χ^2 test for wheat class $\chi^2_{4,0.01}$ critical value = 13.277	50.96***	26.47***	56.87***	17.905***
Wald χ^2 test for ash, color, and protein $\chi^2_{3,0.01}$ critical value = 11.345		75.60***	99.23***	85.935***
Wald χ^2 test for protein quality $\chi^2_{3,0.01}$ critical value = 11.345			23.66***	17.625***

Notes: The dependent variable is the CIF annual average price of five classes of imported wheat normalized using the International Wheat Council wheat price index (1992 = 100). Numbers in parentheses contain the standard error of each parameter. The extensibility measure is the ratio of resistance over extension. One, two, and three asterisks indicate statistical significance at 15% level, 5% level, and 1% level, respectively.

accounting for differences in these added characteristics weighted by their least square estimate. For example, the premium of CWRS over DNS is now 9.72. This implies that almost half of the perceived premium of 18.72 (from Model 1) owing only to wheat class differences is actually attributable to important characteristic differences. Except for ASW, each class of wheat remains significantly different from DNS. The joint hypothesis test on wheat classification was rejected, which indicates that the three wheat characteristics in this model do not fully explain price differences between classes. The

Jarque-Bera test failed to reject the null hypothesis that the errors are normally distributed.

Protein (*PROT*) maintains a marginal value of \$10.63 per ton for each percentage of dry matter content. Ash (*ASH*) is statistically significant at the 15% level and color (*COLOR*) is significant at the 1% level. All three wheat characteristics carry the correct sign. *ASW* receives a premium rather than a discount after adjusting for color, ash, and protein. The Wald chi-squared test indicates that the quality characteristics added to Model 2 are important explanatory variables and that Model 2 is superior to the more simple wheat class model (Model 1).

At this stage of the research, our result can be compared with other studies. The marginal value of protein is within the range of other studies of international wheat markets. For example, the Ahmadi-Esfahani and Stanmore study found an \$8.80 premium per 1% increase in dry matter protein content for Australian wheat exports. They also found ash content's effect to be negative and significant, and they showed that lighter colored wheat flour received significantly higher prices. Uri et al. found that 1% increases in protein generated premiums of \$5.64 and \$14.14 per ton for HRW and DNS wheats, respectively. Larue reported a \$5.49 protein premium for wheats classified high protein and \$1.65 protein premium for wheats classified as having medium protein. Veeman found that the marginal value of protein was \$3.34 during the mid-1970s and rose to \$6.00/ton in the early 1980s. Veeman's study results may have understated protein value in hard wheat because soft wheat data were included as part of the analysis. For the Japanese import market, Wilson (1989) identified small but increasing protein premiums for hard wheats from the mid-1970s (\$2.00/ton) to the mid-1980s (\$3.00/ton).

The third regression model carries all the terms shown in (12). It appends to Model 2 the interaction terms between protein and the variables it attempts to proxy. Binary variables *CWRS* and *HRWORD* remain statistically significant while *ASW* and *HRW13* are not significant. The joint hypothesis test for wheat classification is once again rejected which indicates that the wheat characteristics in this model do not fully explain price differences between classes. Color (*COLOR*) and protein (*PROT*) are statistically significant and maintain the correct sign. Ash (*ASH*) content has the correct sign but is no longer significant. The Buse R^2 indicates that 93% of the variation can be explained in the third model. The Jarque-Bera test indicates that the hypothesis of normal errors was not rejected. The nested hypothesis test for adding the three interaction terms suggests this model structure to be superior to the other two models.

If the model has been specified properly, then had the joint hypothesis test of wheat classes not been rejected, we could have concluded that differences in wheat characteristics and baking quality explain fully the different prices paid for different classes of wheat. However, the joint hypothesis for wheat classes was rejected; therefore, we conclude there are factors outside of the model which are explained with wheat class binary terms. As discussed earlier, some quality contract specifications do not vary year to year but do vary by country of origin. For example, Canada and Australia wheat imported into Japan has lower dockage levels than any of the U.S. wheats. Further, Caplan and Webb report that quality variability in U.S. shipments is higher than that of other importers. Canadian and Australian wheat boards negotiate with the Japanese Food Agency on price, while U.S. firms perform this function. This

