Journal of Agricultural and Applied Economics, 41,3(December 2009):599–611

Willingness-to-Pay for Attribute Level and Variability: The Case of Mexican Millers' Demand for Hard Red Winter Wheat

R. Karina Gallardo, Jayson L. Lusk, Rodney B. Holcomb, and Patricia Rayas-Duarte

In-person interviews were carried out with Mexican millers who were administered a conjoint-type survey designed to incorporate uncertainty in attribute levels. Two methods were used to model millers' risk preferences: a modified mean-variance approach and an explicit expected utility approach. Controlling for variability, Mexican millers are willing to pay premiums for increases in quality factors such as test weight, protein content, falling number, and dough strength/extensibility. We find millers are not particularly sensitive to changes in the variability of quality characteristics. Out-of-sample forecasts suggest the mean-variance model provides an accurate depiction of actual Mexican imports.

Key Words: mean-variance, Mexican wheat market, moment generating function, preference elicitation, wheat quality

JEL Classifications: C35, C42, Q13

International wheat markets are becoming more competitive and increased attention has focused on quality related issues. Such changes are mainly attributable to the privatization of the buying process in importing countries, industry consolidation, technology advances in wheat production and milling, and increased end-user sophistication (Oades, 2005; Wilson and Dahl, 2008). The conceptualization of "quality" is also evolving as increasing attention is given to wheat physical characteristics *and* functionality quality parameters, i.e., flour dough strength (farinograph stability). Currently, U.S. grain quality grades and standards, as established by the Federal Grain Inspection System (FGIS) (U.S. Department of Agriculture, Grain Inspection, Packers and Stockyard Administration, 2007), do not include an assessment of milling and baking quality characteristics deemed important to millers and bakers.

Millers' concerns about quality relate not just to wheat quality characteristics, but to the variability in the quality of inputs. In presence of wheat quality inconsistency, milling machinery might not run continuously and the

R. Karina Gallardo, assistant professor and extension economist, School of Economic Sciences – Tree Fruit Research Extension Center, Washington State University, Wenatchee, WA. Jayson L. Lusk, professor and Willard Sparks Endowed Chair, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK. Rodney B. Holcomb, professor and Browning Endowed Chair of Food Science, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK. Patricia Rayas-Duarte, professor, Department of Biochemistry and Molecular Biology, Oklahoma State University, Stillwater, OK.

The authors acknowledge and appreciate the collaboration of Jose Luis Fuente, Executive President of the National Milling Industry Association in Mexico (CANIMOLT), and the milling companies' representatives in Mexico who agreed to participate in this study. We also thank the editor and two anonymous reviewers for their comments.

finished product might not have the desired characteristics. In most cases, millers adjust their production processes to conform to the quality of inputs, and each adjustment represents increased costs associated with possible interruptions in the milling process, increased wheat inventories, extra wheat mixing during processing, and decreased milling by-products (Atwell, 2001; Dahl and Wilson, 1999; Wilson and Dahl, 2008). These adjustment costs are likely higher for modern high-speed flour mills given their bigger production batches and more continuous processing than smaller mills (Peterson et al., 1998).

Wheat quality inconsistency both between and within shipments is attributed to differences in genetic varieties, handling and grading practices, and growing-environmental conditions (Dahl and Wilson, 1998; Wilson and Dahl, 2008). The United States has no legally binding procedures for controlling wheat variety release. State Agricultural Experiment Stations and Experiment Station Committees provide guidance and recommendations *only.* Moreover, variety release policies and criteria vary across states and are influenced primarily by demands and needs of farmers (Mercier, 1993; U.S. Congress, Office of Technology Assessment, 1989). As a result, numerous wheat varieties coexist in the market, each one with different agronomic and end-use characteristics. Besides adding to the consistency problem, these differences lead to a disparity between wheat varieties with agronomic characteristics most valued by farmers and flour processing companies' requirements, which are varieties with suitable end-use quality characteristics.

Another practice affecting quality uniformity is blending.[1] It is controversial whether blending has a positive or negative impact on the final grain quality and consistency. A positive impact associated with blending lots with different end-use quality might not be fully reflected if premiums and discounts are not sensitive to end-use quality, and might imply further adjustment of milling processes (U.S. Congress, Office of Technology Assessment, 1989). Overall, wheat producers and handlers have some ability to control quality, as some procurement strategies (i.e., specifying varieties, targeting locations, identity preservation, and limiting functional characteristics) were put in place to mitigate the lack of uniformity. However, it is currently unknown whether the value of reducing variability exceeds the costs of changing production management and handling practices (Wilson and Dahl, 2008).

This article focuses on the preferences of a major U.S. wheat client, Mexico. As of 2007, Mexico was the third largest importer for U.S. wheat behind Egypt and Japan. From 1996–1997 to 2005–2006, Mexico accounted for 31% of all U.S. wheat sold to Latin America, and on average, 64% of this wheat was hard red winter wheat (U.S. Department of Agriculture, Economic Research Service, 2007). However, the U.S. competitiveness in Mexico is at risk. Overall U.S. wheat quality consistency is viewed as inferior when compared with Canadian wheat, the major U.S. competitor in the Mexican market.[2] Concerns are centered on quality variability between and within shipments, and the U.S. supply capability of meeting the level of protein and other quality characteristics that buyers prefer (Selected Mexican Milling Companies Representatives, 2007).

The objectives of this research are twofold. First, using a choice experiment, we seek to identify the value that Mexican millers place on the level and variability of selected hard red winter wheat attributes. The choice experiment is a popular methodology in marketing and economic research (see Louviere, Hensher, and Swait, 2000), and the choices made by millers allow us to estimate the parameters of an attribute-based random utility function of the

[1] Blending is the mixing of one or two grain lots. In principle, the main reason for blending is to achieve better quality or greater uniformity.

