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Export Demand for U.S. Wheat

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ABSTRACT

An 18-equation econometric analysis of demand for U.S. wheat exports, 1961-83, indicated importers' wheat production, importers' income, and the U.S. wheat price were major demand determinants. Average 1-year price, income, and exchange rate elasticities were inelastic: -0.31, 0.48, and -0.24.

Keywords: Wheat, exports, demand, price, income, elasticity.

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CONTENTS

SUMMARY

Our econometric analysis of annual data, 1961-83, identifies the major demand determinants for U.S. wheat exports. We quantified and ranked those determinants in order of importance. Wheat production in the importing countries emerged as the most important determinant, followed by income in importing countries. The U.S. wheat price and the Australian wheat price ranked third and fourth.

We also estimated the annual average U.S. export response to changes in some of those demand determinants (that is, price, income, and exchange rate elasticities). To obtain elasticity estimates with respect to the world, we summed country elasticities, weighted by their share of the U.S. export market, across 18 equations. Our estimates of price, income, and exchange rate elasticities of export demand for U.S. wheat were -0.31, 0.48, and -0.24.

U.S. policymakers have little control over the largest determinants of demand for U.S. wheat exports, wheat production and national income in the importing countries. An inelastic price elasticity indicates that U.S. exporters could not increase revenues with price cuts in the short run. However, longrun responses might differ as importers and competing exporters have time to adjust production and import and export policies.

(The price elasticity of U.S. exports is the percentage change in exports resulting from a 1-percent change in price. The elasticity is elastic if the percentage change in exports exceeds the percentage change in price, unitary-elastic if the percentage changes are equal, and inelastic if the percentage change in exports is less than the percentage change in price.)

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INTRODUCTION

Since U.S. agricultural exports rose from the early 1970's through fiscal 1981, the Nation's agricultural sector has become increasingly dependent on foreign markets. During the past 10 years, agricultural exports ranged from nearly $24 billion (fiscal 1977) to almost $44 billion (fiscal 1981), and receded to a little above $26 billion in fiscal 1986. Within that time, wheat was the third-ranked agricultural commodity exported (led by corn and soybeans) in terms of value.

Declining exports clearly demonstrated U.S. agriculture's dependence on foreign markets, and falling farm prices triggered large Federal outlays in producer support payments. Our objectives were to identify the major factors affecting the demand for U.S. exports of wheat, and quantify and rank those factors in order of importance.

METHODOLOGY

U.S. wheat export markets were ranked for 1961-83. Exports to the top 17 markets (Japan, the Soviet Union, the European Community, China, Egypt, Brazil, India, South Korea, Venezuela, Nigeria, the Philippines, Mexico, Taiwan, Peru, Chile, Portugal, and Morocco) represented approximately 80 percent of all U.S. wheat exports during that period. Country-specific import demand functions were estimated for each of these countries and for a rest-of-the-world residual.

Econometric Approach Used

Price elasticities of demand for U.S. agricultural exports are in question. In Gardiner and Dixit's review, published estimates of price elasticities of U.S. wheat exports range from -6.72 to -0.14 (3, pp. 14-15). 1/ Each elasticity is contingent upon the method used, the time period of estimation, the type of data (monthly or annual), and quality of data available to researchers. We chose to directly estimate country-specific import demand equations for U.S. wheat using commodity data within USDA and macroeconomic data from the International Monetary Fund (4, 12).

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*Authors contributed equally.

1/ Underlined numbers in parentheses refer to sources listed in the References section.

An advantage of the econometric approach lies in isolating the effect of price and other variables on exports. For example, with one equation it is possible to obtain income, price, cross-price, and exchange rate elasticities. A further advantage of this approach is that all elasticities can be obtained using a consistent methodology over similar time periods. Major disadvantages of the econometric approach include the intense data requirements necessary to achieve useful estimates and results are often not robust across estimation methods.

We chose to estimate country-specific equations to avoid several problems inherent in estimating a single aggregate import equation for a commodity. A few of the problems of the single equation approach are noted. First, an aggregate equation imposes one specification on all countries. However, different countries have different substitution possibilities that require, for example, unique prices in each country equation. Second, country-specific equations avoid the problems of indices. For example, a single-world equation requires use of a broad exchange rate index. Third, countries have specific elasticities. High-income countries like Japan are not as likely to spend increased income on food imports as middle-income countries like Mexico. A rise in total world income does not reveal the countries that benefitted and may lead to unrealistic income elasticities. Fourth, simultaneous equation bias is likely when U.S. exports to all countries are aggregated. Imports of U.S. products by one or two countries may not influence U.S. prices, but aggregate exports may.

Theoretical Derivation of the Model

We specified models by hypothesizing that countries' import decisions are a two-step process. First, a government decides how much of a product needs to be supplied to the domestic market to achieve government objectives. Second, a government minimizes the cost of importing subject to the total amount of the product required. At a general level, this approach is similar to that of Armington's first assumption that importing is a two-step process (1). However, Armington imposed other more restrictive assumptions, which we do not impose.

