AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

USDA's Economic Research Service
has provided this report for historical
research purposes.

Current reports are available in
AgEcon Search

(http://ageconsearch.umn.edu)

and on https://www.ers.usda.gov.

United States Department of Agriculture
Economic Research Service
https://www.ers.usda.gov

A
93.44
AGES
870723

f

Economic
Research
Service

Agriculture and Trade Analysis Division

Aug 1987

Export Demand for U.S. Corn and Soybeans

Cecil W. Davison
Carlos A. Arnade

WAITE MEMORIAL BOOK COLLECTION
DEPARTMENT OF AGRICULTURAL AND APPLIED ECONOMICS
232 CLASSROOM OFFICE BLDG.
1994 BUFORD AVENUE, UNIVERSITY OF MINNESOTA
ST. PAUL, MINNESOTA 55108

630.72
E36
D387

EXPORT DEMAND FOR U.S. CORN AND SOYBEANS, by Cecil W. Davison and Carlos A. Arnade, Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture. Staff Report No. AGES870723.

ABSTRACT

An econometric analysis of demand for U.S. corn and soybean exports, 1961-83, indicated the U.S. corn price and importers' corn production were major demand determinants for U.S. corn, while importers' income and the U.S. soybean price were major demand determinants for U.S. soybeans. Average 1-year price, income, and exchange rate elasticities were -0.96, 0.15, and -1.06 for corn, and -0.37, 0.75, and -0.08 for soybeans.

Keywords: Corn, soybeans, exports, demand, price, income, elasticity.

ACKNOWLEDGMENTS

The authors appreciate the input, review, and comments from Stephen Heimstra, Maurice Landes, Myles Meilke, Richard Nehring, Gerald Rector, Nancy Schwartz, Stephen Sposato, David Skully, and Ronald Trostle. Roger Spindler helped assemble the database. Mary Maher and Bonnie Moore edited the report. Shirley Brown and Erma McCray prepared the manuscript for publication.

This report was reproduced for limited distribution to the research community outside the U.S. Department of Agriculture.

1301 New York Avenue, NW.
Washington, DC 20005-4788

August 1987

CONTENTS

SUMMARY

Our econometric analysis of annual data, 1961-83, identifies the major demand determinants for U.S. exports of corn and soybeans. We quantified and ranked those determinants in order of importance. The U.S. corn price emerged as the most important determinant of foreign demand for U.S. corn, followed closely by corn production in importing countries. Importers' income was the most important determinant for U.S. soybean exports, followed by the U.S. soybean price.

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 12 equations for corn exports and 6 for soybeans. Our estimates of price, income, and exchange rate elasticities of export demand for U.S. corn were -0.96, 0.15, and -1.06. Similar elasticity estimates for soybean exports were -0.37, 0.75, and -0.08.

U.S. agricultural policymakers have some control over the largest determinant of demand for U.S. corn exports, the U.S. export price of corn. U.S. policymakers have little control over the major determinant of demand for U.S. soybean exports, 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.)

country-specific import demand equations for U.S. corn and soybeans using commodity data within the U.S. Department of Agriculture (USDA) and macroeconomic data from the International Monetary Fund (4, 9).

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.

Aggregating individual country specific elasticities from multiple equations avoids several problems inherent in a single aggregate import equation. First, an aggregate equation imposes one specification on all countries. However, different countries have different substitution possibilities which require, for example, unique prices in each country equation. Second, country-specific equations avoid the problems of indexes. 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 more income on food imports as would middle-income countries like Mexico. A rise in total world income does not reveal the countries that benefited and may lead to unrealistic income elasticities. Fourth, simultaneous equation bias is likely when U.S. exports to all countries are aggregated. U.S. exports to 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 assumed 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:

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

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 (10) for a description).

However, 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 which determines the level of total government imports. If $\underline{a}$ were to represent prices at which traders resell in the domestic retail market, we could represent import demand as a solution to a profit maximization process. But, when $\underline{a}$ 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. Although equations are reduced forms, a priori, it is not difficult to hypothesize the signs on some of the variables. 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:

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

where PR is fixed domestic production, Y* is quantities imported, D(.) is domestic demand which, in this case, represents the sum of input demands into to the livestock market and final consumer demands, PI represents domestic prices lumped into one index, GNP is domestic income, and Z represents other factors which 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:

$$M^*(P_i, PR, PI, GNP, Z). \qquad (3)$$

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:

$M^*(EX, P_e, PI, PR, GNP, Z).$ (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

The country-specific equations 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 instrumental variable (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 and higher order terms of other exogenous variables in the import equation (2, ch. 4). For example, if corn production and corn production squared were specified as exogenous variables in our import equation, these variables and corn 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. 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 market.