[2] Mercier (1993) conducted a survey with selected importing countries and their findings were similar to comments made by Mexican millers when interviewed in 2007 (Selected Mexican Milling Companies Representatives, 2007). Whether or not there is a substantial basis to affirm that U.S. quality is in fact inferior or that quality protocols indicate something different, Mexican millers still perceived that Canadian wheat quality is superior in terms of protein content and uniformity.

type popularized by McFadden (1974). In this study, we conceptualize that millers' utility is a function of wheat quality attributes and quality variability. Second, we compare two different utility modeling for characterizing Mexican millers' preferences for wheat quality attributes.

Background

Numerous studies have been conducted to assess the role of quality, consistency, and end-use (baking) characteristics in international markets. Review of previous studies is organized according to the location in the value chain. Premiums and discounts at the farm level were studied by Parcell and Stiegert (1998). They analyzed Kansas and North Dakota wheat markets, and found that implicit values for quality characteristics in one region were affected by quality characteristics of wheat grown in the other region. They found a $0.218/bushel premium for hard red winter wheat protein. Considering that premiums for specific quality attributes might be affected by the production-weighted values of the same attribute in other districts in the same state, authors estimated intraregional effects. They also estimated the effect on premiums of the value of a wheat attribute in a different state and this was called interregional effect. Protein marginal value considering intraregional effects was −$0.006/bushel, and considering interregional effects was −$0.004/bushel.

Export level premiums and discounts were studied by Veeman (1987), Wilson (1989), Larue (1991), Uri et al. (1994), and Ahmadi-Esfahani and Stanmore (1994). Veeman (1987) found that there was a $6/metric tons (MT) premium for a 1% increase in protein content in world prices for the period 1976–1984. Wilson (1989) determined that protein implicit values varied according to origin and destination location. They found that the premium for a 1% increase in wheat protein content was $3.13/MT in a Japanese port, $21/MT in Holland, and $8.18/MT at the U.S. Pacific port on freight on board basis. Larue (1991) concluded that wheat purchased for different uses should be considered as different products, as implicit values for quality characteristics varied according to end-use. For high-protein wheat, there was a $5.49/MT premium for a 1% increase in protein content, for medium-protein a $1.65/MT premium, and for low-protein a $6.42/MT premium. Uri et al. (1994) focused on individual wheat export transactions rather than on an aggregated basis and found that implicit values for quality characteristics changed over time with no uniform pattern and were different across wheat types: the protein premium for hard red winter wheat was $5.64/MT, for hard red spring $14.14/MT, and for soft white wheat $6.64/MT. Ahmadi-Esfahani and Stanmore (1994) estimated the implicit values of protein in Australian wheat and found that there was an $8.18/MT premium for each additional percent of wheat grain protein and a $5.34/MT for additional percent of flour protein.

These studies have estimated the effect of FGIS grades and other physical attributes (mainly protein content) on prices across time and in different markets. Only a few studies have included end-use performance characteristics in their models. Espinosa and Goodwin (1991) studied premiums and discounts at the farm level for milling and dough characteristics. They found a $0.0017/bushel premium for a percentage increase in the farinograph water absorption lecture, a −$0.16/bushel discount for a percentage increase in the dough mixing time, and a $0.019/bushel premium for a percentage increase in the farinograph stability value. Stiegert and Blanc (1997) used an extension of the hedonic pricing model to analyze Japanese import demand for wheat protein. They identified a $4.75–$5.75 premium for a marginal change in protein content, and concluded that the role of protein in dough stability, extensibility, and absorption resulted in the different values for wheat for different product end-uses.

Given the importance of quality consistency, especially in U.S. export markets, several papers have focused on quality variability. Wilson and Preszler (1992) analyzed demand for wheat considering end-use functionality characteristics and found that excessive variability in wheat quality led to higher flour processing costs. They used the input characteristic model, and treated quality as stochastic, with each wheat attribute described by a probability distribution. The objective was to minimize the cost of producing flour using five different wheat types. Results suggested a positive relationship between attribute variability and costs (i.e., an increase in the farinograph water absorption variance from 9.24 to 10.24 implied a \$0.64 increase in cost). Dahl and Wilson (1999) studied the effect of hard red spring wheat consistency on milling value. Probability distributions for each quality characteristic were used in a Monte Carlo simulation. The simulation measured the milling value of wheat in three different ways: net wheat price, millable wheat index, and value added in milling. Results suggested that the reduction of moisture variability had the greatest effect on milling value and reduction in foreign material, shrunken and broken kernels, and dockage variability had a smaller effect.

In this article, we move beyond previous literature by directly eliciting milling companies' preferences for wheat characteristics, both level and variability, by using an innovative combination of conjoint analysis, in which variability in attribute levels is explicitly introduced, and the random utility model modified to incorporate risk preferences. Previous research has relied on the use of historical, time series data to investigate wheat quality and quality variability.[3] One advantage of such an approach is that the data represent actual transactions made in real markets. A disadvantage, however, is that analyses based on time-series data can suffer from endogeneity and identification problems, measurement error, and omitted variable bias. These difficulties can be overcome by using survey-based methods where variables of interest are explicitly defined and are exogenously varied according to a predefined experimental design that ensures causality can be identified. This is not to say that our stated-preference survey method is *the* best approach for studying these issues, but as has been recognized in the environmental economics and marketing literatures, much can be learned by studying revealed *and* stated preferences.