We assumed government objectives were to stabilize domestic prices or set $\dot{P}_d = 0$ where $\dot{P}_d$ represents domestic retail price changes. From this we get total desired retail imports Y^* as a function of domestic variables such as income, production, and an index of prices. We assume imports from specific countries M_i are transformed into retail imports via $f(M_i) = Y^*$ where M_i is a vector of imports from i supplying nations. Given Y^* we can assume importers desire to minimize the cost of importing. The cost function representing solutions to this choice problem is:

$$C(P_i\ Y^*) = \text{Min}\ P_iM_i \quad \text{ST:} f(M_i) = Y^* \tag{1}$$

If importers are price takers and optimal behavior leads to noncorner solutions, the demand functions can be written $M^*(P_i, Y^*)$, where P_i is a vector of import prices and M^* denotes optimal levels of the choice variable M. This demand function can be portrayed as inheriting properties that are derived from optimization behavior (see Varian (13) for a description).

However, in our instance, imposing such restrictions in estimation is difficult for two reasons. First, it is possible to argue that the function

$f(M_i)$ is additive in imports. In this case, demand functions are not continuous. Second, our ability to impose restrictions implied by cost minimization on our estimators is reduced if Y^* is not explicitly represented in the equation. For example, suppose the solution to the first-stage decision can be written $Y(\underline{a})$ where $\underline{a}$ is a vector of exogenous variables that determines the level of total government imports. If $\underline{a}$ does not represent output prices, properties of $M(P_i, Y^*(\underline{a})) = m(P_i, \underline{a})$ are not readily apparent. To derive such properties is beyond the scope of this report.

Furthermore, one objective of this study is to break the price P_i into two components, an exchange rate component and a price component, and compare elasticities. Deriving the properties of an import demand function whose price arguments are split into two components is problematic at best. When augmented with the problems of preserving such properties by substituting $Y(\underline{a})$ for Y^*, such an exercise could become extremely difficult.

Thus, the dual objectives of price stabilization and import cost minimization are used only to specify the import demand equations. These objectives are not used to impose restrictions on estimators. In this case, the major hypothesis tested is that the variables significantly contribute to explaining the variance of imports. The only other hypothesis tested is that the variables are the correct sign.

The Specification

We assume production is fixed and known at the time of the import decision. The change in domestic prices, $\dot{P}_d$, is a function of excess demand. By setting excess demand equal to zero, importers set $\dot{P}_d$ equal to zero. Excess demand can be written:

$$PR + Y^* - D(PI, GNP, Z) = 0 \tag{2}$$

where PR is fixed domestic production, Y^* is quantities imported, D(.) is domestic demand which, in this case, represents the sum of input demands and final consumer demands, PI represents domestic prices lumped into one index, GNP is domestic income, and Z represents other factors that determine domestic demand and are assumed to be distinct for each country. Thus,

$$Y(\underline{a}) = D(PI, GNP, Z) - PR = Y(PR, PI, GNP, Z).$$

From equation 1, imports from the United States can be written as

$$M(P_i, Y^*(\underline{a})).$$

Substituting in for $Y^*(\underline{a})$, we get

$$M^*(P_i, PR, PI, GNP, Z). \tag{3}$$

By breaking the U.S. price (P_i) into an exchange rate (EX) and U.S. export price components (P_e), imports can be written as

$$M^*(EX, P_e, PI, PR, GNP, Z) \tag{4}$$

Thus, the generic equation used to explain imports from the United States is written as a function of:

The exchange rate between the importer and the United States (EX),
U.S. and competing prices (P_e),
a domestic price index (PI),
the domestic level of production of the commodity (PR),
domestic income (GNP), and
any country-specific variable (Z).

For each country, we combine the nominal GNP and domestic price index into one variable called real GNP. Although domestic demands are typically written to be homogenous degree zero, we did not normalize all price variables on the domestic price index.

The Estimation Procedure

To keep our functional form general, the country-specific models were specified as quadratic in most variables. Limited degrees of freedom prevented us from using interaction terms and specifying a complete Taylor series approximation. Country analysts helped us identify possible country-specific variables, or the Z's. The estimation process can be described in several steps.

1. After identifying the country-specific variables (the Z's), we checked for multicollinearity in various subperiods 1961-68, 1969-76, and 1977-83. We dropped many competitors' prices that were collinear with the U.S. gulf price.

2. We replaced U.S. prices with an instrument (OLS estimate of the U.S. price). The instrument equation for prices was specified as a function of the same exogenous variables in each country's import equation. To ensure identification of the import equation, we used, in our price equation, higher order terms of other exogenous variables in the import equation (2, ch. 4). For example, if wheat production and wheat production squared were specified as exogenous variables in our import equation, these variables and wheat production cubed appeared in our price equation. Assumptions allowing this procedure are presented by Kelejian (5).

