*Journal of Agricultural and Resource Economics*, 19(1): 197–209


# Demand for Wheat Classes by Pacific Rim Countries

**William W. Wilson**

The transcendental logarithmic function is used to derive demand functions which are estimated for wheat classes imported by Pacific Rim countries. Results indicate substantial differences exist in underlying demand parameters for wheat of different classes as well as across countries. In addition, the expenditure level has important impacts on the distribution of imported wheat classes, and preferences have shifted significantly through time, generally toward higher protein wheats.

*Key words:* demand, Pacific Rim, transcendental function, wheat.

## Introduction

Wheats produced in different regions have end-use characteristics, which vary due to varieties, climate, soils, and cultural practices, and are used for many purposes, ranging from pan bread, noodles, pasta, and couscous to animal feed. Consumption of different wheat classes depends on a multitude of factors, including income, relative prices, and tastes, which are influenced by culture and tradition.[1] As a result, wheat class consumption patterns differ and vary throughout the world as well as through time. Of particular importance in understanding wheat demand is substitutability among different types and classes of wheat. Factors that influence substitutability among wheats include products consumed, technology used in processing, and institutional impacts of buying agencies. In some countries, shifts may occur in underlying preferences for different wheat classes due to changes in the composition of products consumed.

The objective of this study is to estimate wheat class demand functions for individual countries and to test for shifts in preferences through time. A conditional demand model is estimated which is derived from a transcendental logarithmic (TL) functional form of the expenditure function. The resulting demand system is a more general model, which both allows for expenditures to have a nonlinear impact on import shares and for substitution elasticities to vary across pairs of imports. Each of these are of particular importance in wheat class demand analysis. The model was estimated for individual Pacific Rim importing countries.

Many theoretical and empirical analyses of international wheat trade and competition implicitly assume perfect substitutability across classes and origins. While some studies allow for imperfect substitutability of wheat among exporting countries, most studies assume perfect substitutability among wheat exported from a particular country. However, wheat substitutability is likely imperfect across classes exported from a given country for a number of technical reasons. Most important are end-use characteristics, which vary

---

The author is a professor in the Department of Agricultural Economics, North Dakota State University, Fargo.

This research was produced under USDA/CSRS Grant No. 89-2580, titled "International Marketing and Trade Policies for Northern Growers Crops." It is published as North Dakota Agricultural Experiment Station Journal Article No. 2138.

The author is grateful to Dr. S. Yang for helpful and insightful comments and to two anonymous reviewers of previous drafts of this paper. However, errors and omissions remain the author's responsibility.

substantially. This is particularly obvious in the United States, where dramatic differences exist among the diverse classes that are exported. Quality differentials have been recognized as having the potential to impact the wheat class purchased (Canada Grains Council 1985; U.S. Congress Office of Technology Assessment). These differences ultimately are manifested in the elasticity of substitution. Technically, substitutability among different classes of wheat may be perfect or imperfect, or even complementary if used for blending.

Substitution possibilities are important in understanding wheat import demand and the potential impacts of particular policies on trade. If perfect substitution is assumed, the response to changes in relative prices is infinite and prices normally would have to be assumed equal. The alternative would allow the degree of substitution to vary. An important point is that substitutability is not restricted to differences in the commodities' technical characteristics, but can refer to perceptions, delivery conditions, and other non-price factors that influence purchasing decisions. Changes in prices are just one factor affecting differentiated product trade (Ireland, pp. 2–4). As the extent of differentiation increases (decreases), the effect of price changes on quantity demanded diminishes (increases).

## Related Literature

A traditional method used to identify price response in international trade is the elasticity of substitution model (Leamer and Stern) in which logarithms of relative import ratios are regressed on logarithms of income and relative prices. Applications of this model in international wheat competition are included in Capel and Rigaux, and in Blandford. However, the functional form used in this specification is not derivable from an underlying model of optimization behavior, and important relationships among demand parameters are ignored.

The Armington model is a frequently used alternative in explaining trade flows of differentiated comodities. It distinguishes imports by origin country and reflects a two-step procedure for making import decisions. This model has restrictive assumptions, resulting from a constant substitution elasticity that is equal across pairs of commodities. In addition, the import demand function is homothetic, implying that the relative distribution of import shares does not respond to expenditures. These assumptions are rather restrictive, especially in demand analysis of products with disparate underlying characteristics, such as wheat classes. Generally, results based on Armington models have been superior for broader aggregates of commodities (Branson). In fact, for less aggregate commodities such as wheat, a naive constant share model has yielded superior predictions compared to those from an Armington-based model (Grennes, Johnson, and Thursby, pp. 72–73). Although the Armington model has been applied in a number of studies, Winters has criticized them on conceptual grounds, and restrictions imbedded in the model's specification were rejected for a number of major wheat-importing countries (Alston et al.).

The AIDS model (Deaton and Muellbauer) is an alternative specification derived explicitly from demand theory. An important feature of the AIDS model is that the expenditure levels are allowed to impact the distribution of shares. The AIDS model has been used to analyze import behavior with respect to aggregated wheat types (Agriculture Canada). In this study, classes were aggregated (e.g., U.S. Hard Red Spring was aggregated with Canadian Western Red Spring; U.S. Hard Red Winter was aggregated with Australia and Argentina; and soft wheats were aggregated within the United States and those from France), and separate import demand models were estimated for regions of the world.

Few studies have focused specifically on demand for different classes of wheat (Gardiner and Dixit). Previous researchers (Oleson; Chai; Grennes, Johnson, and Thursby) have recognized heterogeneity in wheat demand; however, most analyses treat wheat as homogeneous (Konandreas, Bushnell, and Green; Gallagher et al.). Except for the Agriculture Canada study, which analyzed regional import demands for aggregated classes, the few that have analyzed demand for wheat classes (Wang; Chai; Chang) have used loosely specified models with respect to functional form, relationships among elasticities, and, in some cases, variables included.

