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Protein and the demand for hard wheats*

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Wheat protein is one of the most important specifications used in domestic and import purchase contracts and is used partly as a proxy for functional quality. The purpose of this article is to analyse the demand for wheat delineated by protein class. A choice-based econometric model is specified and estimated using a novel dataset of pooled wheat shipments to individual importing countries. Buyers are importing countries that make purchase decisions among different protein levels. The model frames the choice in terms of attributes of the choice and of the importing countries. Results indicate that there have been shifts over time, and purchase probabilities are highly price elastic and vary across importing regions. Functional characteristics including wet gluten content and extraction rates have significant impacts on purchase probabilities. These results have implications for breeders as it clearly illustrates the role of protein and functional characteristics on demand. The results also have implications for analysts modelling wheat trade in that there are many factors impacting market segments that would not be captured in conventional demand specifications.

Key words: choice modelling, hard red spring, hard red winter, market segments, protein, wheat quality.

1. Introduction

An important source of differentiation in the international wheat market is that of protein level, particularly in hard wheats. Protein content is an easily measured proxy for desired functional characteristics. In addition, the major focus of breeding programs in many developed and developing countries relates to increases in protein content (e.g. as discussed in Pena 2007; Kohli and Pena 2007), and several countries have made initiatives to improve protein content. Australia has made strides to increase its protein content to penetrate the higher protein markets, primarily through the class Australian Wheat Board Prime Hard Wheat. In the United States, hard red winter (HRW) and hard red spring (HRS) wheat are the largest classes produced and exported, are higher in protein and differentiation within these classes is

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primarily by protein level. Premiums exist in these markets for protein, which are reflected internationally. There is substantial variability in the demand for wheat protein which varies across countries and through time, and exporting countries and regions compete vigorously on protein content.

The purpose of this article is to analyse the demand for hard wheat classes and the effects of protein on exports from the United States. The article uses a novel dataset which allows us to draw inferences about both protein and wheat class demands using a choice model based on McFadden's (1974) random utility model. The article is motivated by a number of factors. First, existence of demands by protein levels suggests that market segments persist, which has implications for breeding and marketing strategies. Breeders continuously seek to improve functional characteristics which, in the context of our model, is an effort to increase purchase probabilities. Second, protein premiums are highly variable and impact class and protein demands. Third, while buyers' responses to quality and other factors have implications for breeders, an important missing element is how buyers respond to functional characteristics.

The article makes several contributions. First, the model and results allow a direct examination of market segments in the international wheat market. Specifically, we analyse demands by estimating a choice model where importers choose from a set of alternative protein categories as a function of product and country attributes. This approach allows comparisons of choices across both product and country attributes and measures how quality impacts purchase probabilities. For comparison, hedonic studies estimate the implicit price of measurable characteristics but do not indicate how the characteristic impacts demand or purchase decisions. These results indicate that buyers do indeed respond to quality in their demands, or purchase probabilities. These results show that there are clear market segments in the world hard wheat market, and these segments provide a means for marketers to differentiate. Finally, while a number of studies have analysed wheat class demands with highly aggregated data, the use of disaggregated data allows an exploration of market segments which have become highly differentiated across countries, classes, physical attributes, and implicit characteristics. To our knowledge, few studies have used a choice model to frame import demands.

2. Background and previous studies

Wheat has numerous end uses and functional characteristics. Wilson (1989) demonstrated that over time, differentiation (using the Hufbauer index) has increased. Wilson and Gallagher (1990) and Wilson (1989) indicated that there has been a growing diversity of demands for end-use characteristics. Wilson and Dahl (2008) analyse risks and strategic efficiency of different purchase specifications on achieving desired functional performance and Wilson, Dahl and Johnson (2007) analyse vertical integration and purchasing strategies to assure quality requirements. Economic analysis has also made important contributions to wheat breeding decisions and programs including the numerous studies on breeding issues in Australia (i.e. Brennan 1988, 1990, 1997) amongst others in the United States (Lambert and Wilson 2003; Dahl *et al*. 2004a,b).

Most major wheat exporting countries have been analysing institutions that impact exports and quality. The EU changed their intervention policy to encourage adoption of varieties with higher end-use characteristics. In Canada, much of the debate has been on topics related to kernel visual distinguishability. Australia is evolving toward increased emphasis on niche marketing whereby varieties and production regions are being matched to customer needs. The Australian Wheat Board Golden Rewards Varietal Systems (ProFarmer Australia 2004) is an example of varietal marketing with an emphasis on protein. Argentina has studied its system with respect to differences between varieties and the inability to classify them according to functional differences (Cuniberti and Otamendi 2004) and changes have been implemented to class varieties by functional traits. Finally, China, in response to changes in demands, made changes in its wheat classification system in the early 2000s with the goal of improving functional quality (Lohmar *et al*. 2008).

The U.S. grading system measures physical (not functional) characteristics, and these are the mechanisms upon which quality is measured and premiums and discounts derived. Premiums and discounts provide signals to growers and breeders, as well as to buyers, and they exist for grain factors, protein, and dockage. Implicit premiums may emerge for varieties and/or other functional differences in some cases, though these are not common.