3. We econometrically estimated the country-specific and rest-of-world export demand equations using 1961-83 annual data. We stacked commodity equations by region and obtained both three-stage and SUR (seemingly unrelated regression) estimators. SUR (three-stage) estimators are considered efficient relative to OLS (two-stage) estimators. (All estimation and most of the data transformation were done on a microcomputer using the Regression Analysis of Time Series (RATS) statistical package. RATS allows for correction of serial correlation before stacking equations into a SUR framework. We called those estimators CSUR estimators. Since SUR estimators are adjusted by the variance-covariance matrix of error terms, this correction procedure is critical. However, the package did not allow for correction after obtaining SUR estimators. Some models show slight evidence of serial correlation. This would be critical if an iterative SUR procedure were used. However, we did not obtain iterative SUR estimators and are willing to accept serial correlation, which may later prove helpful for forecasting.)

4. We used a test described by Wu to see if SUR (OLS) estimators were significantly different from the three- (two-) stage estimators (2, p. 314). In every case, they were not significantly different and thus we report only the SUR estimators. Since distinct instrument equations on prices were obtained for each country, these results imply that each purchasing country is a price taker on the world wheat market.

5. We used dummy variables and the F test to test two hypotheses: (1) price elasticities changed significantly after 1979, and (2) models with quadratic terms were significantly different from linear models.

6. Finally, we searched for the best income variable. In some countries, foreign exchange reserves gave a better fit than real GNP or GDP. Problems with obtaining an European Community-wide GNP free of exchange rate influences led to the use of dollar reserves as the income variable for that equation. In general, searching for the best explanatory variable can lead to biased estimators. However, we tested several representations of the same variable (income) only when the first representation was not significant.

Eleven country-specific export demand equations for U.S. wheat were estimated in SUR systems using annual data. Equations for the Soviet Union, EC-9, China, India, Venezuela, Portugal, and the rest-of-world were estimated as single equations, using generalized least squares (GLS) or OLS, because their respective data periods were not equal for all of the variables (the microcomputer software required equal observations of all equations in a SUR system). To obtain adequate fits for the Soviet Union equation, we had to break it into a total import equation and an import share equation, a procedure described in Sirhan and Johnson (10). Results of these equations and their fit statistics are reported in table 1.

Ranking Tables

Having obtained the equations, we calculated the average annual influence of independent variables on imports of U.S. wheat. These impacts are in the same units as the dependent variable (1,000 metric tons).

We calculated the influence of linear variables (significant at the 0.1 level) on U.S. wheat exports by multiplying the beta coefficients by the mean change of the independent variable. In nonlinear models, the first derivative with respect to the variable of interest supplied the coefficient that we multiplied by the mean change of the independent variable. (This mean change is an average of the absolute value of the first differences of the independent variables.) These average annual effects of exogenous variables on imports are listed in table 2 for each of 17 equations (variables were not significant in the China equation). The effects were summed by variable across the 17 equations to assess the overall relative importance of the independent variables, or demand determinants, for U.S. wheat exports. We excluded the USSR from the total because the USSR results came from a total import equation, not just imports from the United States.

The ranking tables are useful because they are not unit free. A variable with a low coefficient can be shown to have a large effect on imports of U.S. wheat

Table 1--Right hand side of equations estimating U.S. wheat exports, by country 1/

Variables/data	Japan	USSR	EC-9	China	Egypt	Brazil
Constant	-1,735 (-1.17)	-76,259 (-2.61)**	-5,471 (-1.95)**	-10,693 (-0.82)	-43.15 (-.04)	-755.2 (-1.58)*
Wheat production	-1.166 (-2.38) .0004 (1.46) *	-.1580 (-2.67)***	-.0571 (-1.79)**	.0405 (.40)	.1295 (.27)	-.6206 (-3.93)***
Population	--	590.9 (3.04)***	--	.0097 (.51)	--	--
Real GNP 2/	7.570 (5.74) -.0029 (-5.39)	--	--	--	.0772 (2.95)***	8.623 (3.85)***
Foreign exchange reserves	--	--	.0137 (1.23)	--	--	--
U.S. wheat price, gulf 3/	-655.8 (-1.60) 129.2 (2.22)	-81.52 (-1.82)**	-3.28 (-1.12)	259.7 (.13)	-7.337 (-1.98)**	2.296 (.24)
Australian wheat price	20.48 (2.76) -.0920 (-3.79)	--	--	27.30 (.68)	--	--
Argentine wheat price	--	--	--	--	--	.0775 (.01)
Exchange rate 4/	-1.415 (-.85)	--	1,815.7 (2.29)	--	299.8 (.98)	-1.468 (-1.05)
P.L. 480	--	--	--	-- --	-.0002 (-1.20)	-.0005 (-2.10)**
Livestock	--	--	.0799 (3.39)***	--	--	--
Freight rates	24.95 (2.13)	303.03 (1.10)	-42.59 (-1.06)	--	29.99 (1.23)	16.00 (.86)
Dummy 5/	--	--	--	-2,134 (-.75) -2,883 (-1.67)	-878.4 (-4.87)***	--
$\bar{R}^2$	.94	.64	.75	.47	.69	.90
Durbin-Watson	1.692	1.630	2.22	1.931	1.798	2.327
F 6/	168***	8.49***	10***	3.20**	21***	85***
Degrees of freedom	50	13	14	11	42	51
Estimator 7/	SUR	GLS	GLS	OLS	SUR	CSUR
Data period	1962-83	1965-83	1961-82	1965-82	1961-82	1962-83