This study uses the dual approach to specify demand functions because it offers computational advantages without sacrificing theoretical integrity. Duality has been used in many studies. The seminal work is that of Diewert, with subsequent applications in production and in consumption.[2] The method has been used extensively in studies related to energy substitutability (Berndt and Wood; Christensen and Greene; Griffen and Gregory; Pindyck; Solow). Duality also has been used to derive transport demand functions, in which case modal demands are treated as separable inputs (Oum; Friedlander and Spady; Wilson). Applications of duality in the agricultural sector include the works of Binswanger; Lopez; and Green, Hassan, and Johnson. Swamy and Binswanger employed the use of duality in consumer demand analysis.

TL functions have had limited applications in the case of import demand, except for the studies of Burgess; Kohli (1978, 1982); and Diewert and Morrison. In these studies, the aggregate economy is modeled and input demand endogenized. Imports are treated as inputs, along with labor, capital, and energy, to produce outputs (exports, nontraded goods, and domestic sales). Implicit in these models is that all trade occurs through the production sector and that households only consume domestic goods (Woodland). An underlying purpose of these studies is to identify substitution possibilities among imports, exports, and domestic inputs in the production of aggregate outputs and to identify impacts of currency depreciation. The a priori treatment of viewing aggregate imports as inputs was criticized on a number of goods, but critical review of the data does not support the assumption (Grinols).

Many researchers (e.g., Diewert; Shephard; Deaton and Muellbauer) have shown that dual functions contain the same economically relevant information on preference structure as the utility function when regularity conditions are in force. Information on underlying demand parameters is easily retrieved from estimated dual functions. This phenomenon is computationally advantageous: since the simpler dual function or its derivatives can be estimated to retrieve preference information, the true dual function does not have to be known. Consequently, the dual function can be approximated by a flexible function meeting regularity conditions, and functions with compensated price responses can be estimated in which regularity conditions are easier to enforce. Theoretical consistency is maintained in the estimated equations because regularity conditions are a required consequence of utility maximization.

## Model Specification

This study uses TL demand functions derived from dual relationships. The two motivations for using the TL demand system are (*a*) to allow cross-elasticities to vary across pairs of imports, and, more importantly, (*b*) to allow expenditures to have a nonlinear impact on the distribution of imports. The results describe optimizing behavior in response to changes in prices subject to constraints.

Use of the dual approach to derive demand functions is intuitively appealing for analyzing imports of wheat classes. Dual functions and restrictions ensure the demand relationships are consistent with underlying economic theory. Minimization of expenditures in satisfying a given utility level is hypothesized as an accurate depiction of importer behavior. Individual countries have distinct preferences for wheat-based end products. Opportunities for substitution among wheat classes make the problem facing importers one of purchasing the least expensive mix of classes satisfying a given level of utility. With a given level of utility, importing decisions would be based on movements along the same indifference curve, reflecting changes in prices.

Duality establishes a direct correspondence among the direct utility, expenditures, and indirect utility functions. Under specific conditions, the latter two contain the same information about preferences as contained in the direct form. Duality establishes that constraints on the demand equation are a direct consequence of utility maximization. In this study, a system of demand equations is derived by specifying a utility function $U = f(I_1, I_2, \ldots, I_n)$, where $I_i$ is the consumption of wheat class $i$. Total expenditures on imported wheat are minimized subject to a budget constraint. Separability is imposed to reduce the number of parameters to be estimated.

The TL functional form (Christensen, Jorgenson, and Lau) was chosen because it results in a more general system than either the Armington or the AIDS model. Differentiation of the cost function yields a demand system, which has a flexible functional form and has several important characteristics. It is linear in parameters and satisfies all the general demand restrictions: homogeneity, symmetry, and adding-up constraints. The unrestricted TL demand function is as:

$$S_i = \alpha_i + \beta_{i1}\log(M) + \beta_{i2}\log(M)^2 + \sum_{i=1}^{n} \gamma_{ij}\log(P_i), \tag{1}$$

where $S_i$ is the share of expenditures made on the import of wheat class $i$, $M$ is real expenditures on wheat imports, and $P_i$ is the import price for class $i$. The TL demand system is similar to the AIDS specification except the latter does not include the second-order logarithmic term of expenditures, i.e., $\log(M)^2$. In the context of this specification, the AIDS model imposes the constraint that all $\beta_{i2}$'s are zero. Thus, the TL demand system is more general and results in a more realistic, though more complex, depiction of import behavior.

Adding error terms to each equation $e_i$ results in a set of expenditure equations, which were estimated. Demand restrictions imposed on the model are:

Homogeneous of degree 0: $\sum_j \gamma_{ij} = 0 \ \forall \ i$

and

Symmetry: $\gamma_{ij} = \gamma_{ji} \ \forall \ i,j.$

Since the sum of the $S_i$'s equals unity, one equation was dropped from the system to avoid singularity. Thus, adding up is a maintained hypothesis. The remaining $n - 1$ equations were estimated using seemingly unrelated regression (SUR) with parameter restrictions. The dropped equation was that of the least important type of imported wheat. Demand parameters associated with this class were derived from the relationships among parameters.

Price and income elasticities are defined (Swamy and Binswanger) as:

$$E_{ij} = \frac{\gamma_{ij}}{\hat{S}_i} + \hat{S}_j - \delta_{ij}, \qquad i \neq j;$$

$$E_{im} = \frac{\beta_{i1} + 2\beta_{i2}\log(M)}{\hat{S}_1} + 1, \qquad i < n,$$

where $\delta_{ij}$ is Kronecker delta and $\delta_{ij} = 1$ if $i = j$, and $\delta_{ij} = 0$ otherwise. The elasticities were calculated at $\hat{S}_i$, which was derived from mean values of the independent variables since observed dependent variable means may not correspond to independent variable means.