5. We used dummy variables and the F test to test two hypotheses: price elasticities changed significantly after 1979, and 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 EC-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.

Seven country-specific export demand equations for U.S. corn were estimated in two SUR systems using annual data. Equations for the Soviet Union, Poland, Egypt, China, and the rest-of-world were estimated outside the SUR systems using OLS because their data periods were not equal for all of the variables (the microcomputer software required equal observations of all equations in a SUR system).

Four country-specific and a rest-of-world export demand equations for U.S. soybeans were estimated in a SUR system, using annual data from 1965 to 1983. An equation for Mexico was estimated outside the SUR system using OLS because 1983 data were not available for all of the variables.

Results of these equations are reported in tables 1 and 2. Since F-tests indicated that the quadratic functions were rarely significantly better than the linear ones, the latter are reported for most import demand functions in this study.

Ranking Tables

After estimating the equations, we calculated the average annual influence of independent variables on imports of U.S. corn and soybeans.

We calculated the influence of linear variables (significant at the 0.1 level) on U.S. corn and soybean exports by multiplying the beta coefficients by the mean change of the independent variable. In nonlinear equations, the first derivative with respect to the variable of interest supplied the coefficient which 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 tables 3 and 4 for each of 16 equations (variables were not significant in the China and rest-of-world corn equations). The effects were summed by variable across the 10 corn equations and 6 soybean equations to assess the overall relative importance of the independent variables, or demand determinants, for U.S. corn and soybean exports.

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

Variables/data	EC-9 2/	Japan	USSR	Spain	Mexico	S. Korea
Constant	-140,474	4,670.2	-44,290	2,065.7	1,818.1	-788.0
	(-7.12)***	(1.44)*	(-0.93)	(2.82)***	(1.60)*	(-4.04)***
Real GNP	--	.6577	--	--	109.9	--
	--	(.71)	--	--	(2.18)**	--
Foreign exchange reserves	-.2012	--	--	.3118	--	.3253
	(-2.95)	--	--	(4.45)***	--	(2.23)**
	-.000001					
	(-3.61)					
Livestock 3/	--	.4052	--	-.2519	--	--
	--	(1.20)	--	(-1.13)	--	--
Swine inventory	5.435	--	.2532	--	--	.1637
	(7.06)	--	(1.08)	--	--	(2.52)***
	-.00005					
	(-6.48)					
U.S. corn price, gulf	17.26	-122.8	66.81	-38.18	-28.83	-39.14
	(.77)	(-2.37)**	(.69)	(-2.40)**	(-1.15)	(-1.87)**
U.S. soybean price, gulf	-5.930	-4.255	-5.253	7.811	--	6.933
	(-.61)	(-.48)	(-.12)	(1.55)*	--	(1.75)**
U.S. wheat price	--	--	--	--	26.90	--
	--	--	--	--	(1.64)*	--
U.S. sorghum price, gulf	--	96.50	--	--	--	26.24
	--	(1.83)**	--	--	--	(1.37)*
South African corn price	80.16	84.90	--	--	--	13.88
	(4.14)***	(6.38)***	--	--	--	(1.62)*
Argentine sorghum price	--	--	--	47.20	--	--
	--	--	--	(3.92)***	--	--
Corn production						
Own	-.8936	--	-.5183	-.8454	-.4567	--
	(-4.09)***	--	(-1.73)*	(-1.14)	(-2.56)***	--
EC	--	--	-1.855	--	--	--
	--	--	(-1.75)*	--	--	--
Population	--	--	231.1	--	--	--
	--	--	(1.13)	--	--	--
Exchange rate 4/	-3,624.9	-15.54	--	1.716	-6.368	.0003
	(-1.15)	(-2.15)**	--	(.20)	(-.39)	(1.58)
R^2	.86	.95	.56	.83	.65	.91
Durbin-Watson	2.031	1.875	2.380	1.955	1.726	1.902
F 5/	58***	188***	3.13	54***	27***	97***
Degrees of freedom	45	42	5	45	45	42
Estimator 6/	SUR	SUR	OLS	SUR	SUR	SUR
Data period	1964-82	1961-82	1970-82	1964-82	1964-82	1961-82

Continued--

See notes at end of table.