See notes at end of table.

Continued--

Table 1--Right hand side of equations estimating U.S. wheat exports, by country 1/--Continued

Variables/data	India 8/	S. Korea	Venezuela	Nigeria	Philippines	Mexico
Constant	7,714 (6.19)***	-946.8 (-2.46)***	-417.0 (-1.05)	-1,936 (-3.90)***	895.8 (4.11)***	124.9 (.38)
Wheat production	-103,550 (-1.85)**	2.975 (2.30)	--	--	--	-.7107 (-7.71)***
Wheat stocks	142,467 (1.13)	--	--	--	--	--
Rice stocks	-872,478 (-2.73)***	--	--	--	--	--
Real GNP 2/	--	25.00 (5.28)***	1,381 (3.50) -355.2 (-2.67)	8.616 (3.05) -.0142 (-3.67)	7.329 (5.78) -.0103 (-4.38) ***	55.56 (2.68) -.3867 (-.90) **
Foreign exchange reserves	.9063 (2.63)***	--	--	--	--	--
U.S. wheat price, gulf 3/	-1,197 (-1.55)*	184.8 (1.35)	-4.391 (-.71) .0035 (.14)	-5.371 (-.78) .0250 (.95)	-533.7 (-2.72) 94.57 (3.07)	2.088 (.29) -.0166 (-.55)
Australian wheat price	39.72 (2.11)**	2.524 (.71)	--	--	5.451 (1.31) -.0352 (-2.42)	--
Argentine wheat price	--	--	--	--	--	6.226 (1.19)
U.S. rice price, gulf 9/	--	--	--	5.504 (3.73) -.0052 (-4.23) ***	--	--
Exchange rate 4/	-91.09 (-.30)	-2.879 (-1.96)**	-99.42 (-.98)	-84.24 (-.50)	-54.56 (-3.30)***	2.881 (.73)
P.L. 480	--	-.00002 (-.11)	--	--	--	--
Freight rates	--	-5.486 (-.34)	19.29 (1.89)	27.42 (4.52)	-6.465 (-1.03)	--
Dummy 5/	--	-3.02 (-2.12)**	--	--	--	--
R^2	.74	-.91	.70	.91	.84	.83
Durbin-Watson	2.377	1.980	1.955	1.404	2.331	2.475
F 6/	9.74***	98***	8.84***	82***	56***	53***
Degrees of freedom	15	50	15	42	50	51
Estimator 7/	OLS	SUR	OLS	SUR	SUR	SUR
Data period	1961-83	1962-83	1962-83	1961-82	1962-83	1962-83

See notes at end of table.

Continued--

Table 1--Right hand side of equations estimating U.S. wheat exports, by country 1/--Continued

Variables/data	Taiwan	Peru	Chile	Portugal	Morocco	Rest of world
Constant	2,772 (1.86)**	57.32 (.66)	-540.6 (-3.00)***	873.6 (.69)	-1,219 (-2.85)***	11,310 (6.62)***
Wheat production	--	--	-.0594 (-.65)	--	.2460 (3.47)	-.0512 (-3.52)***
Real GNP 2/	.0949 (3.52) -.000003 (-1.64) ***	--	--	-265.3 (-.97) 16.06 (1.00)	.7481 (1.97)**	--
Foreign exchange reserves	--	.3648 (3.21)***	.2198 (2.47) -.00004 (-2.13) **	--	--	.04 (2.43)**
U.S. wheat price, gulf 3/	-826.5 (-5.73) 130.5 (5.97) *	7.813 (1.67)	13.70 (4.46) -.0472 (-3.40)	3.646 (.69) -.0156 (-.67)	2.590 (1.81)	-6.33 (-.98)
Argentine wheat price 10/	6.335 (1.70) -.0251 (-1.94)	-6.878 (-1.38)	-.359 (-3.04)***	--	--	2.50 (.53)
Exchange rate 4/	-33.41 (-1.54)*	-.0168 (-.10)	--	2.187 (1.48)	304.1 (3.71)	-17.85 (-1.76)*
P.L. 480	--	-.0016 (-2.88)***	-.0011 (-5.48)***	-.0004 (-.83)	-.0012 (-4.54)***	--
Freight rates	-5.619 (-.55)	7.318 (.97)	13.22 (1.83)	10.51 (1.16)	-14.68 (-1.65)*	-10.47 (-.24)
Dummy 5/	--	--	124.2 (-2.99)***	--	--	1,634 (2.38)**
$\bar{R}^2$	.89	.79	.96	.75	.64	.67
Durbin-Watson	2.561	1.665	2.193	2.124	2.246	2.195
F 6/	93***	56***	278***	14***	20***	10***
Degrees of freedom	50	51	51	15	42	14
Estimator 7/	CSUR	SUR	SUR	OLS	SUR	OLS
Data period	1962-83	1962-83	1962-83	1961-83	1961-82	1961-82