Several hypotheses were specifically tested, using the TL demand system. To test for shifts in preferences among wheat classes, the basic model was respecified as:

$$S_i = \alpha_i + \beta_{i1}\log(M) + \beta_{i2}\log(M)^2 + \sum_{i=1}^{n} \gamma_{ij}\log(P_i) + \beta_{it}\log(T), \tag{2}$$

where $T$ is a time trend. This model was estimated and tested against the model in (1). This is a joint test that inclusion of $\log(T)$ was significant across equations (i.e., $H_0$: $\beta_{it} = 0 \ \forall \ i$; $i = 1, \ldots, n$). The second hypothesis was a joint test that the parameters associated with expenditures were equal to zero ($H_0$: $\beta_{i1} = 0$; $\beta_{i2} = 0$).

**Table 1. Descriptive Market Statistics by Country, 1976/77-1988/89**

| Country | Average Market Share 1976/77–1988/89 | | | | | 1988/89 Per Capita | |
|---|---|---|---|---|---|---|---|
| | CWRS | HRS | WHI | ASW | HRW | Consumption (lbs./yr.) | Expenditures (U.S. $) |
| Hong Kong | .14 | .44 | .36 | .01 | .05 | 55 | 4.33 |
| Indonesia | .10 | .18 | .11 | .47 | .14 | 18 | 1.39 |
| Japan | .24 | .16 | .19 | .18 | .23 | 103 | 8.01 |
| Korea | .06 | .08 | .50 | .08 | .28 | 129 | 9.48 |
| Malaysia | .05 | .08 | .02 | .84 | .01 | 73 | 5.55 |
| Philippines | .06 | .62 | .30 | .01 | .01 | 37 | 2.96 |
| Singapore | .05 | .12 | .08 | .72 | .03 | 189 | 14.60 |
| Taiwan | .07 | .30 | .20 | .02 | .41 | 88 | 6.84 |
| Thailand | .02 | .41 | .13 | .33 | .11 | 6 | .52 |

## Scope of Analysis and Data Sources

A separate model was estimated for each of nine Pacific Rim countries. The Pacific Rim is an important region to analyze for a number of reasons: countries in this region have been and are expected to be important growth markets, they import from multiple origins, and, in general, they are cash customers. Each of these countries has a history of purchasing multiple classes of wheat from multiple sources. Consequently, intense international competition exists in these individual markets. Specific countries chosen in this study include Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, Philippines, Singapore, Taiwan, and Thailand. These countries are a subset of "Far East Asia" as defined by the International Monetary Fund (IMF). A number of countries in this region were not included in the analysis for one of three reasons: they were not wheat importers, they were large domestic wheat producers, or they had centrally planned economies. Wheat producing countries were deleted because of simultaneity problems not dissimilar from those encountered in Diewert and Morrison.[3] Countries that are centrally planned also were deleted since they would not necessarily have objectives compatible with expenditure minimization.[4]

The nine countries represented in this study import wheat classes that include U.S. Hard Red Spring (HRS), Hard Red Winter (HRW), White (WHI), Canadian Western Red Spring (CWRS), and Australian Standard White (ASW). Each of these was included in the analysis. Import data for U.S. wheat classes were obtained from various issues of *Grain Market News* (U.S. Department of Agriculture). Australian and Canadian wheat export data were collected from various issues of *World Wheat Statistics* (WWS) of the International Wheat Council.

A time series of delivered prices in local currencies in real terms, $P_{it}$, was derived for each class. To determine these, a time series of free-on-board (FOB) export prices was developed for each class. Ocean shipping rates from each exporting origin to the region of the specific destinations were added to the FOB price to derive the delivered price. Prices for U.S. wheat and ocean shipping rates were taken from the International Wheat Council (IWC) annual reports.

Since HRS and HRW potentially can be imported from either the U.S. Pacific Northwest (PNW) or the Gulf ports, the delivered price for these classes was derived as:

$$P_{it}^{d} = \min(P_{1it} + R_{1dt}, P_{2it} + R_{2dt}), \quad (3)$$

where $R_{kdt}$ = ocean rate from origin $k$ to destination $d$, $k = 1$ for PNW and $k = 2$ for U.S. Gulf; $P_{kit}$ = price of class $i$ at origin $k$. All prices in this equation are in U.S. dollars.

**Table 2. Parameter Estimates for Wheat Class Imports, 1976/77–1988/89**

| Country | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | $\alpha_4$ | $\beta_{11}$ | $\beta_{21}$ | $\beta_{31}$ |
|---|---|---|---|---|---|---|---|
| Hong Kong | 5.07* | −2.87 | 2.72 | | −3.07 | 2.09 | 1.79 |
| | (4.22) | (.59) | (1.00) | | (4.44) | (.76) | (1.15) |
| Indonesia | −17.82 | −23.33 | −7.72 | 65.56* | 5.07 | 6.99 | 2.06 |
| | (1.09) | (1.31) | .48 | (4.01) | (1.13) | (1.34) | (.47) |
| Japan | .18 | 3.66 | −1.02 | 1.17 | .02 | −.97 | .22 |
| | (.09) | (1.67) | (.31) | (.34) | (.04) | (1.61) | (.346) |
| Korea | −136.31 | −2.43 | 67.99 | 103.26 | 30.26 | .58 | −14.77 |
| | (1.71) | (.14) | (1.89) | (1.27) | (1.70) | (.16) | (1.84) |
| Malaysia | 2.43 | 2.69 | −.30 | | −1.76 | −1.82 | .25 |
| | (.64) | (.88) | (.18) | | (.62) | (.80) | (.19) |
| Philippines | 11.16 | −48.95* | 40.27* | | −5.22 | 23.43* | −18.98* |
| | (1.53) | (4.35) | (3.74) | | (1.45) | (4.27) | (3.62) |
| Singapore | .63 | −.06 | .51 | 1.76 | −.22 | .13 | −.36 |
| | (.46) | (.05) | (.481) | (1.31) | (.28) | (.19) | (.60) |
| Taiwan[a] | −3.22 | 11.35* | −.31 | | .99 | 3.62 | .04 |
| | (.29) | (1.22) | (.07) | | (.25) | (1.11) | (.03) |
| Thailand | | .57 | −1.52 | 2.68 | | .009 | 1.35* |
| | | (.65) | (1.64) | (1.62) | | (.01) | (1.88) |