3. Model specification

We model importer decisions to purchase wheat classes and protein levels in a choice framework. The model is conditional on purchases from the United States. Similar data do not exist for exports from other countries and hence, the assumption is maintained and results interpreted accordingly. Importers' choices are amongst two wheat classes (HRS and HRW) with multiple protein levels. Five protein levels are in the choice set. These include W-Ord, W-13, S-13, S-14, and S-15 where W and S stand for HRW and HRS, respectively, Ord refers to ordinary protein for winter wheat, and the numerical values indicate the protein level. The choice set is indexed by $c = 1,2, \ldots, C$.

The choice is framed using McFadden's random utility model, and importers (not consumers) are assumed to make choices based on payoffs. Following convention in the literature, payoffs are represented by utility (U) but may be a direct function of profits if the importer were an end-user; or equivalently U could be interpreted as welfare if the decision-maker is an importing firm, a trading company or a government buying agency. Regardless, the label is of no consequence as the dependent variable is discrete and the payoffs are a function of observed product and country attributes as well as an error term.

For a particular class/protein category (k) to be chosen, it must satisfy $U_k \geq U_c$ for all c. Utility consists of observed deterministic and unobserved components:

$$U_{ci} = x_{ci}^T\beta_c + \varepsilon_{ci} \quad (1)$$

where c represents the choice and i represents the observation. The deterministic component is $x_{ci}^T\beta_c$ and ε_{ci} represents the unobserved component. The probability that choice k is observed is

$$\Pr b(U_{ki} > U_{ci}), \quad (2)$$

which is

$$\Pr b(x_{ki}^T\beta_k - x_{ci}^T\beta_c \geq \varepsilon_{ki} - \varepsilon_{ci}). \quad (3)$$

The data consist of observations that include attributes that vary across the choice made and attributes of the importing countries that do not vary across the choice set. Attributes that vary across the choice set include prices of the choices (P_{ci}) and variables representing expected values of functional characteristics (F_{ci}) for that class and protein choice. In addition to attributes that vary across the choice set, we observe a set of variables that vary across the choice-maker. These are the macroeconomic and demographic variables conventionally considered to impact purchase decisions including income, domestic wheat production, urbanisation, women in the workforce, and traded goods. An intercept (alternative specific dummy), regional dummy variables, and a trend (t) (defined as 1 in 1986, 2 in 1987, etc.) were also included.

The model is specified with reference to specific types of variables. Let c, p, i, t represent the class and protein level imported by country i at time t. With this notation, the choice is a function of the intercept, trend, prices of each alternative, functional characteristics, and a set of importer characteristics represented in the following utility function:

$$U_{cpit} = \alpha_{cp} + \delta_{cp}t + \beta^p P_{cpit} + \beta_{cp}^F F_{cit} + \beta_{cp}^i I_{it} + \varepsilon_{cpit} \quad (4)$$

where

α_{cp} = effect of alternative specific intercepts measured relative to W-Ord;
δ_{cp} = effect of the time trend measured relative to W-Ord;
β^p = effect of the price of class and protein level (c, p) at time t faced by importer i;
β_{cp}^F = effect of functional characteristics (F) which may vary across class and protein (cp); and
β_{cp}^i = effect of variables that vary across importers (i), over time (t), and the response may vary across class and protein (c, p).

The model is a general representation and encompasses other specifications as special cases. A model based on attributes which vary across the choice set is a conditional logit. In the utility function above, such a variable is given by price. The coefficient is constrained equal across the various elements of the choice set. A model based on attributes which are constant across the choice set but vary across the decision maker is a multinomial model. These variables are represented by such variables as income, the level of wheat production, etc. These do not vary across the elements of the choice set, but do vary across countries over time. The corresponding parameters are relative to a base (W-Ord) and are indexed by the alternative. Such differences, though largely terminological, are useful here to delineate the different types of variables.

In choice modelling under conditional logit, all variables that do not vary across importers disappear as the choice is made on the basis of differences in utility functions. If the response of each choice differs across alternative choices as in a multinomial logit (i.e. a different β for each alternative), then estimation proceeds by normalising the coefficient vector with respect to one of the alternatives. The parameters and marginal effects are then measured and interpreted relative to that alternative. In our case, the conditional and multinomial approaches are combined. We normalise with respect to W-Ord and the coefficients are interpreted relative to that alternative. The conditional logit model is obtained if the alternative specific dummy variables, the trend (interacted with the alternative specific dummy variables), functional characteristics, and the importers' specific characteristics are each jointly equal to zero. If the effect of price and functional characteristics is zero, the multinomial logit model is obtained. In the end, we estimate a model that allows for each type of effect. Specifically, the model contains variables that vary across the choice (e.g. price) and variables that vary only across the importers (e.g. income).

4. Data sources and behaviour

A novel dataset of individual shipments and characteristics is used in this study. It is the Export Grain Inspection System (EGIS) data from the Federal Grain Inspection Service (USDA-GIPSA 2003). Similar data are not reported for other exporting countries. The dependent variable is the purchase decision for an individual shipment among different wheat types. Variables included in these data are detailed ship-lot grade and grain characteristics. For each shipment it contains grade, grade factors, class, protein, and whether protein is specified. These variables are reported for each shipment, which is our unit of observation, to each importing country. The EGIS data reflect the discrete decisions of importers about the characteristics of the purchase decision. Protein categories are class dependent. For HRW wheat, the two protein categories were 13 per cent or higher and 'Ord' for average protein levels less than 13 per cent. For HRS wheat, the three categories of protein were 13, 14, and 15 per cent for protein levels less than 14 per cent, 14–15 per cent, and 15 per cent or higher, respectively. The dataset contains a total of 23 282 usable observations from 1986 to 2002, and 145 countries are included, all of whom had purchased these classes of wheat at some time during the period of study.