Conceptual Framework

To elicit milling companies' preferences, we rely on the random utility framework. A miller's utility is assumed to consist of a systematic component and a random component:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

where U_{ij} is the utility derived from the j^{th} wheat alternative by the i^{th} miller, V_{ij} is the systematic component, which is a function of the attributes of wheat alternative j, and ε_{ij} is a random component, which accounts for all factors influencing an individual preference that cannot be observed. We assume that consumers choose the alternative that yields the highest utility.

A departure from typical random utility models is that we assume uncertainty exists in one or more attributes, making V_{ij} stochastic. One way to model consumer preferences for uncertainty is the mean-variance approach. This framework assumes people evaluate outcomes based on the mean attribute level and its variance—the first two moments of the probability distribution. The assumption of mean-variance preferences produces a simple functional form for the utility function, V_{ij}, which is linear in parameters. In particular, assuming wheat option j can be characterized by K non-price attributes, each of which is independently distributed, mean-variance preferences imply:

$$V_{ij} = \alpha_j + \sum_{k=1}^{K} \beta_k mean_{ijk} + \sum_{k=1}^{K} \phi_k \mathrm{var}_{ijk} + \gamma Price_j \tag{2}$$

where α_j is an alternative-specific constant, $mean_{ijk}$ represents the expected value of attribute k (as will be discussed later attributes are factors like: test weight, protein, falling number, farinograph stability, alveograph P/L ratio, and kernel diameter), var_{ijk} is the variance of each quality attribute, $Price_j$ is the price of alternative j, β_k is a parameter related to the marginal utility of the expected value of attribute k, φ_k is a parameter characterizing people's preferences for risk in attribute k, and γ is a parameter

[3] One exception is the study by Pick et al. (1994) that used primary data. Their study focused on buyers' perceptions of the importance of a quality characteristic in Mercier (1993) and their suppliers' ability to provide that quality characteristic.

representing the marginal utility of price, which is expected to be negative.

Although the mean-variance approach is relatively easy to implement and the associated parameters can be estimated using standard statistical software packages, the assumptions underlying the model may not be valid. The mean-variance approach is consistent with expected utility theory assuming: (1) the decision maker's utility function is quadratic in the attribute, (2) the random attribute is normally distributed, and (3) the utility function is a monotonic linear function of a single random variable (Hanson and Ladd, 1991; Liu, 2003). However, Collins and Gbur (1991) note that these assumptions are often violated. For example, the quadratic utility function violates the nonsatiation axiom and continuously increasing risk aversion is often implausible. Furthermore, the assumption of normally distributed attributes can be violated. For example, in our survey context, it is much easier to describe a uniformly distributed attribute to survey participants than a normally distributed attribute.

To complement the results obtained from the mean-variance model, we also estimated choice preferences by using an explicit expected utility specification where the decision maker's utility of each attribute is assumed to take a negative exponential functional form and where, consistent with our empirical approach, the attributes are uniformly distributed. In particular, for each attribute k, we assume individuals evaluate the attribute according to the familiar negative exponential utility form: $u_k = -e^{-r_k x_k}$, where x_k represents the level of attribute k, and where r_k captures preferences toward risk for attribute k. In particular, r_k represents the Arrow-Pratt coefficient of absolute risk aversion, where $r_k > 0$ implies risk aversion for attribute k, $r_k = 0$ implies risk neutrality, and $r_k < 0$ implies risk seeking in attribute k. In general, the expected utility from attribute k can be written as:

$$(3) \qquad E[u_k(x_k)] = \int_{-\infty}^{+\infty} u_k(x_k) g_k(x_k) dx_k,$$

where $g_k\,(x_k)$ is the probability density function describing the randomness in x_k. Now if we assume that x_k is uniformly distributed on the interval $[a_k, b_k]$ and that the person's utility for attribute k can be described by the negative exponential form, Equation (3) can be rewritten as:

$$(4) \qquad E[u_k(x_k)] = \int_{a_k}^{b_k} -\frac{e^{(-r_k x_k)}}{b_k - a_k} dx_k.$$

Evaluating the integral in Equation (4) yields:[4]

$$(5) \qquad E[u_k(x_k)] = -\frac{e^{-r_k a_k} - e^{-r_k b_k}}{r_k(b_k - a_k)}.$$

Because each of the attributes in our study was designed to be independently distributed, miller i's utility for wheat option j is additively separable in the expected utility of each of the k random attributes. In particular, the systematic portion of the utility function is:

$$(6) \qquad V_{ij} = \alpha_j + \sum_{k=1}^{K} \lambda_k \left(-\frac{e^{r_k a_k} - e^{r_k b_k}}{r_k(b_k - a_k)} \right) + \gamma Price_j$$

where λ_k, is a parameter related to the marginal expected utility of attribute k, and all other variables and parameters are previously defined.

Regardless of whether Equation (2) or Equation (6) characterizes the systematic portion of the utility function, it is assumed that miller i chooses the option j, out of a subject of J total options that is most desirable. The probability that option j is chosen over all competing options is the probability that $V_{ij} + \varepsilon_{ij} > V_{iq} + \varepsilon_{iq}\ \forall\ q \neq j$. If the error terms, ε_{ij}, are distributed type I extreme value, then Louviere, Hensher, and Swait (2000) showed that the probability option j being chosen out of J total alternatives is:

$$(7) \qquad P_{ij} = \frac{e^{V_{ij}}}{\sum_{q=1}^{J} e^{V_{iq}}}$$

Equation (7) describes the familiar multinomial logit model. For the mean-variance preferences case, Equation (2) is substituted into Equation

[4] Our approach is equivalent to that followed by Yassour, Zilberman, and Rausser (1981) who illustrate the expected utility of wealth assuming a negative exponential utility function and the moment generating function for a variable following any distribution.