-- = variable not in equation. 1/ T-values in parentheses. Significance levels (1-tail test): * = 10%, ** = 5%, *** = 1%. Quadratic terms indicated with beta estimates and T-values beneath the first degree variable, and the significance level of the combined T-values at the bottom. 2/ Nominal GNP in Egypt and the Philippines. 3/ Western white wheat price at Portland for Japan, China, Korea, and Taiwan. Weighted average of hard red spring and Western white for Philippines. 4/ Foreign currency units per dollar, differenced in Korea. 5/ In China, the cultural revolution; in Egypt, the 1967 war; in Korea, change in average price elasticity after 1978; in Chile, the Allende regime; in rest-of-world, the Soviet grain embargo. 6/ Test of significance of model, see Chow (2, pp. 58-60). 7/ SUR = seemingly unrelated regression; GLS = generalized least squares; OLS = ordinary least squares; CSUR = SUR corrected for serial correlation. 8/ Production and stocks on per-capita basis. 9/ Weighted average of Houston and Thai rice prices. 10/ Canadian wheat price in Taiwan. Wheat stocks in Chile.

Table 2--Ranking of foreign demand determinants by average annual effect on U.S. wheat exports, 1961-83

Market	Market share 1/	Ranking share 2/
	Percent	1,000 metric tons
Japan	11.5	
Wheat production		178
Soviet Union 3/	10.9	
Wheat production		2,887
Population		1,371
U.S. wheat price, gulf		1,165
EC-9	8.8	
Wheat production		192
Livestock		151
China	8.3	
Variables not significant		
Egypt	6.0	
U.S. wheat price, gulf		105
Nominal GNP		62
Dummy variable for 1967 war		42
Brazil	5.3	
Wheat production		309
Real GNP		138
P.L. 480		49
India	4.4	
Stocks of rice		977
Australian wheat price		673
U.S. wheat price, Portland		454
Wheat production		406
Foreign exchange reserves		405
S. Korea	4.2	
Real GNP		139
Exchange rate		81
Venezuela	2.5	
Variables not significant		
Nigeria	2.2	
Average price of U.S. and Thai rice		283
Philippines	2.2	
Nominal GNP		120
Exchange rate		29
Mexico	2.0	
Wheat production		358
Real GNP		101

See notes at end of table

Continued--

Table 2--Ranking of foreign demand determinants by average annual effect on U.S. wheat exports, 1961-83--Continued

Market	Market share 1/	Ranking share 2/
	Percent	1,000 metric tons
Taiwan	2.0	
U.S. wheat price, Portland		314
Real GNP		77
Exchange rate		15
Peru	1.8	
Foreign exchange reserves		67
P.L. 480		29
Chile	1.4	
P.L. 480		61
Foreign exchange reserves		55
Dummy for Allende regime		12
Stocks of wheat		1
Portugal	1.3	
Variables not significant		
Morocco	1.0	
P.L. 480		156
Foreign exchange reserves		76
Freight rates		42
Rest of world	24.2	
Wheat production		516
Foreign exchange reserves		262
Exchange rate		232
Dummy for 1980 USSR grain embargo		74
Total, excluding USSR	100.0	
Wheat production		1,959
Income (real or nominal GNP or nominal foreign exchange reserves)		1,502
U.S. wheat price (gulf or Portland)		873
Australian wheat price		673
Exchange rate		357
P.L. 480		295
Livestock		151
Freight rates		42

1/ Average share of U.S. export market, 1961-83.
2/ The annual average variation in U.S. wheat exports associated with the annual average variation in the respective demand determinants (all significant at the 10% level).
3/ From model of total wheat imports.

if the average annual change in that variable is large. For example, over the period of estimation, incomes have a large effect on imports of U.S. wheat largely because of the magnitude of changes in incomes.

Elasticities

Elasticities in the linear models were calculated as the product of the estimators ($\hat{b}$) times the mean of the independent variable ($\bar{x}$) divided by the mean of the wheat exports ($\bar{y}$), $E = \hat{b}\bar{x}/\bar{y}$. Elasticities from each of the 17 equations were first weighted by their respective share of U.S. wheat exports, 1961-83, and then added to get aggregate U.S. elasticities with respect to the world.