End users specify hard wheats of different protein levels because of their underlying functional characteristics. These characteristics include falling numbers, wet gluten, absorption, extraction rates, and various farinograph measures such as stability and peak time. Typically, greater values are preferred, depending on the product being produced. These characteristics are particularly important to produce the types of products requiring higher gluten content (Wheat Marketing Center 2004). The exact value required varies by product and process and would differ across importing countries. Typically, though not always, values for these functional characteristics are used as explicit contract terms between millers and bakers, or from an expectation based on previous experiences.

Functional characteristics are normally not measured within the marketing system (with the exception of falling numbers) nor observed in the data, but their numerical values are apparent from previous purchases and are reflected in crop quality reports that are widely distributed. Wheat protein, which is easily and routinely measured, is used as a proxy for these desired end-use characteristics. Values of functional characteristics explain at least part of the vertical differentiation between the classes and affect importers' decisions. If the characteristic increases and/or is greater for a possible choice relative to other possible choices, the probability of choosing the one with the higher characteristic should be larger.

Table 1 shows the means of wheat protein and the underlying functional characteristics by class, as well as the correlations among them. These were estimated from annual average values for export cargo surveys from 1985 through 2003 for HRS and HRW wheat using observations for both by port area (Pacific North-west (PNW) and Gulf for HRW; and PNW, Gulf, and Lakes for HRS) (U.S. Wheat Associates various years). Strong correlations exist between protein and wet gluten and amongst these variables with absorption, peak time and tolerance.

We explain choices for class and protein with a set of attributes which apply to the choice made, for example, prices and functional characteristics, a set of attributes that apply to the importing country, and a trend. Annual wheat prices and protein premiums were used and derived for HRS (13, 14, 15) at Minneapolis, and for HRW at Kansas City. The final set of variables (apart from trend and regional dummy variables) is the set of importer characteristics. These are macroeconomic indicators and/or demographic variables that may impact preferences and choices. These variables vary across importers and through time, but not across the choice set, and reflect different preferences and import patterns across countries. We retained macro variables for which a complete set of observations was available for all countries, which included per capita income, wheat production in the importing country, and traded goods, which is a measure of a country's macro dependence on trade.

Table 1 Mean and correlation of protein and selected quality characteristics (HRS and HRW export cargo survey data, 1985–2004)*

	HRW	HRS	Protein	Falling Numbers	Wet gluten	Absorption	Peak time	Tolerance	Loaf volume	Extract rate	Flour ash
	Mean		Correlations								
Protein (%)	12.1	14.1	1	–0.41	0.95	0.78	0.70	0.57	0.71	–0.64	
Fall numbers (s)	432	363		1	–0.41	–0.35				0.34	0.34
Wet gluten (%)	27	35			1	0.78	0.63	0.49	0.74	–0.71	
Absorption (%)	60	64				1	0.60	0.42	0.56	–0.54	
Peak time (min)	6	10					1	0.86	0.36	–0.48	
Tolerance (min)	12	15						1	0.34	–0.33	
Loaf volume (cc)	785	927							1	–0.43	0.40
Extraction rate (%)	71	72								1	
Flour ash (%)	0.458	0.462									1

Correlations estimated from annual export cargo survey data, 1985–2004, for HRS and HRW contained in U.S. Wheat Associates, *Crop Quality Reports*.
*Only statistically significant ($P < 0.05$) correlations are reported.

A set of regional dummy variables was included to reflect interregional differences in preferences. We also included urbanisation and women in the workforce to reflect the demand for convenience, product choice, and impacts on wheat import quality decisions. Several organisations point to the role of these variables on the demand for quality (Courtmanche 2004; Lohmar 2004; ProExporter 2005a,b), but their impacts are not well understood empirically. Data for these parameters were obtained from the World Bank (2004).

5. Empirical results

5.1 Model selection

There are a number of econometric issues in estimating the choice model using individual trade data over time by different countries. Given the data are individual trades, the market shares are relatively small, and since prices are proxy variables (aggregate border prices for each element of the choice set), they were treated as exogenous. In addition, the data have panel features but are unbalanced. Thus, within the panel, some countries may appear and not appear, in any given time period, and a specific country may also have an unequal number of purchases.

We first present a set of specifications for descriptive purposes as well as to delineate the effects of relationship across broad classes of variables (i.e. trends, prices, importer characteristics, and functional attributes). We describe the models and the resulting final specification first and then provide an economic interpretation of the results.

The first specification included intercepts, trends, and prices.[1] The results suggest that over time the shares for S-15, S-13, and W-13 are declining, while those for S-14 and W-Ord are increasing. In addition, prices are important, and their inclusion does not impact the direction of the trends. Income and regional effects and importer country attributes were included in Model 1 (Table 2). Regional dummies were added for Africa, Asia, Central and South America, Europe, Former Soviet Union, North America, and Oceania with Asia as the 'base' dummy. The results suggest strong effects for price, income, regional, and importer attributes (females in the workplace, urbanisation, and traded goods).