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

Variables/data	Portugal	China	Poland	Taiwan	Egypt	Rest-of-world 2/
Constant	-960.8 (-4.71)***	867.8 (.58)	-2,161 (-1.57)*	13,721 (4.48)***	737.2 (1.58)*	165,987 (2.04)**
Nominal GNP 7/	-- --	-- --	-- --	22.44 (.43)	.0937 (4.58)***	-- --
Foreign exchange reserves	.0951 (.73)	-- --	-- --	.2521 (7.20)***	-- --	.421 (1.56) -.000005 (-1.48)
Swine inventory 8/	-- --	-- --	.2507 (2.01)**	-.2250 (-1.92)	1.573 (1.69)*	-- --
U.S. corn price, gulf	-22.07 (-3.07)***	-7.513 (-.48)	-58.77 (-2.47)**	-11.73 (-.90)	3.561 (2.62)	-385.5 (-.55) 1.724 (.55)
U.S. soybean price, gulf	8.151 (4.04)***	-- --	12.22 (1.88)**	4.812 (2.67)***	-- --	-- --
U.S. sorghum price, gulf	-- --	-- --	-- --	-19.53 (-1.44)	-- --	-- --
South African corn price	13.85 (3.29)***	-- --	-- --	17.95 (5.53)***	-- --	-- --
Argentine sorghum price	10.86 (1.97)**	-- --	25.71 (1.61)*	-- --	-- --	-66.22 (-.17) .0823 (.05)
Corn production Own 9/	-- --	28,224 (.66)	2.432 (.93)	-- --	-.6319 (-3.70)***	-1.130 (-1.86) .000005 (2.57)
USSR	-- --	-- --	-.0940 (-1.35)	-- --	-- --	-- --
Exchange rate 4/	7.566 (1.70)	-- --	-- --	-319.1 (-4.61)***	151.2 (1.03)	-1,522.5 (-1.13) 6.03 (1.45)
Dummy 10/	-- --	-1,407.1 (-2.67)**	-- --	-- --	-84.18 (-1.05)	-- --
R^2	.93	.53	.63	.94	.94	.91
Durbin-Watson	1.870	1.900	1.849	2.126	2.071	1.899
F 5/	159***	4.72**	5.03**	134***	38***	21***
Degrees of freedom	45	7	10	42	12	11
Estimator 6/	SUR	OLS	OLS	SUR	OLS	OLS
Data period	1964-82	1972-82	1965-82	1961-82	1964-82	1961-82

-- = variable not in equation.

1/ T-values in parentheses. Significance levels (1-tail test): * = 10%, ** = 5%, *** = 1%. 2/ Contains quadratic terms, with beta estimates and T-values beneath the first degree variable, and the significance level of the combined T-values at the bottom. 3/ 0.9 swine inventory and 0.1 poultry production. 4/ Foreign currency units per U.S. dollar, Korea exchange rate differenced. 5/ Test of significance of model, see Chow (2, pp. 58-60). 6/ SUR = seemingly unrelated regression; OLS = ordinary least squares. 7/ Change in real GNP for Taiwan. 8/ Poultry production in Egypt. 9/ Per capita in China. 10/ Cultural revolution in China; 1967 war in Egypt.

Table 2--Right hand side of equations estimating U.S. soybean exports, by country, 1965-83 1/