(7). In the case of the specification assuming negative exponential preferences with uniformly distributed attributes, Equation (6) is substituted into (7). With either approach, the parameters of the model are obtained by maximum likelihood estimation. In particular, the parameters are chosen to maximize:

$$\sum_{i=1}^{N}\sum_{j=1}^{J} y_{ij}\ln(P_{ij}) \tag{8}$$

where y_{ij} equals 1 if individual i chose option j and zero otherwise.

Methods

An in-person survey was administered to major wheat milling companies in Mexico in January and February 2007. With the assistance of CANIMOLT, the Mexican Milling Industry Association, 14 milling companies were contacted and surveyed. These companies were representative of the entire Mexican Republic, as they were located in the state of Mexico, Guanajuato, Guadalajara, Monterrey, and Sonora. The milling capacity of the 14 companies in our sample is 17,577 MT/day and the total milling capacity in all of Mexico is 24,848 MT/day (Fuente, 2007). Hence, our respondents represent 71% of the total Mexican wheat milling capacity and represent 80% of all the wheat imported into Mexico from the United States.[5] Thus, although the sample size is somewhat small in terms of the number of respondents, the measured preferences are responsible for the vast majority of U.S. wheat imports. To ensure high-quality, reliable responses, personal interviews were conducted with either the purchasing manager or the quality control chief for each of the 14 companies.

[5] Our argument concurs with McCloskey (1985) who stated that large samples would not always lead to the soundest results; mostly they will be reflected in the significance of the estimates. Statistically significant does not mean substantively or economically significant, and the overuse of statistical tests of significance and its misinterpretation might lead to inaccurate conclusions.

Survey Design

Previous literature and experts in wheat milling were consulted to identify the wheat quality attributes to include in this study. The selected attributes were test weight, protein content, falling number, farinograph stability, dough extensibility/resistance ratio (P/L) ratio, and kernel diameter. Each of the attributes is described briefly.

Test weight is defined by the U.S. Department of Agriculture, Grain Inspection, Packers and Stockyard Administration (2007) as the weight per Winchester bushel or 2,150.42 cubic inches; it is an indicator for wheat kernel density and flour yield. A positive sign for test weight is expected. Protein content, measured at a 12% moisture basis, is an indicator of end-use functionality and is given by the gluten protein. The desirability for functionality characteristics depends on the final product to be baked. For example, hard wheat gluten with good gas-holding properties is preferred for bread, whereas soft wheat gluten has better functionality for crackers, cakes, or cookies. Gluten functionality is given by the proportion of its two main components: gliadin and glutenin. When mixed with water, gliadin adds extensibility properties and glutenin adds resistance, providing the cohesiveness required to form the dough. This cohesiveness allows the product to rise before baking. A positive sign for protein content is expected. The relation between extensibility and resistance is given by the P/L ratio parameter also included in the survey. For yeasted breads, the optimal value for P/L is one, hence the smaller the difference from one the better (Atwell, 2001).

Falling number is the measure of enzyme activity and is an indicator of wheat soundness or sprouting absence. Low values of α-amylase imply sprout-damaged wheat and can be corrected by adding extra enzyme during milling which represents an extra cost, whereas extreme high values for falling number are detrimental to the dough handling properties and breadcrumb texture. Considering the falling number values included in the survey, a positive sign is expected. Farinograph stability is a measure of dough strength; according to

Stiegert and Blanc (1997, p. 110), it is "the time interval in which the dough remains at or above the farinograph measure of 500 Brabender units." In general, longer stability values imply that the flour is more tolerant to over-mixing (i.e., better bread-making characteristics). However, extremely high values represent extremely strong dough implying "poor machining properties." Considering the stability values included in the survey, a positive sign is expected (Atwell, 2001; Espinosa and Goodwin, 1991).

Kernel diameter is the measure in millimeters of wheat kernels at their widest point, and is an indicator of flour extraction. A larger kernel diameter leads to greater endosperm content, hence flour extraction is higher. Millers prefer a larger kernel diameter; however they express a greater concern for the consistency of the kernel size. The milling process can be adjusted for either big or small wheat kernels; repeated adjustments require extra time and costs (Lyford and Starbird, 2000). A positive sign for kernel diameter is expected.

Given these quality characteristics, we faced the task of deciding how to create a variety of possible wheat options that differed according to each of the six quality attributes with the intention that millers would indicate which option was most desirable. Most conjoint analysis of this sort simply varies each attribute across several different levels, but because concerns for consistency were of importance in this analysis, we had to vary the *distribution* of each attribute. For each attribute, k, we

Table 1. Wheat Quality Attributes and Attribute Mean and Standard Deviation in the Survey