Functional characteristics and domestic wheat production were added in Model 2 and have a significant impact on purchase choices. Wet gluten and extraction rates were included as choice attributes reflecting functional characteristics of the underlying choice. These were introduced by allowing the effect to vary through the variables. These effects are significant. Domestic production is significant and was found to also have an interaction effect with urbanisation as shown in Model 3.

[1] These are not repeated but are available in (Wilson *et al.* 2005).

Table 2 Description of variables

Variable	Abbreviation	Units	Description
Dependent variables			
Purchase choice amongst classes (HRS or HRW) and protein level (13, 14, 15 and Ord)	S13, S14, S15, W-ORD, W13	0/1	Indication of class and protein of the individual purchase and shipment
Independent variables (number following the variable names in Table 3 references the alternative)			
Trend	TRE		$t = 1985 \ldots 2002$
Prices	Price	$/bu	Prices and the functional characteristics vary through time and across classes and proteins, but not across countries
Wet gluten	Wetglute	%	
Extraction	Extrate	%	
Income	GDP	$	Values vary across importing countries
Females in the work force	LF	%	
Traded goods	TrG	% of GDP	
Urbanisation	Urb	%	
Wheat production	Wht	1000 MT	
Regions (defined as):	AFR, Africa; CSA, Central and South America; EUR, European Union; FSU, Former Soviet Union; NAM, North America; OCE, Oceana		

To evaluate the models we derived McFadden 1974 R2 (a likelihood ratio index). These values are 0.37, 0.39 and 0.42 for Models 1, 2 and 3, respectively.[2] A specification test was conducted to determine whether Model 3 was superior to others using a likelihood ratio test. Given we have the 'unrestricted model' identified, we derived the LR statistic for each of the 'restricted models' using this test. The log-likelihood statistics for Models 1, 2, and 3 were –19 576, –18 592, and –17 805, respectively. The results are all statistically significant, indicating that Model 3 is superior to the others and, thus, we use Model 3 for our economic interpretation below. The overall level of fit for Model 3, using McFadden's likelihood ratio index, is 0.41 without intercepts and 0.24 measured with intercepts only. We also calculated the overall classification rate for each model. The classification rates were 46, 48 and 50 for Models 1, 2 and 3, respectively. Finally, across specifications, the coefficients, remain statistically significant and similar in magnitude, pointing to the robustness of results.

The model has attributes that vary across choice and others that vary across individuals. To test this, we followed Greene's procedures which rest on testing to see if the former differs across various subsets of alternatives excluded. The McFadden-Hausman statistic was derived. These statistics indicated that IIA was not always satisfied. Inspection of the coefficients across the various subsets indicated that the coefficients on wet gluten and

[2] These were derived. The LRI = 1 – ln(L)/ln(L0) where LnL is the likelihood maximised (the results reported) and Ln(L0) is the restricted likelihood (coefficients = 0) (McFadden 1974).

extraction were stable. One solution to a violation of IIA is to estimate a mixed logit (in addition to others) or to group the choices. We re-estimated a reduced version of the model as a mixed logit which does not place prior restrictions on the substitution effects. In this procedure, the coefficient on price was assumed to follow a normal distribution. The results from the mixed logit are very similar to those of the standard logit model, and the standard deviation was not statistically different from zero.[3] Given that the results are very similar, we use the standard logit model to explain and interpret the results below.

5.2 Economic interpretation

The economic interpretation of these results uses elasticities and/or marginal values derived from Model 3. Each is useful depending on the variable being evaluated, and their interpretations differ. Own-price and cross-price elasticities are calculated at each point in the sample and then averaged. These are evaluated using conventional formulas, e.g. Train (1993, p. 40) and Greene (2003, p. 723). To illustrate, the formula to represent an increase in the price of the k^{th} alternative on the probability of the j^{th} alterative is.

$$\frac{\partial \log \Pr b_i}{\partial \log \text{Price}_k} = \text{Price}_k[1(j = k) - \Pr b_k]\beta_{\text{price}}. \quad (5)$$

We derived marginal effects for relevant discrete and physical variables. Marginal effects are the derivatives of the probability equation except in the case of regional dummy variables. For variables that vary across the choice (e.g. price), denoted for this purpose as x_c the marginal effect is

$$\frac{\partial \Pr b_j}{\partial x_c} = (\Pr b_j)(1(j = c) - \Pr b_c)\beta x_c \text{ for } c = 1, \ldots, c \quad (6)$$

where βx_c is the coefficient on x_c. Elasticities were obtained by multiplying the marginal change in probability by the ratio of price to probability. For variables that vary across importers but not across choices, we denoted for this purpose as x_i, the marginal effect is

$$\frac{\partial \Pr b_c}{\partial x_i} = (\Pr b_c)\left(\beta_c - \sum_{k=0}^{C} \Pr b_k \beta_k\right) \quad (7)$$

[3] One explanation for the general failure of the IIA test and the mixed logit results is that the IIA test tests for differences in the parameter vectors. The test statistic, however, also has the difference in the covariance structures. The null may be rejected due to either a large difference in parameters or a small difference in the covariance structures. Given that the mixed logit gives small differences in the parameters, we take the failure to be the result of similar covariance structures.

and may not have the same sign as the coefficient. Finally, for discrete right-hand side variables, the marginal effect is the difference in predicted probability schedules at mean values of the continuous variables. In this case, we evaluated the probability function using means and differenced them with and without the dummies. All elasticities and marginals reported were derived by calculating the statistic at every point in the data and then averaging the result, except for the marginals reported on the dummy variables. In this case, we used mean values of the continuous right-hand side variables.