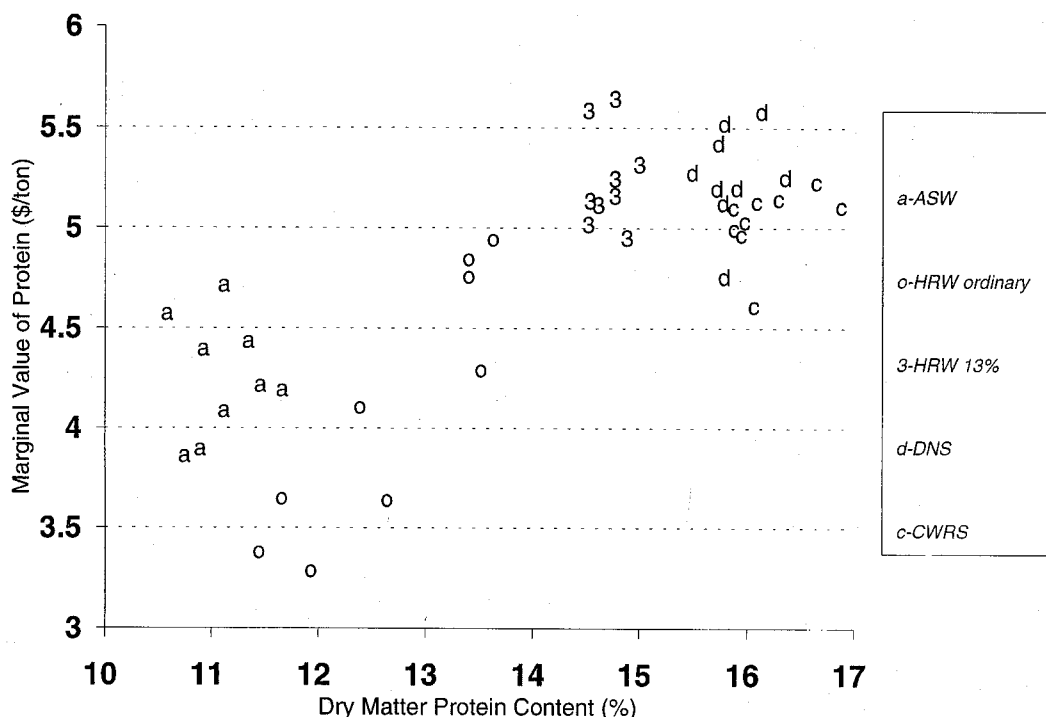


Figure 1. Marginal value of protein, farinograph stability and absorption, and extensibility interaction terms included, Japanese wheat imports: 1984-92

structural difference may have a role in determining prices paid for wheat from each importer.⁹

The protein-baking characteristic interaction terms provide a rather interesting and revealing picture of the protein market for Japanese wheat imports. All three parameters on these terms are statistically significant. Before discussing the results of each baking characteristic, examine first figure 1 which charts the *marginal value* (\$/ton) of protein at each observed level of protein quantity (dry matter basis). Protein levels for *each class* are labeled and tend to congregate together. ASW is the lowest protein wheat in the sample followed by HRW ordinary, HRW 13%, DNS, and CWRS (see table 1 for means). These marginal values are calculated using the hedonic price equation given in (9) and tested for statistical significance using (10). All but four of the protein marginal values points are significant at the 10% level. Although ASW wheat maintains the lowest protein of the sampled wheats, its marginal values are higher than many of the marginal values for HRW ordinary. As we discuss below, this results from superior protein quality for specific end-use demands in Japan and perhaps from other regional and global competitive forces.

The measure of protein stability (*STAB*PROT*) becomes smaller when the dough test indicates more stability. Therefore, the negative coefficient for protein-stability interaction correctly assigns greater value to higher wheat stability. In figure 1, protein marginal

⁹ Japan, for perhaps a number of reasons (political, tradition, efficiency), purchases about the same percentage of wheat from each customer each year (see Caplan and Webb for a discussion). With the limited ability of each importer to affect quantities, structural differences between the way a wheat board and a private firm negotiate price may also be a reason country of origin is important.

values for HRW ordinary wheat trends upward from about \$3.25/ton to \$5.00/ton. This trend is produced primarily because of improving dough stability as dry matter protein increased. For the higher protein wheats, dough stability did not improve with higher protein and even declined some for CWRS (table 1).

ASW wheat has high stability numbers (table 1); therefore, this is *not* the source of superior quality over HRW ordinary that we mentioned earlier in reference to figure 1. A key finding in the study is, however, that dough stability has a major role in shaping the marginal value of protein across hard wheats.

The water absorption measure increases as more water is taken into a standard dough. The negative parameter value ($ABS*PROT$), therefore, lowers the marginal value of protein when higher absorption is observed. For low protein wheats (ASW and HRW ordinary), this is generally consistent with their end use. Low absorption is a desired characteristic in processing Japanese style noodles, which are dried in the latter stages of processing. Low absorption is also important at the consumer preparation stage, because it prevents the noodle from becoming mushy. In bread production, water can be considered a free input, so higher absorption is usually desired. Our results do not suggest that the increasing absorption in wheats used in bread production (CWRS, DNS, HRW 13%) translated into higher marginal values for protein. Apparently, the premium price for CWRS and DNS could not be linked with this particular feature of these classes of wheat. Because the absorption data did not vary much compared with the stability data, it had a smaller impact in shaping the marginal value of protein as shown in figure 1.