Notes: Numbers in parentheses are $t$-values. An asterisk (*) indicates significance at the 10% level. Definitions used for parameter subscripts are as follows: 1 = CWRS, 2 = HRS, 3 = WHI, 4 = ASW, and 5 = HRW.
[a] Taiwan figures for columns headed $\alpha$ and $\beta$ are 1976/77–1987/88; figures for columns headed $\gamma$ are 1976/77–1988/89.

Published U.S. prices exclude the value of the Export Enhancement Program (EEP) subsidy, which was used in recent years for sales to the Philippines. To adjust prices for EEP sales to the Philippines, a weighted average export price was calculated to deduct from the delivered price the value of the EEP bonus paid on the proportion of purchases under EEP in that particular year. Specifically, for each U.S. class $i$, the effective delivered price was derived as:

$$P^d_{it} = \min(P_{1it} + R_{1dt}, P_{2it} + R_{2dt}) - EEP_{it}(Q_{it}), \tag{4}$$

where $P^d_{it}$ was defined earlier, $EEP_{it}$ is the average export bonus, and $Q_{it}$ is the proportion of sales of class $i$ sold with EEP subsidy in year $t$.

Canadian and Australian prices also are available from the IWC. However, these are "asking" prices and, in recent years, have diverged substantially from competitor values. Thus, a series of "realized" prices was developed for each of these classes. In the case of Canada, the weighted average value of Red Spring wheat from wheat exported to Asia (in Canadian dollars) was derived from *Grains Base* (Canada Grains Council 1989). These are "in-store," and annual average fobbing costs were added to create a representative realized FOB price. Similar procedures were used to create a FOB series for Australian exports. The ASW price before deductions for bulk handling, freight, dockage, and wheat taxes was used. The result is an average realized FOB price for ASW. Both of these were converted to U.S. dollars, and, by adding the ocean rate in year $t$, the delivered price was derived.

Using the delivered price as described above, import prices were converted to local currencies and stated in real terms as:

$$P_{it} = P^d_{it} \cdot X_t / WPI_t, \tag{5}$$

where $X_t$ is the local currency per U.S. dollar and $WPI$ is the wholesale price index (1985 = 100).

Total expenditures and expenditure shares were derived from these variables. Expenditures shares on specific classes were defined as:

$$S_{it} = (I_{it}P_{it}) \Big/ \sum_{i=1}^{n} I_{it}P_{it}, \tag{6}$$

**Table 2. Extended.**

| $\beta_{41}$ | $\beta_{12}$ | $\beta_{22}$ | $\beta_{32}$ | $\beta_{42}$ | $\beta_{1t}$ | $\beta_{2t}$ | $\beta_{3t}$ | $\beta_{4t}$ |
|---|---|---|---|---|---|---|---|---|
| | .47* | −.33 | −.25 | | | | | |
| | (4.74) | (.82) | (1.14) | | | | | |
| −17.87* | −.35 | −.46 | −.14 | 1.22* | | | | |
| (3.97) | (1.16) | (1.36) | (.45) | (3.96) | | | | |
| −.24 | −.0015 | .07 | −.02 | .01 | −.0017 | .03* | −.01 | −.01 |
| (.25) | (.04) | (1.59) | (.326) | (.23) | (.22) | (4.76) | (1.03) | (.94) |
| −23.21 | −1.68 | −.03 | .81 | 1.30 | .07* | .02* | −.12* | .09* |
| (1.28) | (1.69) | (.17) | (1.82) | (1.30) | (2.13) | (4.47) | (7.67) | (2.45) |
| | .33 | −1.82 | .25 | | | | | |
| | (.62) | (.80) | (.19) | | | | | |
| | .62 | −2.78* | 2.25* | | −.15* | .21* | −.056 | |
| | (1.45) | (4.18) | (3.54) | | (3.71) | (3.72) | (1.0) | |
| −.40 | .02 | −.02 | .06 | .06 | | | | |
| (.74) | (.16) | (.24) | (.71) | (.85) | | | | |
| | −.07 | .29 | .009 | | .04* | −.0001 | −.01 | |
| | (.22) | (1.04) | (.07) | | (2.40) | (.09) | (2.33) | |
| −1.97 | | −.009 | −.28* | .40 | | −.04* | .03* | −.005 |
| (1.54) | | (.06) | (2.01) | (1.63) | | (3.27) | (2.10) | (.19) |

where $S_{it}$ is the expenditure share on wheat class $i$ ($n = 5$), $I_{it}$ is the quantity imported, and $P_{it}$ is the price as defined earlier. Total expenditure on imported wheat was defined as real per capita expenditures in local currencies and defined as:

$$M_t = [(\Sigma\ I_{it}P_{it}/Pop_t)]/WPI_t, \tag{7}$$

where $M$ is the real per capita expenditure in local currencies, and *Pop* is population.

The IMF *International Financial Statistics* were data sources for population, foreign exchange rates, and WPI. The estimation period was 1976/77 to 1988/89 commodity years and was limited by the availability of accurate prices received for CWRS before 1976.[5]

Market shares for each class of wheat in each country are shown in table 1. Dominance of particular wheat classes varies despite other similarities of countries in this region. CWRS dominates in Japan; HRS dominates in Hong Kong, Philippines, and Thailand; WHI in Korea; ASW in Indonesia, Singapore, and Malaysia; and HRW in Taiwan. The distribution of shares ranges from being relatively equal across classes, as in Japan, to being highly dominated by one class, as in Malaysia. Per capita consumption and expenditures also vary drastically across these countries. Consumption also varies substantially, ranging from a low of 6 lbs./year in Thailand to a high of 189 lbs./year in Singapore.