There has been substantial variability in premiums for higher protein choices over the time period of the study. Prices capture differences across choices as well as their variability over time. The own and cross-price elasticities (Table 3) indicate the percentage change in expected quantity from a percentage change in price. These are highly price elastic, and the elasticity is generally greater for higher protein choices and less for those with lower protein. In all cases, the impact is significant. The cross-price elasticities indicate that a change in prices of the alternatives (other class/protein options) has relatively little impact on purchase probabilities for S-15, S-13, and W-13. However, purchase probabilities for S-14 and W-Ord are highly responsive to price changes of other choices.

The macroeconomic and demographic variables retained in the final model include the level of traded goods, the percentage of females in the workforce, income, urbanisation, and wheat production. These are shown in the lower panels of Table 3. The level of trade is positively related to each choice. An increase in trade has the impact of increasing the purchase probability of W-13, S-13, S-14, and S-15 at the cost of W-Ord. Countries with greater trade have greater purchase probabilities for these choices.

Variability in income impacts choice. These are positive and relatively inelastic, with the exception of S-13. Countries with greater incomes have greater purchase probabilities for S-15, S-14, and W-13 relative to W-Ord. However, they have a lesser purchase probability for S-13. This suggests that low income countries have a greater tendency to purchase S-13, whereas higher income countries have a greater tendency to purchase higher protein choices.

Female participation and urbanisation were included as a measure of the demand for convenience. Greater female participation in the workforce tends to have a greater demand for products that would be more convenient and for ingredients necessary to produce these products (e.g. meals away from home, hamburgers, fast food, pizza, etc.). These results indicate that this is a very significant effect. The elasticities for each of the HRS wheat choices are all positive and relatively large. In addition, the elasticities for S-15 are nearly double those for the lower protein HRS wheats. These suggest that countries with a greater female workforce tend to buy a greater proportion of higher protein HRS wheats than others.

The other demographic variable is urbanisation. There has been a growing trend for countries to become urbanised, and there is substantial variability

Table 3 Impacts of domestic wheat production and functional traits

	Model 1			Model 2			Model 3		
	Parameter	*T*-Ratio	Significance	Parameter	*T*-Ratio	Significance	Parameter	*T*-Ratio	Significance
Price	–0.735	–16.301	***	–0.7935	–16.29	***	–0.7921	–16.0240	***
A_S15	–6.1796	–15.189	***	–7.9984	–18.518	***	–6.6066	–14.9330	***
A_S14	–4.3311	–21.932	***	–6.1802	–26.426	***	–4.9585	–21.0330	***
A_S13	–6.2386	–22.196	***	–8.0842	–25.461	***	–5.3564	–16.8500	***
A_W13	–3.4545	–8.814	***	–3.1442	–7.912	***	–3.5096	–7.8120	***
S15xTRE1	–0.1224	–14.294	***	–0.1145	–13.192	***	–0.1173	–13.0960	***
S15xGDP1	0.0001	13.767	***	0.0001	12.92	***	0.49D-04	9.9860	***
S15xAFR1	–1.8401	–7.725	***	–2.1199	–8.15	***	–2.5027	–9.6370	***
S15xCSA1	1.3341	10.598	***	1.3418	10.513	***	0.9490	7.2850	***
S15xEUR1	3.4601	27.274	***	3.3642	26.188	***	2.0756	14.6670	***
S15xFSU1	–32.8363	0		–32.7698	0		–40.3299	0.0000	
S15xNAM1	–0.4458	–2.251	**	–0.3817	–1.906	*	–5.7002	–13.5080	***
S15xOCE1	–30.1042	0		–30.2297	0		–30.0775	0.0000	
S15xLF_1	0.1149	13.128	***	0.1234	13.338	***	0.0978	10.2940	***
S15xTRG1	0.0309	29.956	***	0.0292	27.305	***	0.0285	27.0580	***
S15xURB1	–0.0256	–9.844	***	–0.0291	–10.86	***	–0.0348	–12.8740	***
S15xWHT1				0	–2.647	***	–0.0002	–20.0620	***
S15*U_W1							0.73D-05	20.8500	***
S14xTRE2	–0.0007	–0.162		0.0026	0.54		0.0139	2.8170	***
S14xGDP2	0	21.665	***	0	18.593	***	0.28D-04	12.9600	***
S14xAFR2	–1.4059	–16.27	***	–1.7736	–19.03	***	–2.1969	–23.3610	***
S14xCSA2	1.0371	17.601	***	0.8992	14.672	***	0.5253	8.5240	***
S14xEUR2	1.4968	14.455	***	1.37	13.032	***	0.3357	2.9390	***
S14xFSU2	–33.4469	0		–33.4253	0		–40.3799	0.0000	
S14xNAM2	–1.8871	–19.944	***	–1.8338	–18.93	***	–4.8648	–22.9550	***
S14xOCE2	2.7439	2.671	***	2.473	2.389	**	2.5642	2.4760	**
S14xLF_2	0.0748	17.464	***	0.0894	18.689	***	0.0643	13.6070	***
S14xTRG2	0.0185	21.888	***	0.0153	17.405	***	0.0133	15.6510	***
S14xURB2	0.0024	1.942	*	–0.0008	–0.622		–0.0043	–3.2090	***
S14xWHT2				0	–9.618	***	–0.0002	–24.1450	***
S14*U_W2							0.60D-05	23.3550	***