Quality Attributes	Mean	Standard Deviation	Range		
1. Test weight (kg/hl)	78.000	0.289	77.500	–	78.500
		0.866	76.500	–	79.500
	80.000	0.289	79.500	–	80.500
		0.866	78.500	–	81.500
2. Protein (%)	11.000	0.289	10.500	–	11.500
		0.866	9.500	–	12.500
	13.000	0.289	12.500	–	13.500
		0.866	11.500	–	14.500
3. Falling number (sec)	300.000	8.660	285.000	–	315.000
		25.981	255.000	–	345.000
	400.000	8.660	385.000	–	415.000
		25.981	355.000	–	445.000
4. Farinograph stability (min)	9.000	0.577	8.000	–	10.000
		1.732	6.000	–	12.000
	13.000	0.577	12.000	–	14.000
		1.732	10.000	–	16.000
5. P/L ratio	0.850	0.029	0.800	–	0.900
		0.115	0.650	–	1.050
	1.100	0.029	1.050	–	1.150
		0.115	0.900	–	1.300
6. Kernel diameter (mm)	2.000	0.029	1.950	–	2.050
		0.173	1.700	–	2.300
	2.300	0.029	2.250	–	2.350
		0.173	2.000	–	2.600
7. Price ($/MT)	170.000				
	180.000				

specified a uniform distribution defined on the interval $[a_k, b_k]$. For each attribute, we wished to vary both the mean and the variability independently so that the effects of both could be identified. As such, four possible distributions were created for each attribute: high variability/high mean, high variability/low mean, low variability/high mean, and low variability/low mean. These variability/mean levels were chosen for each attribute simply by varying the bounds, a_k, b_k, on the uniform distribution.

Thus, there are six attributes, each varied at four levels. Table 1 shows the different levels of each attribute. Added to this was a price attribute, varied at two levels ($170/MT or $180/MT). This means there are $4^6 \times 2 = 8{,}192$ possible wheat descriptions that could be created. This, of course, is far too many combinations for any survey respondent to reasonably evaluate. As such, a main-effects fractional factorial design was used to select 32 different combinations, which were paired to create choice options. It was further felt that 32 choice questions might be too lengthy for the respondent, so two survey versions were created, each with 16 choices.

Before personally administering the survey, a cover letter was sent to explain the study. The cover letter informed respondents about the purposes of the study and ensured confidentiality of responses. In the letter, the mill's quality control chief, purchasing agent, or equivalent was asked to meet with the authors to complete the survey. Each survey contained 16 choice questions, and in each choice question there were three alternatives (two wheat options and a third, "I wouldn't choose either of these options"). An example of a survey question is shown in Figure 1.

Results

Multinomial Logit Parameter Estimates

Table 2 reports parameter estimates from the multinomial logit following the mean-variance and negative exponential models. As of the mean-variance estimates, increases in the mean levels of test weight, protein, falling number, farinograph stability, and P/L ratio significantly increased Mexican millers' utility. Changes in

Features	Option A	Option B	Option C
1) Test weight minimum (kg/hl)	78	78	I would NOT choose any of the alternatives presented
Test weight values within the range:	77.5-78.5	76.5-79.5	
2) Wheat protein 12% (%)	11	13	
Wheat protein values within the range:	10.5-11.5	12.5-13.5	
3) Falling number minimum 14% (sec)	400	400	
Falling number values within the range:	385-415	355-445	
4) Farinograph stability minimum (min)	9	9	
Farinograph stability values within the range:	8-10	6-12	
5) Alveograph P/L ratio	1.1	0.85	
Alveograph P/L ratio values within the range:	1.05-1.15	0.8-0.9	
6) Kernel diameter (mm)	2.3	2.3	
Kernel diameter values within the range:	2.0-2.6	2.25-2.35	
7) Price ($/MT)	170	180	
I would choose*			

* If you choose option C please indicate why: ____________

Figure 1. Example of a Survey Question

Table 2. Multinomial Logit Estimates

Attribute	Parameter Estimates: Mean-Variance	Parameter Estimates: Negative Exponential
Intercept (Option A)	−43.592* (10.700)[a]	
Intercept (Option B)	−43.549* (10.708)	
Intercept (Option A and B)		79.813* (35.554)
Price ($/MT)	−0.027 (0.023)	−4.595* (0.279)
Test weight (kg/hl)	0.403* (0.113)	84.657* (30.334)
Protein 12% moisture base (%)	0.617* (0.118)	42.375* (15.954)
Falling number 12% moisture base (%)	0.006* (0.002)	394.395 (862.577)
Farinograph stability (min)	0.282* (0.057)	11.424* (1.109)
P/L ratio	1.930* (0.934)	15.007 (74.390)
Kernel diameter (mm)	1.264 (0.816)	84.788 (140.833)
Test weight standard deviation[b]/risk aversion coefficient[c]	0.386 (0.379)	0.807 (1.776)
Protein standard deviation/risk aversion coefficient	−0.091 (0.433)	0.215 (0.212)
Falling number standard deviation/risk aversion coefficient	−0.011 (0.014)	7.587* (3.406)
Farinograph stability standard deviation/risk aversion coefficient	−0.242 (0.216)	2.111 (17.327)
P/L ratio standard deviation/risk aversion coefficient	−1.469 (2.742)	3.302* (1.727)
Kernel diameter standard deviation/risk aversion coefficient	−0.600 (1.645)	5.163* (2.655)

Notes: Number of observations = 224. Mean-variance: Log likelihood value = −206.819; Pseudo R^2 = 0.160; Negative exponential: Log likelihood value = −208.375; Pseudo R^2 = 0.153.

[a] Numbers in parenthesis are standard errors.

[b] Standard deviation from the mean-variance approach.

[c] Risk aversion coefficient from the negative exponential approach.

* Statistical significance at the 5% level.

mean kernel diameter were not statistically significant.

Although most coefficient estimates associated with the attribute standard deviations were negative (indicating that millers, independent of quality levels, dislike variability in wheat quality attributes), none of the estimates were statistically significant, which stands in stark contrast to expressed concerns about quality variability. The positive sign for test weight standard deviation might be associated with the lower limit of 77 kg/hl for wheat to be grade 2 or better. It seems that Mexican buyers do not show great concern for the variability of test weight as long as this value is equal to or greater than 77 kg/hl. The alternative specific constants for options A and B were negative, implying that millers were more likely to choose the third, "I would not buy either option" when each wheat attribute is at the level zero. This behavior implies unwillingness on the part of the millers to choose a wheat purchasing scenario unless it possesses certain quality characteristics.