Variables/data	EC-9	Japan	Mexico 2/	Spain	Taiwan	Rest-of-world
Constant	-7,185 (-4.93)***	1,873 (2.97)***	-89.23 (-.68)	28.06 (.08)	-2,514 (-2.69)***	1,336 (2.44)***
Real GNP	--	.7168 (4.58)***	--	--	.1224 (6.31)***	--
Foreign exchange reserves	.0264 (3.70)***	--	.3424 (3.24)***	.0846 (3.65)***	--	.0654 (6.79)***
Swine inventory	-.0163 (-2.84)	--	--	1.997 (3.76)***	-.1158 (-2.43)	--
Poultry production	--	2.349 (9.57)***	-1.136 (-.79)	--	--	--
U.S. soybean price, gulf	-4.941 (-.89)	-4.051 (-2.97)***	1.762 (1.06)	-9.125 (-4.86)***	-2.711 (-2.54)***	-7.468 (-1.73)**
U.S. corn price, gulf	-3.173 (-.32)	5.058 (2.15)**	--	9.992 (3.48)***	4.192 (2.54)***	15.44 (2.14)**
U.S. sorghum price, gulf	--	--	-5.860 (-1.21)	--	--	--
Soybean production	--	--	1.068 (2.28)	--	2.455 (.86)	--
Soybean production Brazil and Argentina	--	--	--	.0122 (.44)	--	-.2905 (-3.53)***
Exchange rate 3/	8.206 (7.01)	-3.710 (-2.71)***	2.078 (.47)	5.986 (2.07)	59.44 (3.22)	-3.401 (-1.47)*
$\bar{R}^2$	.95	.98	.76	.91	.90	.88
Durbin-Watson	2.110	2.400	2.016	1.945	2.359	1.557
F 4/	303***	689***	9.65***	156***	146***	131***
Degrees of freedom	63	63	11	63	63	63
Estimator 5/	SUR	SUR	OLS	SUR	SUR	SUR

-- = variable not in equation.

1/ T-values in parentheses. Significance levels (1-tail test): * = 10%, ** = 5%, *** = 1%.

2/ Data for 1965-82.

3/ Foreign currency units per U.S. dollar.

4/ Test of significance of model, see Chow (2, pp. 58-60).

5/ SUR = seemingly unrelated regression; OLS = ordinary least squares.

Table 3--Ranking of foreign demand determinants by average annual effect on U.S. corn exports, 1961-82

Market 1/	Market share 2/	Ranking share 3/
	Percent	1,000 metric tons
EC-9 (1964-82)	23.8	
Corn production		1,263
South African corn price		688
Japan (1961-82)	15.1	
U.S. corn price, gulf		1,356
U.S. sorghum price, gulf		1,000
South African corn price		730
Exchange rate		256
Soviet Union (1970-82)	14.1	
EC corn production		2,621
Soviet corn production		1,127
Spain (1964-82)	5.4	
Argentine sorghum price		461
U.S. corn price, gulf		421
Foreign exchange reserves		365
U.S. soybean price, gulf		197
Mexico (1964-82)	2.8	
Corn production		540
U.S. wheat price, gulf		458
Real GNP		220
South Korea (1961-82)	2.6	
U.S. corn price, gulf		433
U.S. sorghum price, gulf		272
U.S. soybean price, gulf		195
Swine inventory		139
South African corn price		119
Foreign exchange reserves		92
Portugal (1964-82)	2.5	
U.S. corn price, gulf		243
U.S. soybean price, gulf		205
South African corn price		120
Argentine sorghum price		105

See notes at end of table.

Continued--

Table 3--Ranking of foreign demand determinants by average annual effect on U.S. corn exports, 1961-82--Continued

Market 1/	Market share 2/	Ranking share 3/
	Percent	1,000 metric tons
China (1972-82)	2.2	
Variables not significant		0
Poland (1965-82)	2.0	
U.S. corn price, gulf		647
U.S. soybean price, gulf		345
Swine inventory		332
Argentine sorghum price		283
Taiwan (1961-82)	2.0	
Foreign exchange reserves		408
South African corn price		154
Exchange rate		151
U.S. soybean price, gulf		136
Egypt (1964-82)	1.1	
Nominal GNP		180
Corn production		86
Poultry production		16
Rest-of-world (1961-82)	26.4	
Variables not significant		0
Total	100.0	
U.S. corn price, gulf		3,100
Own corn production		3,016
EC corn production (in Soviet Union equation)		2,621
South African corn price		1,811
U.S. sorghum price, gulf		1,272
Income (real or nominal GNP or nominal foreign exchange reserves)		1,265
U.S. soybean price, gulf		1,078
Argentine sorghum price		849
Swine and poultry		487
U.S. wheat price, gulf		458
Exchange rate		407

1/ Data periods in parentheses.
2/ Average share of U.S. export market, 1961-82.
3/ The annual average variation in U.S. exports associated with the annual average variation in the respective demand determinants (all significant at the 10% level).