S13xTRE3	–0.0215	–3.251	***	–0.0209	–3.076	***	0.0024	0.3470	
S13xGDP3	0	2.697	***	0	1.848	*	–0.30D-04	–5.6680	***
S13xAFR3	0.1331	1.435		–0.1655	–1.651	*	–0.8847	–8.8910	***
S13xCSA3	1.1814	13.552	***	0.9335	10.155	***	0.1570	1.7090	*
S13xEUR3	1.3159	8.105	***	1.2033	7.405	***	–0.0219	–0.1230	
S13xFSU3	–3.4836	–3.44	***	–3.5845	–3.541	***	–11.8751	–10.7750	***
S13xNAM3	0.3461	3.557	***	0.3308	3.299	***	–2.9336	–15.6870	***
S13xOCE3	1.7057	1.203		1.4002	0.984		1.7202	1.2070	
S13xLF_3	0.0919	15.694	***	0.1077	16.579	***	0.0522	8.0920	***
S13xTRG3	0.0234	23.833	***	0.0181	16.382	***	0.0151	13.3350	***
S13xURB3	–0.0033	–1.671	*	–0.0058	–2.726	***	–0.0107	–5.0180	***
S13xWHT3				0	–4.187	***	–0.0002	–23.5860	***
S13xU_W3							0.69D-05	24.7320	***
W13xTRE4	–0.072	–9.039	***	–0.0757	–9.109	***	–0.0803	–9.4900	***
W13xGDP4	0.0001	26.646	***	0.0001	25.474	***	0.93D-04	23.8490	***
W13xAFR4	0.5881	3.95	***	0.5497	3.582	***	0.6102	3.6200	***
W13xCSA4	0.0154	0.104		0.0547	0.369		0.1881	1.1790	
W13xEUR4	–0.9801	–3.061	***	–0.9661	–3.014	***	–1.3087	–4.0230	***
W13xFSU4	–0.4855	–0.661		–0.4786	–0.656		–0.7615	–0.9460	
W13xNAM4	–0.4423	–2.997	***	–0.5	–3.33	***	–0.1066	–0.5430	
W13xOCE4	2.7213	2.212	**	2.8153	2.288	**	2.7950	2.2710	**
W13xLF_4	–0.0123	–1.479		–0.0146	–1.683	*	–0.0032	–0.3350	
W13xTRG4	0.0232	20.865	***	0.0206	18.098	***	0.0188	16.8370	***
W13xURB4	0.0014	0.428		0.0009	0.275		0.0013	0.3770	
W13xWHT4				0	1.261		–0.39D-05	–0.3060	
W13xU_W4							0.32D-06	0.7460	
WETGLUTE			0.3106	24.866	***	0.3369	25.6250	***	
EXTRATE				0.3638	24.202	***	0.3920	24.7790	***
Log-likelihood	–19586.5			–18591.5			–17805.4		

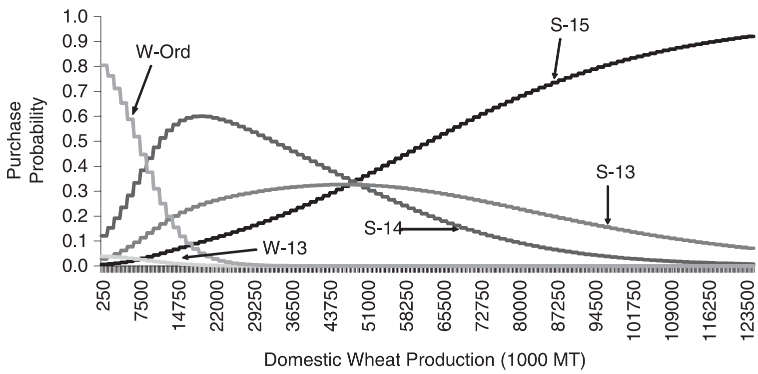

Figure 1 Effect of wheat production (and its interaction at median urbanization) on purchase probabilities, derived using median values.

in urbanisation across countries. By itself, greater urbanisation has the impact of reducing purchase probabilities of the HRS wheat choices. However, this is highly dependent on the level of domestic wheat production. As it turns out, this impact has quite an interesting effect on choice probabilities. The effect of both wheat production and urbanisation is negative when evaluated individually, but the interaction effect is positive.