In some countries, particular classes of wheat were excluded from the equation system. If imports of a particular class were equal to zero over a large part of the sample period, that class was not included in the analysis. For this reason, CWRS was dropped from Thailand, ASW from Hong Kong and Taiwan, and HRW from Malaysia and Philippines. For each of these countries, the class was dropped from derivation of $S_i$ and from the estimation. However, HRS and WHI were contained in each country's import demand system.

## Empirical Results

Parameter estimates for the TL demand systems are shown in table 2. In addition, coefficients for log($T$) are shown where significant and will be discussed later. The degrees of freedom vary depending on the number of classes and wheat parameter estimates included in the models presented. The system $R^2$s indicate relatively good explanatory power for most of the importing countries' equation systems. This may be reflective of the relatively short data set used to estimate the system. Malaysia and Thailand, however, have much lower system $R^2$s compared to the other countries.

**Table 2. Continued.**

| Country | $\gamma_{11}$ | $\gamma_{12}$ | $\gamma_{13}$ | $\gamma_{14}$ | $\gamma_{15}$ | $\gamma_{22}$ | $\gamma_{23}$ |
|---|---|---|---|---|---|---|---|
| Hong Kong | −.02 | .07 | .007 | | −.06 | .15 | −.62 |
| | (.22) | (.38) | (.06) | | (.44) | (.18) | (1.47) |
| Indonesia | .45 | −.43 | .17 | .02 | −.21 | −1.00 | .51 |
| | (1.65) | (1.44) | (.65) | (.10) | (−.47) | (1.09) | (1.50) |
| Japan | .20 | −.05 | −.11 | −.008 | (−.03) | .05 | .14 |
| | (1.20) | (1.11) | (1.87) | (.18) | .66 | (.41) | (1.06) |
| Korea | .21 | .09 | −.23 | −.51 | .44* | .22 | .47* |
| | (.60) | (.79) | (1.51) | (1.51) | (5.18) | (.52) | (2.35) |
| Malaysia | .33 | −.14 | −.07 | −.12 | | −.13 | .27* |
| | (1.44) | (.75) | (.93) | (.58) | | (.58) | (2.33) |
| Philippines | .31 | −.19 | −.32 | .19* | | .66 | −.47 |
| | (1.45) | (1.00) | (1.23) | (4.95) | | (1.45) | (1.45) |
| Singapore | −.56 | −.03 | −.11 | .41 | .29 | .35 | .75 |
| | (1.15) | (.07) | (.31) | (1.14) | (.60) | (.25) | (.98) |
| Taiwan | .15 | .28* | −.07 | | −.36* | −.30 | .09 |
| | (1.01) | (2.37) | (1.72) | | (2.75) | (1.29) | (1.05) |
| Thailand | | | | | | −.15 | −.11 |
| | | | | | | (.58) | (.40) |

The parameters for prices generally are not highly significant. Price parameters are significant in six of the nine countries. Most important is that of Korea, where five price parameters are significant. However, the price coefficients are all insignificant in Hong Kong, Singapore, and Thailand. Results from the tests of hypotheses are shown in table 3. The first column shows $F$-statistics for the null hypothesis of no shifts in preferences through time. The results indicate non-neutral shifts in preferences have occurred in five of these countries. Comparing the parameters in table 2 reveals the nature of the specific shifts. Those of particular interest indicate (*a*) positive shifts in preference for CWRS in two of the four countries importing this class; (*b*) positive and significant shifts in demand for HRS in three of the five countries (i.e., Japan, Korea, and Philippines); and (*c*) positive and significant shifts in Korea for each class, except for negative shifts in preference for U.S. WHI.

Results of hypothesis tests regarding significance of expenditures on $S_i$ also are shown in table 3. This is a joint hypothesis that both coefficients ($\beta_{i1}$ and $\beta_{i2}$) equal zero. These are shown for each of the first $n - 1$ included classes. The column shows the test's $F$-statistic for class $i$. Results indicate that the expenditure level has a significant impact on import shares in five countries. In these countries, income has a nonlinear impact on wheat class import demand.

**Table 3. Tests of Hypotheses for Wheat Class Demand Functions, 1976/77-1988/89**

| Country | Preference Shifts | Expenditures ($M$) | | | |
|---|---|---|---|---|---|
| | | CWRS | HRS | WHI | ASW |
| Hong Kong | 1.43 | 24.16* | .97 | .43 | — |
| Indonesia | 1.40 | .71 | .56 | .13 | 4.01* |
| Japan | 9.58* | .02 | 1.94 | .68 | .55 |
| Korea | 10.27* | .48 | .08 | 1.70 | .42 |
| Malaysia | 1.35 | .18 | .95 | .15 | — |
| Philippines | 23.02* | .71 | 7.66* | 5.45* | 1.31 |
| Singapore | .99 | 1.45 | .18 | 1.18 | 1.30 |
| Taiwan | 3.42* | .63 | 3.47* | 9.76* | — |
| Thailand | 3.17* | — | .14 | 1.62* | 1.08 |

Notes: $F$-values shown for tests of hypotheses. An asterisk (*) indicates significance at the 10% level.