Table 4--Ranking of foreign demand determinants by average annual effect on U.S. soybean exports, 1965-83

Market	Market share 1/	Ranking share 2/
	Percent	1,000 metric tons
EC-9	36.3	
Foreign exchange reserves		215
Japan	18.6	
Poultry production		142
U.S. soybean price, gulf		110
U.S. corn price, gulf		73
Real GNP		62
Exchange rate		53
Mexico 3/	15.6	
Foreign exchange reserves		128
Spain	8.0	
U.S. soybean price, gulf		249
U.S. corn price, gulf		146
Foreign exchange reserves		99
Swine inventory		88
Taiwan	4.1	
Real GNP		104
U.S. soybean price, gulf		74
U.S. corn price, gulf		61
Rest-of-world	17.4	
Foreign exchange reserves		489
South American production 4/		390
U.S. corn price, gulf		227
U.S. soybean price, gulf		204
Exchange rate		82
Total	100.0	
Income (real GNP or nominal foreign exchange reserves)		1,097
U.S. soybean price, gulf		637
U.S. corn price, gulf		507
South American production 4/		390
Poultry and swine		230
Exchange rate		135

1/ Average share of U.S. export market, 1965-83.
2/ The annual average variation in U.S. exports associated with the annual average variation in the respective demand determinants (all significant at the 10% level).
3/ 1965-82.
4/ Soybeans in Brazil and Argentina.

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. corn or soybeans 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. soybeans largely because of the magnitude of changes in incomes.

Elasticities

Elasticities in the linear equations 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 corn or soybean exports ($\bar{y}$), $E = \hat{b}\bar{x}/\bar{y}$. Elasticities from each of the six soybean equations were first weighted by their respective share of U.S. soybean exports, 1965-83, and then added to get aggregate U.S. elasticities with respect to the world. Elasticities from the 12 corn equations were aggregated similarly.

Elasticities from nonlinear equations 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 corn equations are listed in tables 5 and 6 and from the soybean equations in tables 7 and 8.

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 OF CORN EQUATIONS

The ranking table presents the average annual effect on U.S. corn exports of each of the variables, significant at the 0.1 level, in the corn equations (table 3). 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. corn exports.

U.S. Corn Price Largest Demand Determinant

Equations of Japan, Spain, South Korea, Portugal, and Poland produced estimates of price elasticities that were statistically significant and elastic, which indicates a price sensitivity for imports of U.S. corn. Price elasticity estimates were not statistically significant for most of the other countries, many of which are strong U.S. trading partners.

Customers' Own Corn Production Ranked Second

Corn production in the EC, Mexico, and Egypt was significant at the 1-percent level, and at the 10-percent level in the Soviet Union. Corn production in

Table 5--Price, income, and exchange rate elasticities for U.S. corn exports, 1961-82

Market	Elasticities 1/ Price	Income	Exchange rate	Market share 2/	Weighted elasticities 3/ Price	Income	Exchange rate
EC-9	4/0.16 (.77)	4/-0.42 (-4.10)	-0.44 (-1.15)	0.238	0.038	-0.099	-0.105
Japan	-1.79 (-2.37)**	4/-.14 (-.71)	-.77 (-2.15)**	.151	-.271**	-.021	-.116**
USSR	4/1.04 (.69)	--	--	.141	.147	--	--
Spain	-1.55 (-2.40)**	.69 (4.45)***	4/1.71 (.20)	.054	-.084**	.037***	.092
Mexico	-2.27 (-1.15)	2.72 (2.18)**	-.12 (-.39)	.028	-.063	.076**	-.003
S. Korea	-3.39 (-1.87)**	.41 (2.23)**	--	.026	-.088**	.011**	--
Portugal	-1.92 (-3.07)***	.03 (.73)	4/.28 (1.70)	.025	-.048***	.001	.007
China	-.75 (-.48)	--	--	.022	-.016	--	--
Poland	-6.42 (-2.47)**	.13 (.43)	--	.020	-.129**	.003	--
Taiwan	-1.30 (-.90)	.52 (7.20)***	-15.80 (-4.61)***	.020	-.025	.010***	-.316***
Egypt	4/.68 (2.62)	1.49 (4.58)***	4/.70 (1.03)	.011	.007	.016***	.008
Rest-of-world	-.89 (-.19)	4/-.02 (-.01)	-1.97 (-.24)	.264	-.235	-.005	-.520
World total				1.000			
Right sign, significant at 10% level					-.62	.15	-.43
Right sign					-.96	.15	-1.06
All					-.77	.03	-.95

-- = data not available.
Significance levels (1-tail test): ** = 5%, *** = 1%.
1/ T-values in parentheses.
2/ Average share of U.S. export market, 1961-82.
3/ Elasticities times market share, computed from unrounded data.
4/ Wrong sign.