These relationships are shown in Figure 1. As domestic wheat production increases, the purchase probability for S-15 increases. This is because in many countries, local wheat production is generally of lower quality, which has the impact of shifting the choice probability for imports to higher proteins for blending purposes. For S-14 and S-13, the effect of wheat production is initially positive and then becomes negative. For countries with lower levels of wheat production, the effect of these choices is positive; but for countries with a larger level of wheat production, the effect turns negative. For both W-13 and W-Ord, the effect is largely negative but highly non-linear. For these choices, increases in local wheat production have the impact of reducing the imports of this class. This is likely due to the demand for blending. Since local production is generally of lower quality and protein, there is less need to supplement imports with like-quality wheat. These results provide much better clarity on the role of urbanisation vs. previous suggestions. As urbanisation and wheat production change, the quality and protein of imports should change as well.

Wet gluten content and extraction rates are two important characteristics, and values for these were included as choice attributes. These effects were highly significant. To evaluate their effect, we derived elasticities (Table 4) and marginal effects of each (Table 5). Improvement in both has a positive impact on the purchase probability for that choice. As shown in the elasticities, the impact is greater for higher protein choices and for HRS wheat. The own-marginal effects are greatest for S-14 and W-Ord for both wet gluten and extraction. These mean that a 1 unit increase in wet gluten results in a

Table 4 Elasticities: own, cross-price, and others

Choice	Own price	Cross-price of wheat
S-15	–3.53	0.19
S-14	–2.31	1.09
S-13	–3.02	0.25
W-13	–3.06	0.18
W-Ord	–1.56	1.50

Other elasticities					
	Wet gluten	Extraction rate	Trend	Income	
S-15	11.11	25.86	–0.005	0.469	
S-14	7.92	18.41	0.002	0.157	
S-13	10.84	25.23	0.000	–2.940	
W-13	8.58	26.35	–0.004	0.830	
W-Ord	4.60	14.23			
	LA_Female	TR goods	Urban	WhtProd	U_WhtPro
S-15	3.40	1.31	–2.08	–1.00	1.38
S-14	1.57	0.44	–0.18	–0.78	0.97
S-13	1.77	0.69	–0.63	–1.00	1.23
W-13	–0.11	0.89	0.08	–0.02	0.06
W-Ord					

*Elasticities derived from Model 3.
Note: Variables are as previously defined: LA_Female is the percent of females in the workforce; TR goods is the level of traded goods; Urban is the level of urbanisation; WhtPRod is the level of wheat production, and U_WhtPro is the interaction of wheat production and urbanisation.

0.06 increase in purchase probability of S-14 and a decline in the purchase probability for each of the other choices. That for W-Ord declines the most. The elasticities indicate a 1 per cent change in wet gluten has a 4–10 per cent change in the purchase probabilities, whereas a 1 per cent change in extraction has a 13–25 per cent change in purchase probabilities.

These results have important implications for breeders. They indicate that improvements in quality, measured here by wet gluten content and extraction, result in an increase in purchase probabilities or market shares. These effects are significant assuming the impact of prices, as well as other macro and demographic variables, are constant. Thus, quality improvement is reflected in an increase in purchase probabilities and market shares for that choice. These are traits that can be bred for, and these results provide positive motivation for focus on these factors, which is fairly important. These results provide greater insight on this issue than those reflected in other studies using hedonic price functions.

Interpretation of regional coefficients is the change in the log odds of choosing class/protein relative to W-Ord. The effect of regions was evaluated by fitting the probability function for each alternative with and without the dummy for each region (following Greene 2003, p. 668). The marginal effect

Table 5 Marginal effects of wet gluten and extraction rates

	S-15	S-14	S-13	W-13	W-Ord
			Wet gluten		
S-15	0.014	–0.008	–0.001	–0.001	–0.004
S-14	–0.008	0.059	–0.007	–0.007	–0.035
S-13	–0.002	–0.009	–0.001	–0.001	–0.010
W-13	–0.001	–0.007	0.016	0.016	–0.008
W-Ord	–0.004	–0.035	–0.008	–0.008	0.056
			Extraction rate		
S-15	0.016	–0.009	–0.002	–0.001	–0.004
S-14	–0.009	0.069	–0.011	–0.008	–0.041
S-13	–0.002	–0.011	0.025	–0.001	–0.011
W-13	–0.001	–0.008	–0.001	0.019	–0.009
W-Ord	–0.004	–0.041	–0.001	–0.009	0.066

Regional differences (Measured relative to Asia)						
	Africa	Central and South America	Europe	Former Soviet Union	North America	Oceania
S-15	–1.33	1.81	9.01	–1.47	–1.46	–1.47
S-14	–14.25	7.56	4.15	–16.29	–16.14	34.74
S-13	–1.40	0.03	–0.32	–2.63	–2.45	0.91
W-13	7.63	0.32	–5.37	–2.72	0.96	20.86
W-Ord	9.35	–9.73	–7.48	23.11	19.09	–55.04

*Marginal effects for the discrete regions were derived from individual observations that were averaged and reported as the mean value.

of a region is the difference of the two probabilities. Interpretation of values (lower panel of Table 5) is the difference in the probabilities mean values of demanding a specific grade (S-15) between the regions listed (e.g. Africa) and the base region (Asia). The value is the change in the probability with and without the dummy. For example, suppose the estimated probability of S-14 for Asia is 0.50, the value of –9.79 for Africa means the estimated probability for Africa is 0.40.