Elasticities from nonlinear models required taking the first derivative of the equation with respect to the variable of interest, calculated at its mean. We then multiplied this estimator by the mean of the independent variable and divided by the mean of the imports. T statistics for elasticities derived from nonlinear variables were more complex than typical T statistics and involved variances and covariances between estimators. Elasticities from the equations are listed in tables 3 and 4.

We summed the weighted country elasticities three ways. First, we totaled the elasticities that were statistically significant at the 10-percent level and the right sign. The second alternative was to total all elasticities of the right sign, both significant and nonsignificant. The third total is a summation of all the elasticities, including those with wrong signs. The first total is equivalent to assigning a zero value to those nonsignificant and wrong-sign elasticities that were omitted. Since all these individual econometric estimators are the best linear unbiased estimators (BLUE), and none approximated zero in value, the second and third totals appear more relevant than the total that substitutes a zero value when a BLUE is available.

RESULTS FROM EQUATIONS

The ranking table presents the average annual effect, on U.S. wheat exports, of each of the variables significant at the 0.1 level in the wheat equations (table 2). These effects, measured in 1,000 metric tons and summed across the equations, allow the quantification and ranking of the relative importance of the individual variables on the demand for U.S. wheat exports.

Customers' Wheat Output Largest Determinant

The most important variable affecting U.S. wheat exports was wheat production in importing countries, particularly in the Soviet Union, India, Mexico, and Brazil.

Foreign Income Ranked Second

Rising income, whether measured as real GNP or foreign exchange reserves, was the second major factor affecting 1961-83 U.S. exports of wheat. In some countries, the effect comes not from high elasticities but from high rates of income growth.

Table 3--Price, income, and exchange rate elasticities, U.S. wheat exports, 1961-83

Market	Elasticities 1/ Price	Elasticities 1/ Income	Elasticities 1/ Exchange rate	Market share 2/	Weighted elasticities 3/ Price	Weighted elasticities 3/ Income	Weighted elasticities 3/ Exchange rate
Japan	4/0.08 (.02)	0.32 (.54)	-0.17 (-.85)	0.115	0.009	0.037	-0.019
Soviet Union	-1.04 (-1.82)**	--	--	.109	-.113**	--	--
EC-9	-.17 (-1.12)	.21 (1.23)	4/1.01 (2.29)	.088	-.015	.018	.089
China	4/.44 (.13)	--	--	.083	.036	--	--
Egypt	-.54 (-1.98)**	.37 (2.95)***	4/.45 (.98)	.060	-.033**	.022***	.027
Brazil	-.16 (-.24)	1.50 (3.85)***	-.04 (-1.05)	.053	-.008	.080***	-.002
India	-1.28 (-1.55)*	.68 (2.63)***	-.69 (-.30)	.044	-.056*	.030***	-.030
S. Korea	4/ 5/.54 (.59)	1.15 (5.28)***	--	.042	.022	.048***	--
Venezuela	-.72 (-.62)	.92 (.88)	-.75 (-.98)	.025	-.018	.023	-.018
Nigeria	-.02 (-.01)	.62 (.32)	-.15 (-.50)	.022	-.0004	.014	-.003
Philippines	-.004 (-.03)	1.65 (6.80)*	-.67 (-3.30)***	.022	-.0001	.036*	-.014***
Mexico	-1.15 (-.18)	1.95 (1.71)**	4/.16 (.73)	.020	-.023	.039**	.003
Taiwan	-.61 (-1.35)*	.96 6/***	-2.80 (-1.54)*	.020	-.012*	.019*	-.055*
Peru	4/2.03 (1.67)	.41 (3.21)***	-.56 (-.10)	.018	.036	.007***	-.010
Chile	4/1.20 (.46)	.26 (1.73)**	--	.014	.017	.004**	--
Portugal	4/.12 (.25)	.88 (.67)	4/3.33 (1.48)	.013	.002	.011	.043
Morocco	4/1.12 (1.81)	.69 (1.97)**	4/1.19 (3.71)	.010	.011	.007**	.012
Rest of world	-.12 (-.98)	.35 (2.43)**	-.37 (-1.76)*	.242	-.029	.084**	-.088*
World total				1.000			
Right sign, significant at 10% level					-.21	.38	-.16
Right sign					-.31	.48	-.24
All					-.17	.48	-.06

Significance levels (1-tail test): * = 10%, ** = 5%, *** = 1%.
-- = data not available.
1/ T-values in parentheses.
2/ Average share of U.S. export market, 1961-83.
3/ Elasticities times market share, computed from unrounded data.
4/ Wrong sign.
5/ After 1978.
6/ Denominator of T-value extremely small.