**Table 2. Continued. Extended.**

| $\gamma_{24}$ | $\gamma_{25}$ | $\gamma_{33}$ | $\gamma_{34}$ | $\gamma_{35}$ | $\gamma_{44}$ | $\gamma_{45}$ | d.f. | System $R^2$ |
|---|---|---|---|---|---|---|---|---|
| | .41 | .42 | | .20 | | | 24 | .78 |
| | (.98) | (1.26) | | (.66) | | | | |
| .46 | .46 | −.26 | −.86* | .42 | .55 | −.19 | 30 | .94 |
| (.91) | (.33) | (.91) | (3.45) | (.82) | (1.24) | (.21) | | |
| −.16* | .008 | −.07 | .12 | −.09 | .03 | .004 | 26 | .87 |
| (2.19) | .07 | (.35) | (1.31) | (.82) | (.39) | (.05) | | |
| .20 | −.97* | −.82* | .68* | −.08 | −.22 | −.13 | 26 | .98 |
| (1.32) | (4.33) | (4.76) | (3.21) | (−.69) | (.53) | (1.29) | | |
| | | −.20* | 4.87 | | | | 26 | .31 |
| | | (1.78) | (.01) | | | | | |
| | | .79 | | | | | 23 | .87 |
| | | (1.36) | | | | | | |
| .27 | −1.34 | −.75 | .56 | −.44 | −.57 | −.67 | 30 | .63 |
| (.34) | (.93) | (1.07) | (1.02) | (.55) | (.93) | (.74) | | |
| | −.07 | −.11 | | .08 | | | 21 | .78 |
| | (.34) | (.98) | | (.78) | | | | |
| .34 | | −.02 | −.0003 | .14 | .07 | .005 | 21 | .44 |
| (1.39) | | (.08) | (.001) | (.69) | (.22) | (.02) | | |

Specific interpretation of the effects of expenditures on the distribution of imports across wheat classes can be inferred from the expenditure elasticities shown in table 4. Some expenditure elasticities are relatively large, such as those for CWRS in Hong Kong, HRS in the Philippines, ASW in Indonesia, and WHI in Taiwan. Increases in import expenditures on wheat in these countries have shifted toward increased purchases of these classes. Negative values were observed for a number of classes in several countries. However, the only negative effects which are significant are WHI in the Philippines and HRS in Taiwan. These indicate that at $\hat{S}_i$, increased expenditures reduce the proportion of imports of these classes. These impacts are of particular importance because of the prominence of these classes in these markets (table 1).

Price elasticities were derived for those countries with significant price coefficients, using $\hat{S}_i$, and are shown in table 5 for each importing country. The results indicate that elasticities vary substantially across countries. In some countries, all are essentially nil (e.g., Japan, and for Hong Kong, Singapore, and Thailand for which all price coefficients were insignificant); but in others, the price elasticities are substantially greater. Some own-price elasticities have positive signs; however, each of these is associated with price coefficients which are insignificant. Own-price elasticities tend to be greater and are more significant for white wheats (WHI and ASW).

Cross-price elasticities vary across pairs of wheat classes. The results illustrate that both substitute and complementary relationships exist among imported wheat classes. How-

**Table 4. Expenditure Elasticities**

| Importing Country | Wheat Class | | | | |
|---|---|---|---|---|---|
| | CWRS | HRS | WHI | ASW | HRW |
| Hong Kong | 3.51* | .51 | .94 | — | .03 |
| Indonesia | −.65 | .20 | 1.33 | 1.50* | 1.80 |
| Japan | .98 | 1.16 | 1.03 | .92 | .92 |
| Korea | .14 | .61 | .70 | 5.96 | .76 |
| Malaysia | 1.10 | −.24 | −.42 | .13 | — |
| Philippines | 2.75 | 1.29* | −.33* | −2.74 | — |
| Singapore | −3.13 | .79 | 2.15 | 1.09 | .90 |
| Taiwan | 2.64 | −.05* | 1.74* | — | 1.10 |
| Thailand | — | .92 | .14* | 1.59 | .94 |

* Indicates effect is significant at the 10% level.

**Table 5. Price Elasticities**

| Type | CWRS | HRS | WHI | ASW | HRW |
|---|---|---|---|---|---|
| | | | Indonesia | | |
| CWRS | 2.8 | −3.34 | 1.56 | .58 | −1.64 |
| HRS | −1.85 | −5.4 | 2.49 | 2.51 | 2.27 |
| WHI | 1.62 | 4.68 | −3.11 | −7.03 | 3.84 |
| ASW | .18 | 1.41 | −2.08 | .83 | −.32 |
| HRW | −1.22 | 3.06 | −2.75 | −.77 | −3.8 |
| | | | Japan | | |
| CWRS | .05 | −.02 | −.25 | .13 | .09 |
| HRS | −.02 | −.53 | .99 | −.21 | .27 |
| WHI | −.34 | .76 | −1.21 | .83 | −.25 |
| ASW | .19 | −.76 | .92 | −.61 | .25 |
| HRW | .09 | .21 | .21 | .18 | −.28 |
| | | | Korea | | |
| CWRS | .93 | .86 | −1.55 | −4.26 | −4.02 |
| HRS | 1.06 | 1.35 | 5.30 | 2.12 | −.98 |
| WHI | −.41 | 1.15 | −2.42 | 1.60 | .08 |
| ASW | −7.5 | 3.02 | 10.47 | −4.23 | 1.76 |
| HRW | 1.72 | −3.41 | .13 | −.43 | 1.99 |
| | | | Malaysia | | |
| CWRS | 6.33 | −3.10 | −1.47 | −1.76 | — |
| HRS | −1.96 | −2.75 | 3.85 | .86 | — |
| WHI | −2.98 | 12.38 | −10.26 | .86 | — |
| ASW | −.09 | .07 | .62 | −.001 | — |
| | | | Philippines | | |
| CWRS | −63.3 | 39.02 | 62.93 | −38.63 | — |
| HRS | −.23 | .63 | −.41 | .01 | — |
| WHI | −2.18 | −2.39 | 4.56 | .01 | — |
| ASW | 15.81 | .84 | .14 | −.16 | — |
| | | | Taiwan | | |
| CWRS | .78 | 3.49 | −.65 | — | −3.62 |
| HRS | .98 | −1.66 | .50 | — | .18 |
| WHI | −.29 | .81 | −1.34 | — | .83 |
| ASW | — | — | — | — | — |
| HRW | −.80 | .14 | .40 | — | .25 |