The measure of protein extensibility (proportional number=dough resistance/extension) is positively related to the flexibility and strength of the dough. Therefore, the negative parameter ($PROPN*PROT$) assigned the greatest value to low proportional numbers. For ASW wheat, the mean for proportional number was not the lowest of all classes (table 1); however, it was considerably lower than that of HRW ordinary. *This is the reason that the marginal value of ASW protein is higher than that for HRW ordinary.* As we discussed earlier, processors of Japanese style noodles look for a low proportional number and ASW provides this characteristic. A key finding in the study is that, in order to obtain quality in Japanese style noodles, Japanese wheat importers are willing to pay for protein with low absorption and low proportional numbers.

Wheat breeders need to consider these factors in development and release decisions. State sponsored breeding programs such as the one at Kansas State University often set objectives for releasing varieties that meet the needs of nearby customers. Because bread products dominate this customer base for Kansas, there is a strong tendency for the breeding program to focus on bread milling and baking characteristics which would value higher, not lower, absorption and proportional number levels. For growing regions in which "high protein" varieties do not perform well (i.e., poor yields, disease tolerance, or low protein content), having varieties that maintain low absorption in lower protein ranges are likely to generate additional returns to producers and/or grain handlers marketing into regions that produce dry (i.e., Japanese style) noodles.

The proportional number is a ratio of dough resistance over its extension in a standardized test. As table 1 shows, the mean values of these ratio components are quite varied. To gain a better understanding of protein quality, a fourth model is presented which breaks out these ratio components into individual protein interaction terms. The results of Model 4 are quite similar to Model 3. None of the joint hypothesis test results from the previous models changed. Further, the results for protein, protein interaction

with the stability measure, and protein interaction with the absorption measure are nearly identical to Model 3. When the proportional number is broken out, we can see that resistance ($RES*PROT$) is statistically significant while extension ($EXT*PROT$) is not. Although not shown, the marginal protein values across protein quantities are close to those shown in figure 1.

The results suggest that Japan seeks a wheat for bread baking that is not too high in the resistance measure. Conventionally, we attribute high resistance with producing strong doughs that are good in bread baking. However, too much resistance is not always desirable and can lead to doughs that are bucky. Based on the means presented in table 1, CWRS followed by DNS produces the dough extension characteristics most ideally suited to increase the marginal value of its protein content.

Summary and Conclusions

Over the past 25 years, international wheat marketing has evolved from a simple structure in which wheat was viewed as a largely homogeneous good to a market that is very price conscious with respect to intrinsic wheat qualities as they define end-use performance. Previous research indicates that significant price differentials exist for wheat from different origins and suggests that these differences could be caused by standard grading characteristics and also the quantity of wheat protein. However, no study had addressed the question of protein quality in international or domestic markets. This study analyzed the demand for wheat and protein quality using annual Japanese import data on five wheat classes from the three major exporting nations: U.S., Canada, and Australia.

The marginal value of wheat protein is linked significantly to dough stability, extensibility, and absorption. The predominant link is a positive association between protein value and dough stability. As a result, the marginal value of higher protein wheats were generally above the marginal values for lower protein wheats. Marginal values of high protein wheats (DNS, HRW 13%, and CWRS) tended to be fairly constant in the \$4.75–\$5.75/ton for each percentage increase in protein content. Thus, one conclusion of the study is that increasing the protein content in higher protein wheats has led to constant flat marginal protein pricing. This result generally supports the model and conclusions obtained by Larue for wheats he classified as high protein.

Our results indicate that, for lower protein wheats destined for Japanese style noodle production, low extensibility (measured by proportional number, which is a measure of dough strength) and low water absorption raised their marginal value of protein. This is especially true for ASW wheat which has a considerably lower proportional number. The result suggests that varieties grown in regions where high protein is difficult to achieve, wheat breeders and producers should consider making selections that lead to low levels of water absorption and proportional numbers in flour tests.

The price/quality relationship that defines the Japanese market did not evolve in a vacuum but, rather, is defined in a reasonably competitive Pacific Rim region. If data were available, one is likely to find more similarities than differences across Pacific Rim countries in the way marginal protein values are defined. Therefore, the issue is not just Japan. Marketing wheat at the highest possible prices and volumes may depend critically on developing the quality characteristics these countries desire. As privatization takes hold in the global wheat marketing system, profit-seeking firms will not have current

political allegiances or incentives to purchase wheat from any particular source. They will simply choose importers that provide the best quality at the lowest prices. Therefore, the challenge facing the U.S. wheat breeding and marketing system is to find efficient ways to compete in quantity and quality terms. A considerable research effort has shown that there are situations in which the benefits from providing clean wheat outweigh the costs in several regions worldwide. As the analysis in this article indicates, there are benefits to be derived in producing and internationally marketing wheat based on end-use characteristics.

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