Table 4--Cross-price elasticities for U.S. wheat exports, 1961-83

Competitor/ market	Competitor's wheat price	T-statistic	Market share 1/
Australian wheat:			
Japan	0.06	0.22	0.115
China	1.71	.68	.083
India	1.50	2.11**	.044
Korea	.27	.71	.042
Philippines	2/-.32	-.46	.022
Argentine wheat:			
Brazil	.006	.01	.053
Mexico	1.39	1.19	.020
Peru	2/-1.70	-1.38*	.018
Canadian wheat:			
Taiwan	.11	.11	.020

Significance levels (1-tail test): * = 10%, ** = 5%.
1/ Average share of U.S. export market, 1961-83.
2/ Wrong sign.

We got low (inelastic) and insignificant income elasticities for the EC and Japan, both high-income regions (table 2). This may support the theory of diminishing marginal propensity to consume food items, or concave Engel curves. Future increases of U.S. wheat exports to these regions will likely be due to factors other than rising incomes.

High (elastic) income elasticities were estimated for Mexico, the Philippines, and Brazil, countries with fast-growing populations. Recent declines in real incomes in these countries may explain some recent declines in U.S. exports. Equations with lower income elasticities (Peru, Chile, Morocco, and the rest of the world) were estimated using a foreign reserves variable. Such a measure may be more constrained than GNP, producing smaller elasticity estimates. Or, poor countries may be more aware of their income constraints and less likely to spend new income outside their countries. Debt service payments may limit income available for imports. Neither foreign reserves nor GNP accurately measure disposable income, for which we had no data.

The significance of changing production (which shifts shortrun supply curves) and changing income (which shifts domestic demand curves) means these variables can go a long way in explaining future wheat imports of many countries. In the short run, governments in these countries may set retail sale targets to achieve specific goals, predict domestic production, and then import the rest. In the longer run, governments can use price incentives or input subsidies to increase domestic production.

U.S. Wheat Price Ranked Third

Countries' immediate response to U.S. wheat price changes vary greatly but were usually small. Models of India, the USSR, Taiwan, and Egypt produced statistically significant elasticities (table 3). The first two countries show an elastic shortrun price response, indicating a price sensitivity for U.S. wheat purchased. The inelastic response of Taiwan and Egypt may indicate bilateral trade commitments with the United States that are stronger than those of India and the USSR. In contrast, price elasticity estimates are not statistically significant for Japan, the Philippines, the EC, Brazil, and Korea, which are also strong U.S. trading partners.

The low or insignificant price elasticities indicate that much of the world wheat market over the 1960's and 1970's may have functioned as a contract market rather than an auction market. Okun described a contract market as one where steady relationships develop between customer and supplier based on implicit trusts and a desire to avoid the disruption and cost of searching for the best deal (7). For example, Japan may purchase U.S. wheat even when a competitor's wheat price is slightly cheaper to avoid disrupting a relationship that extends beyond the wheat market.

Australian Wheat Price Ranked Fourth

This ranking reflects the effect of the Australian wheat price variable in the equation for India. Although this variable was significant at the 5-percent level, the equation's R^2 value of 0.74 was not as strong as some of the other equations.

Exchange Rates Ranked Fifth

Estimated exchange rate elasticities for the Philippines and the rest of the world were significant (1- and 10-percent levels, respectively) and inelastic (table 3). The estimated elasticity for Taiwan was significant at the 10-percent level and elastic. We used nominal exchange rates in individual country currencies in the country equations.

Other Variables Influencing Wheat Exports

Other variables significant at least at the 10-percent level include P.L. 480, livestock (used in the EC equation), and freight rates. However, none of these variables exceeded 5 percent of the total effect of all the significant variables on U.S. wheat exports, and collectively this last group represented less than 10 percent of that total effect.

SOME POLICY IMPLICATIONS

U.S. agricultural policymakers have little direct control over foreign wheat production, the largest demand determinant across the country equations. Although lower U.S. prices over a sustained period might slow the expansion of wheat production in customer countries, the aggregate inelastic price elasticity (-0.31) indicates that U.S. exporters could not increase revenues with price cuts in the short run. However, longrun import responses to a price change might differ as importers and competing exporters have time to adjust production and import and export policies.

U.S. policymakers also have little control over the second-largest demand determinant, foreign income (represented as real or nominal GNP or nominal foreign exchange reserves). Policies that weaken foreign income growth, especially in developing countries, such as major industrialized importers' quotas and tariffs that limit developing country exports, adversely affect U.S. farm exports. This is particularly true for policies affecting countries with high marginal propensities of consumption for food, such as Mexico. Decisions on management of foreign debt, which can affect foreign disposable income and foreign reserves, may also affect U.S. agricultural exports.

Policymakers need accurate estimates of current elasticities, not just historical averages. With the use of dummy variables, no significant change was found in 1-year price elasticities after 1978, indicating that current elasticities may not be significantly different from those calculated for the entire data period.