ever, neither of these is pervasive. Strong substitute relationships would suggest intense competition between any pair of wheat classes. The strongest substitute relationships exist between WHI and HRS in Malaysia (12.38) and between ASW and WHI in Korea (10.47). Strong substitute relationships also exist between both HRS and WHI with CWRS in the Philippines. Complementary relationships exist due to blending different types of wheat, which is common in most countries and processing plants. Strongest complementary relationships exist between ASW and WHI in Indonesia, ASW and CWRS in Korea and the Philippines, and CWRS and HRW in Taiwan. Most of these would be expected based simply on blending of wheats with disparate values of underlying protein.

## Conclusions

Emphases of some recent empirical estimates of demand have stressed the importance of allowing for differentiation by origin. However, these have implicitly assumed perfect substitutability across classes exported from a particular country. This is clearly inappropriate, particularly for export of U.S. wheat in which characteristics of different classes are distinct. Excluding, or aggregating, wheat classes impacts measures of substitution within an exporting country as well as measures across countries. Further, important underlying shifts in preferences may be masked by excluding these impacts.

Traditional models for analyzing import demand for differentiated products include the Armington and AIDS. However, the Armington model assumes (*a*) a single constant elasticity of substitution, and (*b*) homotheticity—expenditure levels do not impact shares. The AIDS model is less restrictive, but the impact of expenditures on imports is posed as a simple relationship. In this article, we estimate wheat class import demands using a more general model. A transcendental logarithmic functional form of the expenditure function was specified to derive share equations. It allows substitution elasticities to vary across pairs of imports, and the level of expenditures is allowed to impact imports in a nonlinear fashion. Each of these factors are particularly important in wheat class demand analysis. In addition, tests were conducted for shifts in preferences through time.

The model was estimated for a group of nine Pacific Rim importing countries. Results indicated that, in general, price impacts vary drastically across wheat classes and across importing countries. For example, none of the price parameters were significant in Hong Kong, Singapore, or Thailand, and only one in Japan; however, they were all significant in Korea.

These results also indicated significant shifts in preferences in five countries. While unique in each importing country, in general, these have been toward the higher protein wheats of CWRS and HRS. The most dramatic shifts have occurred in Korea, with shifts away from WHI toward each of the other classes. The level of expenditures also has a significant impact on the distribution of wheat class imports. Since the squared expenditure term was significant in five countries, the expenditure elasticity of wheat class consumption would not be constant over extended ranges. The results indicate that the impact of rising expenditures in the Pacific Rim has a non-neutral effect on wheat imports by class. Both the shifts in preferences and the expenditure elasticities, which vary substantially, have important implications for longer-term market shares among exporting countries.

These results have a number of important implications for the analysis of wheat demand and trade flows. Since the level of expenditures has an impact on the distribution of wheat import shares, the Armington model is inappropriate. Further, since the squared expenditure term was significant in a number of countries, the AIDS model would be inappropriate, at least a priori. A more general model would be preferred, particularly in analyses that differentiate to any extent beyond simply the originating country. A second important conclusion is that it is inappropriate in demand analysis to assume that wheat classes are perfectly substitutable. The range of elasticity values indicates the need to treat classes in a less aggregated manner.

[*Received July 1993; final revision received January 1994.*]

## Notes

[1] Throughout this article, we refer to "classes" to encompass wheat types, classes, and origins.

[2] Extensive reviews of the method are contained in Pope; Young et al.; Deaton and Muellbauer; Phlips; and Johnson, Hassan, and Green.

[3] This is the fundamental reason for Grinols' criticism of these specifications.

[4] Some studies use broader aggregates. Most of the studies reviewed by Gardiner and Dixit estimated a world model, and the few that did not estimated regional models without attempting to disaggregate to the level of the importing country.

[5] Prices similar to the series used could be derived for the period before 1976 from the Annual Report of the Canadian Wheat Board (reported as "Sales Value" in the financial statements). However, these are for all destinations rather than for specific geographic markets.

## References

Agriculture Canada. *Analysis of Strategic Mixes for Canadian Wheat Exports.* Guelph, Ontario: Agriculture Canada, 1987.

Alston, J., C. Carter, R. Green, and D. Pick. "Whither Armington Trade Models?" *Amer. J. Agr. Econ.* 72(1990): 455–67.

Berndt, E., and D. Wood. "Technology, Prices, and the Derived Demand for Energy." *Rev. Econ. and Statis.* 57(1975):259–68.