Table 6--Cross-price elasticities for U.S. corn exports, 1961-82

Market	Variable	Elasticity	T-statistic
EC-9	U.S. soybean price, gulf	-0.05	-0.61
	South African corn price	.67	4.14***
Japan	U.S. soybean price, gulf	-.49	-.48
	South African corn price	1.03	6.38***
	U.S. sorghum price, gulf	1.32	1.83**
USSR	U.S. soybean price, gulf	-.20	-.12
Spain	U.S. soybean price, gulf	.74	1.55*
	Argentine sorghum price	1.64	3.92***
Mexico	U.S. wheat price, gulf	2.16	1.64*
S. Korea	U.S. soybean price, gulf	1.44	1.75**
	South African corn price	1.00	1.62*
	U.S. sorghum price, gulf	2.15	1.37*
Portugal	U.S. soybean price, gulf	1.65	4.04***
	South African corn price	1.08	3.29***
	Argentine sorghum price	.81	1.97**
China	Variables not in equation	--	--
Poland	U.S. soybean price, gulf	3.22	1.88**
	Argentine sorghum price	2.40	1.61*
Taiwan	U.S. soybean price, gulf	1.30	2.67***
	South African corn price	1.78	5.53***
	U.S. sorghum price, gulf	1/-2.07	-1.44
Egypt	Variables not in equation	--	--
Rest-of-world	Argentine sorghum price	1/-.38	-.16

-- = data not available.
Significance levels (1-tail test): * = 10%, ** = 5%, *** = 1%.
1/ Wrong sign.

Table 7--Price, income, and exchange rate elasticities, U.S. soybean exports, 1965-83

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
EC-9	-0.17 (-.89)	0.18 (3.70)***	4/0.001 (7.01)	0.363	-0.062	0.065***	0.0005
Japan	-.28 (-2.97)***	.30 (4.58)***	-.36 (-2.71)***	.186	-.052***	.056***	-.066***
Mexico 5/	4/1.37 (1.06)	1.84 (3.24)***	4/.21 (.47)	.156	.213	.287***	.033
Spain	-1.42 (-4.86)***	.31 (3.65)***	4/.38 (2.07)	.080	-.114***	.025***	.030
Taiwan	-.82 (-2.54)***	1.93 (6.31)***	4/3.42 (3.22)	.041	-.034***	.079***	.140
Rest-of-world	-.60 (-1.73)**	1.36 (6.79)***	-.07 (-1.47)*	.174	-.104**	.237***	-.013*
World total				1.000			
Right sign, significant at 10% level					-.30	.75	-.08
Right sign					-.37	.75	-.08
All					-.15	.75	.13

1/ T-values in parentheses. Significance levels (1-tail test): * = 10%, ** = 5%, *** = 1%. 2/ Average share of U.S. export market, 1965-83. 3/ Elasticities times market share, computed from unrounded data. 4/ Wrong sign. 5/ 1965-82.

Table 8--Cross-price elasticities, U.S. soybean exports, 1965-83

Market	Variable	Elasticity	T-statistic
EC	U.S. corn price, gulf	-0.06	-0.32
Japan	U.S. corn price, gulf	.18	2.15**
Mexico 1/	U.S. sorghum price, gulf	-2.56	-1.21
Spain	U.S. corn price, gulf	.79	3.48***
Taiwan	U.S. corn price, gulf	.64	2.54***
Rest-of-world	U.S. corn price, gulf	.63	2.14**

Significance levels (1-tail test): ** = 5%, *** = 1%.
1/ 1965-82 data for Mexico.

the EC and the Soviet Union comprised nearly 80 percent of the effect of this variable on U.S. corn exports (among variables significant at the 10-percent level or higher), which is not surprising since these two customers took nearly 40 percent of U.S. corn exports during the data period.

EC Corn Production (in Soviet Union Equation) Ranked Third

Corn production in the EC was the only other significant variable in the Soviet Union equation (in addition to Soviet corn production). The EC corn production variable in the Soviet Union equation may be acting as a proxy for grain production in Europe and the Soviet Union, which would tend to displace U.S. corn exports to the Soviet Union because of lower costs.