Estimates assuming negative exponential preferences and uniformly distributed attributes are also reported in Table 2. Because the model was highly nonlinear in parameters, each attribute level was scaled so that the mean levels equaled one to facilitate model convergence. Standard errors for each parameter estimate were calculated by using the delete-1 jackknife variance estimator described in Efron (1979). As expected, the sign for the price coefficient was negative and statistically significant. The coefficients associated with the marginal expected utility of test weight, protein, and farinograph stability were statistically significant and positive. The estimated absolute risk aversion coefficients for falling number, P/L ratio, and kernel diameter were statistically significant and positive. This suggests risk aversion over these attributes (i.e., the utility function for these attributes is concave). Estimates for the absolute coefficient of risk aversion vary from 0.215 to 7.587, implying that Mexican millers concern for variability differs for each wheat quality attribute.[6] In other words, respondents exhibit a more concave or more risk averse preference for falling number, kernel diameter, and P/L ratio rather than for test weight, protein, and farinograph stability.

Validation Procedure

Parameter estimates in Table 2 illustrate that the two modeling approaches yield different results. Which model specification is most appropriate? Is either model reliable or valid? Answering this latter question is particularly important as survey results are often looked at with a suspicious eye. To answer these questions, we investigated the external validity of the survey by using an out-of-sample test to measure the predictability power of both models. Results indicate that the mean-variance approach predicted respondents' choice with more success than the negative exponential, 47.32% compared with 34.38% (note: because we have three options, A, B, and C, a model of pure chance would correctly predict outcomes only 33% of the time). These findings reveal a better forecasting performance of the mean-variance compared with the negative-exponential expected utility model, and increase the confidence we can place in the results disseminating from this survey approach.[7]

Willingness-to-Pay

Table 3 reports willingness-to-pay to move from the lowest to the highest mean/standard deviation used in the conjoint survey, following the mean-variance approach, which according to our validation procedure, yielded better results. These willingness-to-pay estimates are obtained by multiplying the marginal willingness-to-pay by the difference between the high and low quality level as used in the experiment. The

[6] The magnitude of these risk aversion coefficients is not dissimilar to some estimates of farmers' levels of risk aversion reported in the literature (e.g., see Abdulkadri, Langemeier, and Featherstone, 2003). However, we note most estimates of coefficients of risk aversion reported in the literature deal with the curvature of the utility function over wealth—something very different than curvature of the utility function over wheat quality attributes.

[7] To investigate the external validity of the survey estimates, we also compared forecasted market share of U.S. and Canadian wheat purchased by Mexican millers to the actual market share observed in 2006. To obtain market share estimates, levels of each of the quality attributes had to be obtained for the United States and Canada. We used the production-weighted average values for the quality characteristics from different wheat growing regions in both the United States and Canada corresponding to the 2006 crop year. Information was obtained from the U.S. Wheat Associates (2006) wheat crop quality report and Canadian Grain Commission (2006) crop quality data and National Canada Statistical Agency (2007). Constraints in data availability made us use the "closest to best" available data, however we acknowledge it might not be the most realistic for this validation. Prices for both United States and Canada were obtained respectively from U.S. Wheat Associates (2006) and Canadian Grain Commission price reports. U.S. prices were Freight on Board measured at the Gulf of Mexico. Both U.S. and Canadian prices included transportation costs from the shipping port to the point of entrance in Mexico, considering rates for the route U.S. Gulf to Veracruz, Mexico (U.S. Grains Council, 2007). Given that transportation costs data for Canada were not available, we used as a proxy the ocean vessel freight rate from U.S. Pacific Northwest to Manzanillo, Mexico (Oades, 2007). Market shares were estimated by substituting the levels of each quality attribute into either Equation (2) or (6), depending on the model specification, for both United States and Canada (i.e., the two wheat options), which were then substituted into Equation (7). Predicted imports of U.S. wheat from the mean-variance model (66.98%) are very close to the actual share of U.S. imports reported by CANIMOLT for year 2006 (64%) (Fuente, 2007). Forecasted market shares from the negative exponential model were not as accurate (54.69%), but were not totally off-base.

Table 3. Willingness-to-Pay to Move from the Lowest Mean Level (or lowest standard deviation) to the Highest Level Employed in the Survey—Mean Variance Approach

Attribute	Willingness-to-Pay ($/MT)
Test weight: 78 kg/hl vs. 80 kg/hl	30.301
Protein 12% moisture base (%): 11% vs. 13%	46.428
Falling number 12% moisture base: 300 sec vs. 400 sec	21.297
Farinograph stability: 9 min vs. 13 min	42.481
P/L ratio: 0.85 vs. 1.1	18.140
Kernel diameter: 2 mm vs. 2.3 mm	14.261
Test weight standard deviation: 0.289 vs. 0.866	8.382
Protein 12% moisture base standard deviation: 0.289 vs. 0.866	−1.974
Falling number 12% moisture base standard deviation: 8.660 vs. 25.981	−7.033
Farinograph stability standard deviation: 0.577 vs. 1.732	−10.508
P/L ratio standard deviation: 0.029–0.115	−4.749
Kernel diameter standard deviation: 0.029–0.173	−3.249

marginal willingness-to-pay is the amount of money the individual would have to give up to be indifferent toward a one-unit increase in the quality characteristic. This statistic is calculated by dividing the marginal utility of each quality characteristic by the marginal utility of price (multiplied by negative one).