Binswanger, H. P. "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution." *Amer. J. Agr. Econ.* 56(1974):377–86.
Blandford, D. "Market Share Models and the Elasticity of Demand for U.S. Agricultural Exports." In *Elasticities in International Agricultural Trade,* eds., W. Gardiner and C. Carter. Boulder CO: Westview Press, 1978.
Branson, W. H. "The Trade Effects of the 1971 Currency Realignment." In *Brookings Papers on Economic Activity.* Washington DC: Brookings Institute, 1972.
Burgess, D. F. "A Cost Minimization Approach to Import Demand Equations." *Rev. Econ. and Statis.* 56(May 1974):225–34.
Canada Grains Council. *Grains Base.* Winnipeg: Canada Grains Council, 1989.
———. *Wheat Grades for Canada—Maintaining Excellence.* Winnipeg: Canada Grains Council, 1985.
Capel, R. E., and L. R. Rigaux. "Analysis of Export Demand for Canadian Wheat." *Can. J. Agr. Econ.* 22(1974): 1–14.
Chai, J. "The U.S. Food Demand for Wheat by Class." Staff Pap. No. P72–14, Dept. Agr. and Appl. Econ., University of Minnesota, May 1972.
Chang, J. "Analysis of Import Demand for Hard Red Spring and Hard Red Winter Wheat in the International Market." Unpub. M.S. thesis, North Dakota State University, 1981.
Christensen, L. R., and W. H. Greene. "Economies of Scale in U.S. Electric Power Generation." *J. Polit. Econ.* 84,4(1976):655–76.
Christensen, L. R., D. W. Jorgenson, and L. J. Lau. "Conjugate Duality and the Transcendental Logarithmic Production Function." *Econometrica* 39,4(July 1971):255–56.
Deaton, A., and J. Muellbauer. *Economics and Consumer Behavior.* Cambridge: Cambridge University Press, 1980.
Diewert, W. E. "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function." *J. Polit. Econ.* 79,3(1971):481–507.
Diewert, W. E., and C. J. Morrison. "Export Supply and Import Demand Functions: A Production Theory Approach." In *Empirical Methods for International Trade,* ed., R. C. Feenstra, pp. 207–22. London: The MIT Press, 1988.
Friedlander, A. F., and R. H. Spady. "A Derived Demand Function for Freight Transportation." *Rev. Econ. and Statis.* 62,3(1980):432–41.
Gallagher, P., M. Lancaster, M. Bredahl, and T. J. Ryan. "The U.S. Wheat Economy in an International Setting: An Econometric Investigation." ESS/USDA Tech. Bull. No. 1644, U.S. Department of Agriculture, Washington DC, March 1981.
Gardiner, W. H., and P. M. Dixit. "Price Elasticity of Export Demand: Concepts and Estimates." ERS/USDA Staff Rep. No. AGE-5860408, U.S. Department of Agriculture, Washington DC, 1986.
Green, R., Z. Hassan, and S. Johnson. "Alternative Estimates of State and Dynamic Demand Systems for Canada." *Amer. J. Agr. Econ.* 60(1978):93–107.
Grennes, T., P. R. Johnson, and M. Thursby. *The Economics of World Grain Trade.* New York: Praeger Publishers, 1977.
Griffen, J., and P. Gregory. "An Intercountry Translog Model of Energy Substitution." *Amer. Econ. Rev.* 66(1976):845–57.
Grinols, E. L. "Comments." In *Empirical Methods for International Trade,* ed., R. C. Feenstra, pp. 223–30. London: The MIT Press, 1988.
International Monetary Fund. *International Financial Statistics.* Annual yearbook, International Monetary Fund, Washington DC. Annual issues, 1984–86.
International Wheat Council. *World Wheat Statistics.* International Wheat Council, London. Annual issues, 1960–85.
Ireland, N. *Product Differentiation and Non-Price Competition.* New York: Basil Blackwell, 1987.
Johnson, S., Z. Hassan, and R. Green. *Demand Systems Estimation.* Ames IA: Iowa State University Press, 1984.
Kohli, U. R. "A Gross National Product Function and the Derived Demand for Imports and Supply of Exports." *Can. J. Econ.* XI,2(1978):167–82.
———. "Relative Price Effects and the Demand for Imports." *Can. J. Econ.* XV,2(1982):205–19.
Konandreas, P., P. Bushnell, and R. Green. "Estimation of Export Demand Functions for U.S. Wheat." *West. J. Agr. Econ.* 3(1978):39–49.
Leamer, E., and R. Stern. *Quantitative International Economics.* Boston: Allyn and Bacon, 1970.
Lopez, R. E. "Applications of Duality Theory in Agriculture." *West J. Agr. Econ.* 7(1982):353–66.
Oleson, B. "Price Determination and Market Share Formation in the International Wheat Market." Unpub. Ph.D. diss., University of Minnesota, 1979.
Oum, T. H. "Derived Demand for Freight Transport and Inter-Modal Competition in Canada." *J. Transport Econ. Policy* 12(1978):149–68.
Phlips, L. *Applied Consumption Analysis.* New York: North-Holland, 1983.
Pindyck, R. S. "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison." *Rev. Econ. and Statis.* 61(1979):169–79.
Pope, R. D. "To Dual or Not to Dual." *West. J. Agr. Econ.* 7(1982):337–52.
Shephard, R. *Theory of Cost and Production Functions.* Princeton: Princeton University Press, 1970.
Solow, J. L. "The Capital-Energy Complementary Debate Revised." *Amer. Econ. Rev.* 77(1987):605–14.

Swamy, G., and H. Binswanger. "Flexible Consumer Demand Systems and Linear Estimation: Food in India." *Amer. J. Agr. Econ.* 65(1983):675–84.

U.S. Congress, Office of Technology Assessment. "Grain Quality in International Trade: A Comparison of Major U.S. Competitors." OTA Pub. No. F-402, Office of Technology Assessment, Washington DC, February 1989.

U.S. Department of Agriculture. *Grain Market News.* USDA, Washington DC. Various issues, 1976–89.

Wang, Y. "The Demand and Price Structure for Various Classes of Wheat." Unpub. Ph.D. diss., The Ohio State University, 1962.

Wilson, W. W. "Estimation of Modal Demand Elasticities in Grain Transportation." *West. J. Agr. Econ.* 9(1984): 244–58.

Winters, L. A. "Separability and the Specification of Foreign Trade Functions." *J. Internat. Econ.* 17(1984): 239–63.

Woodland, A. D. "Comments." In *Empirical Methods for International Trade,* ed., R. C. Feenstra, pp. 251–56. London: The MIT Press, 1988.

Young, D., R. Mittelhammer, A. Rostamizadeh, and D. Holland. "Duality Theory and Applied Production Economics Research: A Pedagogical Treatise." College of Agr. Res. Center Bull. No. 0962, Washington State University, 1985.