South African Corn Price Ranked Fourth

The South African corn price, which may be a proxy for all other competitors' corn prices, was significant at the 10-percent level in 5 of the 12 equations. This variable produced the strongest influence on U.S. corn exports in the Japan and the EC equations, which represented nearly 40 percent of the U.S. corn export market.

U.S. Sorghum Price Ranked Fifth

The U.S. sorghum price represented the price of a substitute product in feed rations, and was significant at the 10-percent level in the equations for Japan and South Korea. The largest influence of this variable on U.S. corn exports appeared in the Japan equation.

Foreign Income Ranked Sixth

Foreign income, represented by real or nominal GNP or nominal foreign exchange reserves (minus gold), was significant at the 1- or 5-percent level in the Spain, Mexico, South Korea, Taiwan, and Egypt equations. Demand for U.S. corn in Mexico and Egypt was shown to be elastic with respect to income, indicating a high marginal propensity to consume food items (direct or derived).

U.S. Soybean Price Ranked Seventh

U.S. soybeans can be considered either as a substitute for, or complement to, U.S. corn (or sorghum) as livestock feed. Within limits, they are substitutes for energy and protein, but are frequently used as supplements, with soybean meal supplying protein and corn supplying the energy in feed mixes. The response to U.S. soybean price changes was elastic and significant at least at the 10-percent level in the South Korea, Portugal, Poland, and Taiwan equations, and inelastic in the Spain equation.

Other Variables Influencing Corn Imports

Other variables significant at least at the 10-percent level were the Argentine sorghum price, livestock variables (swine inventories and poultry meat production), the U.S. wheat export price, and nominal exchange rates. However, none of these variables exceeded 5 percent of the total effect of all the significant variables on U.S. corn exports, and collectively this last group represented less than 15 percent of that total effect.

RESULTS OF SOYBEAN EQUATIONS

The ranking table presents the average annual effect on U.S. soybean exports of each of the variables, significant at the 0.1 level, in the soybean equations (table 4). 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. soybean exports.

Foreign Income Largest Demand Determinant

Foreign income, represented by real GNP or nominal foreign exchange reserves, was the major factor affecting 1965-83 U.S. soybean exports. This is particularly true for Mexico, Taiwan, and the rest of the world where demand for U.S. soybean exports was elastic with respect to income (table 7), and where income grew significantly over the estimation period.

Low income elasticities for the EC-9 and Japan, both high-income regions, support the theory of diminishing marginal propensity to consume food items (direct or derived), or concave Engel curves. Future increases of U.S. soybean exports to these regions will likely be due to factors other than rising incomes. Spain's low elasticity may reflect policies limiting soybean imports to protect domestic olive oil production.

U.S. Soybean Price Ranked Second

Equations of Japan, Spain, Taiwan, and the rest of the world produced statistically significant price elasticities (table 7). Spain shows an elastic price response, indicating a price sensitivity for the limited amount of U.S. soybeans it imported. The inelastic response of Japan and Taiwan may indicate bilateral trade commitments with the United States that are stronger than those of Spain. Price elasticity estimates are not statistically significant for the EC-9 and Mexico, which are also strong U.S. trading partners.

U.S. Corn Price Ranked Third

U.S. soybeans can be considered either as a substitute for, or complement to, U.S. corn (or sorghum) as livestock feed. Within limits, they are substitutes for energy and protein, but are frequently used as supplements, with soybean meal supplying protein and corn supplying the energy in feed mixes. The U.S. corn price was inelastic and significant at the 1-percent level in the Spain and Taiwan equations, and at the 5-percent level in the Japan and rest-of-world equations. (No prices were significant in the EC-9 and Mexico models.)

South American Production Ranked Fourth

Soybean production in Brazil and Argentina was significant at the 1-percent level in the rest-of-world equation. It is not surprising that this would be an important variable in minor U.S. soybean markets that constituted only 17 percent of the total U.S. soybean export market.

Poultry and Swine Ranked Fifth

Poultry meat production in Japan and the swine inventory in Spain were significant at the 1-percent level.

Exchange Rates Ranked Sixth

Estimated exchange rate elasticities for Japan and the rest of the world were significant (1- and 10-percent levels), negative (as expected), and inelastic (table 7). However, elasticities estimated for the other four equations had positive signs. Nominal exchange rates in individual country currencies were used in the country equations.