Results suggest that Mexican milling companies are willing to pay the most for an increase in protein content from 11 to 13%, for an increase in farinograph stability from 9 min to 13 min, and for an increase in test weight from 78 kg/hl to 80 kg/hl; willingness-to-pay are $46.23/MT, $42.48/MT, and $30.30/MT, respectively.[8] The greatest discount was given to increased variability in farinograph stability followed by falling number. An implication of these results is that Mexican milling companies' criteria to pay premiums and discounts is based primarily on the already established FGIS grades and standards, because greater premiums are offered for protein and test weight. Also, our findings suggest an interest in functionality quality parameters as reflected in the willingness-to-pay premium for farinograph stability. As expected all willingness-to-pay estimates for wheat quality variability, except for test weight,[9] were negative. This means millers would have to be compensated by the amount shown to accept the higher level of variability. Although none of these coefficients were statistically significant, their signs indicated that Mexican milling companies are willing to discount prices when wheat quality is highly variable. Our results are consistent with the findings of Wilson and Dahl (2008) that millers' concerns about attribute variability might be mitigated if procurement strategies are put in practice. Findings from Schlecht, Wilson, and Dahl (2004) and Kenkel, Anderson, and Lyford (1999) indicate that segregation or sorting by protein levels might not be cost effective; nonetheless the existence of such

[8] We estimated the marginal willingness-to-pay values for each attribute and consistency level. Results are available upon request. Our findings suggest that marginal willingness-to-pay for protein content, $23.21/MT, is similar to previous results from a study by Wilson (1989) who determined that a premium for protein for hard red winter wheat in the Cost, Insurance, and Freight (CIF) Rotterdam market was $21/MT. However, this result is considerably higher than the findings of Parcell and Stiegert (1998) who suggested a $0.218/bushel ($8.04/MT) protein premium for the North Dakota and Kansas markets. Any comparisons to previous studies should be made with caution due to different data sources, geographic regions, time periods, and methodologies employed.

[9] The positive sign for test weight standard deviation might be associated with the lower limit of 77 kg/hl for wheat to be grade 2 or better. It seems that Mexican buyers do not show great concern for the variability of test weight as long as this value is equal to or greater than 77 kg/hl.

practices might give the buyer the perception of lesser variability leading to unwillingness to pay for it.

Conclusions

This study used primary data from a group of Mexican millers to determine the millers' preferences for quality characteristics including those related with end-use performance and attribute variability. Data were analyzed using two modeling approaches, one the mean-variance where utility is assumed to be a linear function of the mean level and variance of a quality attribute. The second approach assumed that utility for each attribute was negative exponential and attribute variability followed a uniform distribution (the latter of which is strictly true given that our survey described each attribute as uniformly distributed). Out-of-sample validation reveals that the mean-variance approach yielded a higher level of external validity.

Also, this study shows that Mexican millers are willing to pay premiums for increases in grain quality factors such as test weight, protein content, falling number, and dough strength/extensibility characteristics given by farinograph stability and P/L ratio. Unlike the argument made in several previous studies (e.g., Wilson and Preszler, 1992), we did not find strong evidence that millers were particularly concerned with quality variability.

Implications of this study can be extended to the farmer's dilemma, whether choosing wheat varieties with the best agronomic or end-use functionality characteristics. Given no strong evidence that the market rewards end-use quality; wheat variety release criteria is focused primarily on agronomic characteristics rather than millers' and bakers' requirements. This study provides evidence that to gain a better positioning in the Mexican market, release criteria should also consider millers preferences. However, one should be cautious when generalizing these findings and the scope of the circumstances taking place when the experiment was conducted. Preferences might not be consistent through time hence further research into the valuation of quality uniformity might be required to establish thoroughly the cost effectiveness of alternative procurement strategies.

[Received October 2008; Accepted February 2009.]

References

Abdulkadri, A.O., M.R. Langemeier, and A.M. Featherstone. "Estimating Risk Aversion Coefficients for Dryland Wheat, Irrigated Corn, and Dairy Producers in Kansas." *Applied Economics* 35(2003):825–34.

Ahmadi-Esfahani, F., and R. Stanmore. "Values of Australian Wheat and Flour Quality Characteristics." *Agribusiness* 10(1994):529–36.

Atwell, W.A. *Wheat Flour*. St. Paul, Minnesota: Eagan Press, 2001.

Canadian Grains Commission. *Harvest Quality Reports,* 2006. Internet site: http://www.grainscanada.gc.ca/statistics-statistiques/gsw-shg/gswm-mshg-eng.htm (Accessed October 2007).

Collins, R.A., and E.E. Gbur. "Quadratic Utility and Linear Mean-Variance: A Pedagogic Note." *Review of Agricultural Economics.* 13(1991): 28–291.

Dahl, B.L., and W.W. Wilson. "Consistency of Quality Characteristics in Hard Red Spring Wheat." Report 393. Department of Agricultural Economics, North Dakota State University, 1998. Internet site: http://ageconsearch.umn.edu/bitstream/23455/1/aer393.pdf (Accessed October 2007).

———. "Effect of Hard Red Spring Wheat Consistency on Milling Value." Report 413. Department of Agricultural Economics, North Dakota State University, 1999. Internet site: http://ageconsearch.umn.edu/bitstream/23378/1/aer413.pdf (Accessed October 2007).

Efron, B. "Bootstrap Methods: Another Look at the Jackknife." *The Annals of Statistics* 7(1979):1–26.

Espinosa, J.A., and B.K. Goodwin. "Hedonic Price Estimation for Kansas Wheat Characteristics." *Western Journal of Agricultural Economics* 16(1991):72–85.