The results can be interpreted as a region's idiosyncratic preference relative to those in Asia. Africa has negative preference for S-15, S-14, and S-13 but a very strong preference for W-13 and W-Ord. The results are nearly just the opposite in Europe, which has a preference for S-14 and S-15, but weaker preference for S-13, W-13, and W-Ord. Compared to Asia and holding everything else constant, Europe will import nearly 4 per cent more of S-15 but substantially less of the other classes. Finally, Central and South America have strong preferences for all spring wheats, but not lower protein winter wheat, and Oceania has extremely strong preferences for S-14 and W-13 but extremely negative (weak) preferences for W-Ord.

China is one of the more interesting and dynamic countries in the world wheat market. China is a very large producer of wheat, its urbanisation is

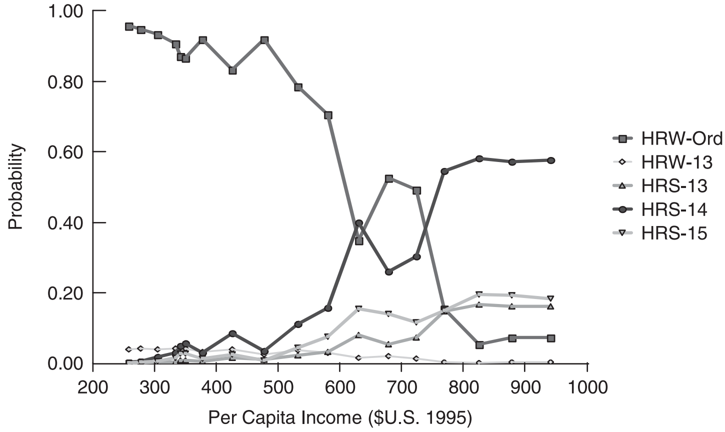

Figure 2 Impacts of Chinese income on purchase probabilities for wheat classes and proteins.

changing, and incomes have been increasing rapidly (Lohmar 2004). Traditionally, imports by China consisted of lower protein wheats from the United States and lower grades from Canada. For illustration, the model was used to explain the impacts of these variables on the composition of wheat imports into that country (Figure 2). Results show that as incomes increase, combined with the impacts of urbanisation and changes in wheat production, there are shifts in demands for wheat classes and proteins. As incomes increase, there are drastic reductions in the import share of HRW-Ord. This is offset by a sharp increase in demands for HRS-13 and concurrent increases in HRS-14 and HRS-15, each of which converge toward 20 per cent. Indeed, recent purchase behaviour has nearly mimicked these changes (International Grains Council 2005).

6. Summary and implications

Protein is a quality characteristic that is measured in the marketing system and is an important specification in most hard wheat transactions. It has premiums and discounts which are important and are highly variable. Some buyers buy only one protein level while others buy multiple levels and/or classes, and these choices vary through time. The purpose of this article was to analyse the demand for protein choices in the hard wheat market and to evaluate factors that impact these choices. We developed a choice-based model of wheat purchasing and estimated it using a hybrid specification, incorporating multinomial and conditional relationships. We used a novel dataset on individual export shipments across countries and through time which included which class and protein level they purchased.

The results indicate that there have been increasing trends (in the unconditional model) in S-14 and W-Ord but decreases in other choices. Prices are highly elastic and greater for higher protein levels. Urbanisation and females in the workforce had important impacts, generally favouring higher protein wheats and reflecting demands for convenience. Urbanisation and wheat production have an interesting impact on purchase probabilities. For each there is a negative direct effect for the higher protein classes relative to W-Ord. However, direct interpretation is more complicated due to a significant positive interaction between urbanisation and production. Thus, for the higher protein classes, the effects of urbanisation (production) are tempered by or may affect the sign of the effect of the level of production (urbanisation). These results suggest that importers' choices of protein are highly impacted by their country's wheat production. For countries with higher production, there is a tendency to shift to higher protein imports, suggesting the need for blending purposes. For countries with lower wheat production, there is a greater tendency to increase their purchases of the lower protein HRW wheats. Finally, functional characteristics have an important impact on purchase probabilities. In particular, increases in either extraction rates or wet gluten have had a significant impact on purchase probabilities.

There are three implications from these results. First, the results provide a better understanding of the role of quality and wheat protein on importers' choice. These are important for numerous countries that are evaluating their marketing systems with respect to wheat quality. While there have been a number of studies on wheat class demands, the distinctions among class, protein and functional characteristics have not been considered empirically. Likewise, there are many studies that measure the hedonic value of characteristics, but, these are of measured characteristics and do not indicate how they impact demands. These results provide a better understanding of the role of these classes and protein of wheat in international trade and competition. They also indicate preferences within the hard wheat market, as well as factors impacting these preferences. Second, they clearly indicate there are segments in the international wheat market. In this case, these are segmented by class and protein choice. Incomes, geography, and demographics all impact a country's purchase choices. These findings help explain the existence of market segments, which has implications for marketing and promotion. The results indicate that HRS wheat and higher proteins are preferred in some regions, but not others. There is demand for both lower and higher protein hard wheats, and these vary by geography and demographic characteristics. Thus, in a segmented market, it may be appropriate to promote development of both higher and lower protein hard wheats. Finally, the results have important implications for breeders. In particular, they indicate that improvements in functional characteristics increase purchase probabilities and market shares, and these should provide motivations for longer term improvement in quality.

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