LIMITATIONS OF STUDY

In the Gardiner and Dixit review, published estimates of price elasticities of U.S. wheat exports range from -6.72 to -0.14 (3). Such lack of robustness indicates that the results of any model must be viewed as conditional. While our results are within the range found by Gardiner and Dixit, they would be more useful for policy analysis when combined with other information, such as production response data for customers and competitors.

Nominal exchange rate variables were used in the equations. A real exchange rate variable may be more appropriate when exchange rates are fixed, because it adjusts for significantly different inflation rates in the two countries continually, rather than only at official realignments. However, a nominal exchange rate variable theoretically includes adjustments for inflation differences when exchange rates are flexible. The equations were estimated over periods of both fixed and flexible exchange rates. Since most of the movement in relative consumer price indices among most of these U.S. wheat importers occurred during flexible exchange rates after 1972, use of a nominal exchange rate variable for the period of fixed exchange rates (1961-72), when inflation was relatively low, should not significantly distort the elasticity estimates.

The EC equation was estimated without adjusting for the effects of the variable import levy system, which would affect the elasticity estimates. While it might be useful to separate the variable levy and price influences on imports, direct estimation without such separation reflects the realities of the EC system.

Model estimation might be improved by using only data since 1972, and using a disposable income variable. A real exchange rate variable may or may not give better estimates for countries whose exchange rates have floated since 1972.

DATA USED IN STUDY

Data for the model can be divided into two components: macroeconomic data were mostly gathered from the IMF's International Financial Statistics and agricultural data were gathered from official USDA sources. A description of each variable is given below.

Exports

U.S. commercial wheat exports to specific countries for July-June were obtained by subtracting P.L. 480 shipments from USDA export estimates and are listed in 1,000 metric tons (12).

Production

Domestic country production data, also USDA data in 1,000 metric tons, are on a calendar-year basis and precede import data by 6 months. For example, production data during January-December 1980 is used to explain U.S. exports from July 1980 through June 1981 (12).

Prices

Prices are f.o.b. gulf wheat prices that represent a market-weighted price of several types of wheat, and are listed in dollars per metric ton. Portland wheat prices were used in the Asian wheat models and represent Western White wheat prices on a per-bushel basis. The Philippine wheat equation contains a per-bushel price, which is a weighted average of Western White and Hard Red Spring prices.

The covariance of monthly imports from several countries and U.S. prices was highest at a 2-month lag. (Neither imports nor prices were filtered through ARIMA (autoregressive integrated moving average) models, which would give stronger results.) Thus, the yearly price series represent a May-April average of monthly prices, 2 months ahead of July-June exports, allowing for time differences between sales and shipments.

Freight Rates

The freight rate series represents wheat freight rates from the St. Lawrence Seaway to southern England, in dollars per metric ton. Although the level of Atlantic freight rates may not be a good approximation of world freight rates, the variability of this series should reflect that of world freight rates. Data are available from the authors.

Stocks

Stocks data, in 1,000 metric tons, were rarely used because country analysts often expressed little faith in their accuracy. When used, stocks represent those held early in the year. Thus, foreign stocks in early 1980 are used to explain U.S. exports from July 1980 through June 1981.

P.L. 480

P.L. 480 data represent P.L. 480 shipments, in metric tons, during July-June for most of the data. However, recent P.L. 480 data represent an October-September year (11). Adjusted historical series were not available. Data for other credit programs were not consistently available for the time period we used in our estimation.

Livestock

The livestock variable used in the EC equation was a weighted average of January 1 swine and cattle inventories (1,000 animals), reflecting wheat used as feed in EC pork, beef, and milk production (6, 12).

Economic Data

Macroeconomic data, with the exception of Taiwan, were obtained from the International Monetary Fund (4). Data for Taiwan were obtained from that country's government publications (8, 9). GNP data are in own-currency calendar years and in most models deflated by the CPI. Thus, 1980 real GNP was used to explain U.S. exports from July 1980 through June 1981.

Dollar reserves are foreign exchange reserves minus gold reported as of the end of the calendar year.

Exchange rate data are kept in nominal terms and, except when noted, are in foreign currency units per dollar. The allowance for lag in shipments was not possible with exchange rate data, which are on a July-June year after 1970. Before 1970, exchange rate data showed little monthly movement and are represented by calendar year data.

Thus stocks, foreign exchange reserves, and livestock data represent the previous January's inventory. This was used to avoid simultaneous equation bias (for which we tested) that might result from data concurrent to imports. Most other data both lead and overlap imports for 6 months.

Several adjustments in the data were required. Netherlands data are not included in EC data as the Netherlands is a major transshipment country. The absence of macroeconomic income or reserve data for the Soviet Union and China led to the use of population as an explanatory variable. Missing observations did not pose a major problem. In the few cases where it did arise, earlier and later observations were averaged and used. Finally, exchange rate data were differenced in the Korean wheat equation to eliminate collinearity problems. Thus, a Korean exchange rate elasticity is not calculated from this equation, but the variable is not eliminated altogether.

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