SOME POLICY IMPLICATIONS

U.S. agricultural policymakers have some control over the U.S. export price of corn, the largest demand determinant in the corn equations. The aggregate inelastic price elasticity (-0.96) indicates that U.S. exporters could not increase revenues in the short run with price cuts. 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. For example, lower U.S. prices over a sustained period might slow the expansion of corn production in customer countries, the second-most important variable affecting U.S. corn exports.

For soybean exports, U.S. policymakers have little control over foreign income (represented as real GNP or nominal foreign exchange reserves), the largest demand determinant in the soybean equations. 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. Our inelastic price elasticity (-0.37) indicates that U.S. soybean exporters could not increase revenues in the short run with price cuts.

Policymakers need accurate estimates of current elasticities, not just historical averages. With the use of dummy variables, no significant change was found in the 1-year price elasticities after 1978, indicating that current elasticities may not significantly differ 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. corn exports range from -0.16 to -1.31, and elasticities of U.S. soybean exports range from -0.14 to -2.8. 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.

Economic models are never completely specified. Some variables may serve as proxies for unknown or missing variables. Excluding variables results in biased estimators that can significantly alter results. For example, corn price in the soybean equations may be acting as a proxy for other substitutes for U.S. soybeans, which could only be determined by lengthy testing of other data.

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 corn and soybean equations were estimated over periods of both fixed and flexible exchange rates. Since most of the movement in relative consumer price indexes among most of these U.S. corn and soybean 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 should reflect the realities of the EC system.

Equation estimation might be improved by using only data since 1972; using pork production data instead of, or combined with, swine herd inventories; using U.S. coarse grain exports instead of corn; 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 equations 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. corn and soybean exports to specific countries, July-June, were from USDA estimates and are listed in 1,000 metric tons (9).

Production

Domestic country production data, also USDA data in 1,000 metric tons, are on a marketing-year basis and precede import data. For example, 1980 production data are used to explain U.S. exports from July 1980 through June 1981 (9).

Prices

Prices are f.o.b. (free on board) gulf and are listed in dollars per metric ton. 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, in dollars per metric ton, represent wheat freight rates from the St. Lawrence Seaway to southern England and, in the absence of better data, were used as a proxy for corn and soybean rates. 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.

Livestock

Livestock variables were January 1 swine inventories (1,000 animals), and poultry production (1,000 metric tons) (9).

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 (6, 7). GNP data are in own-currency calendar years and in most equations 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.

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 led to the use of population as an explanatory variable. Changes in the Polish GNP were used in the Polish corn equation (8). Zero observations on the dependent variable occurred in a few cases such as Mexico's corn equation. Rather than attempt a Tobit model, we set zero observations equal to 0.1 and performed GLS. 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 South Korean corn equation to eliminate collinearity problems. Thus, a Korean exchange rate elasticity is not calculated from this equation, but the variable is not entirely eliminated.

REFERENCES

(1) Armington, Paul S. "A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers, Vol. 16 (1969), 159-78.

(2) Chow, Gregory C. Econometrics. New York: McGraw-Hill Book Co., 1983.

(3) Gardiner, Walter H., and Praveen M. Dixit. Price Elasticity of Demand: Concepts and Estimates, FAER-228. U.S. Dept. Agr., Econ. Res. Serv., Feb. 1987.

(4) International Monetary Fund. International Financial Statistics, 1985 Yearbook. Washington, DC.

(5) Kelejian, Harry H. "Two-Stage Least Squares and Econometric Systems Linear in Parameters but Nonlinear in Endogenous Variables," Journal of The American Statistical Association, Vol. 66, No. 334 (June 1971), 373-374.

(6) Republic of China. Taiwan Statistical Data Book. Council for Economic Planning and Development, June 1985, 23.

(7) Republic of China, Taiwan District. Financial Statistics. The Central Bank of China, Economic Research Department. Monthly issues.

(8) U.S. Department of Agriculture, Economic Research Service. High-Value Agricultural Exports: U.S. Opportunities in the 1980's, FAER-188. Sept. 1983.

(9) _______________, Foreign Agricultural Service. Commodity production, supply, and disposition database. Unpublished monthly computer printouts.

(10) Varian, Hal R. Microeconomic Analysis. New York: W.W. Norton and Co., 1978, Chs. 1, 2.

*U.S. GOVERNMENT PRINTING OFFICE:1987-180-916:60035/ERS