Fuente, J.L. Mexican Wheat Milling Industry Association, CANIMOLT. Personal Communication, February 2007.

Hanson, S.D., and G.W. Ladd. "Robustness of the Mean-Variance Model with Truncated Probability Distributions." *American Journal of Agricultural Economics* 73(1991):436–45.

Kenkel, P., K. Anderson, and C. Lyford. "Segregation Strategies for Oklahoma Wheat Elevators." *Current Farm Economics* 71,3(1999): 52–55.

Larue, B. "Is Wheat a Homogeneous Product?" *Canadian Journal of Agricultural Economics* 39(1991):103–17.

Liu, L. "A New Foundation for the Mean-Variance Analysis." *European Journal of Operational Research* 158(2003):229–42.

Louviere, J., D. Hensher, and J. Swait. *Stated Choice Methods: Analysis and Applications*. Cambridge, UK: University Press, 2000.

Lyford, C.P., and S.A. Starbird. "Optimal Grade Definitions for Multiple Quality Characteristics." Paper presented at AAEA annual meeting, Tampa Bay, Florida, July 31–August 2, 2000.

McCloskey, D.N. "The Loss Function Has Been Mislaid: The Rhetoric of Significance Tests." *The American Economic Review* 75(1985): 201–5.

McFadden, D. "Conditional Logit Analysis of Qualitative Choice Behavior." *Frontiers in Econometrics. P. Zarembka*, ed. New York: Academic Press, 1974.

Mercier, S.A. "The Role of Quality in Wheat Import Decision Making." ESCS For. Agr. Econ. Rep. No. 670. U.S. Department of Agriculture, 1993.

National Canada Statistical Agency. *CANSIM. Agriculture, Crops and Horticulture.* Internet site: http://cansim2.statcan.gc.ca/cgi-win/cnsmcgi.pgm (Accessed October 2007).

Oades, J. "Developing a Wheat Value Matrix (Price vs. Value)." Presented at the Workshop Contracting for Wheat Value Organized by U.S. Wheat Associates, Portland, Oregon, July 2005.

———. Wheat Marketing Center, Portland, Oregon. Personal Communication, October 2007.

Parcell, J.L., and K. Stiegert. "Competition for U.S. Hard Wheat Characteristics." *Journal of Agricultural and Resource Economics* 23(1998):140–54.

Peterson, C.J., R.A. Graybosch, D.R. Shelton, and P.S. Baenziger. "Baking Quality of Hard Red Winter Wheat: Response of Cultivars to Environment in the Great Plains." *Euphytica* 100(1998):157–62.

Pick, D., A. Webb, E. Dusch, and K. Gudmunds. "Quantitative Assessment of U.S. Wheat Performance for Quality Characteristics." ESCS For. Agr. Econ. Rep. No. 2. U.S. Department of Agriculture, 1994.

Schlecht, S.M., W.W. Wilson, and B.L. Dahl. "Logistical Costs and Strategies for Wheat Segregation." Report 551. Department of Agribusiness and Applied Economics, North Dakota State University, 2004.

Selected Mexican Milling Companies Representatives. Personal Communication on Imported Wheat Quality. February 2007.

Stiegert, K., and J.P. Blanc. "Japanese Demand for Wheat Protein Quantity and Quality." *Journal of Agricultural and Resource Economics* 22(1997):104–19.

Uri, N., B. Hyberg, S. Mercier, and C. Lyford. "The Market Valuation of the FGIS Grain Quality Characteristics." ESCS For. Agr. Econ. Rep. No. 25. U.S. Department of Agriculture, 1994.

U.S. Congress, Office of Technology Assessment. *Grain Quality in International Trade: A Comparison of Major U.S. Competitors*. Pub. No. OTA-F-402. Washington D.C.: Government Printing Office, 1989.

U.S. Department of Agriculture, Economic Research Service. *Wheat Data: Yearbook Tables*. Washington D.C. Internet site: http://www.ers.usda.gov/Data/Wheat/WheatYearbook.aspx (Accessed October 2007).

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyard Administration. *Federal Grain Inspection System (FGIS) United States Standards for Wheat.* Washington, D.C.: U.S. Department of Agriculture. Internet site: http://archive.gipsa.usda.gov/reference-library/standards/810wheat.pdf (Accessed October 2007).

U.S. Grains Council. *Market Perspectives*. 2007. Internet site: http://www.grains.org/images/stories/market_perspectives/2007/Market_Perspectives_2_16_07.pdf (Accessed September 2007).

U.S. Wheat Associates. *Wheat Quality Report*. 2006. Internet site: http://www.uswheat.org/cropQualityReports/doc (Accessed August 2007).

Veeman, M. "Hedonic Price Functions for Wheat in the World Market: Implications for Canadian Wheat Export Strategy." *Canadian Journal of Agricultural Economics* 35(1987):535–52.

Wilson, W.W. "Differentiation and Implicit Prices in Export Wheat Markets." *Western Journal of Agricultural Economics* 14(1989):67–77.

Wilson, W.W., and B.L. Dahl. "Procurement Strategies to Improve Quality Consistency in Wheat Shipments." *Journal of Agricultural and Resource Economics* 33(2008):69–86.

Wilson, W.W., and T. Preszler. "End-Use Performance Uncertainty and Competition in International Wheat Markets." *Journal of American Agricultural Economics* 74(1992):556–63.

Yassour, J., D. Zilberman, and G.C. Rausser. "Optimal Choices Among Alternative Technologies with Stochastic Yield." *American Journal of Agricultural Economics* 63(1981):718–23.