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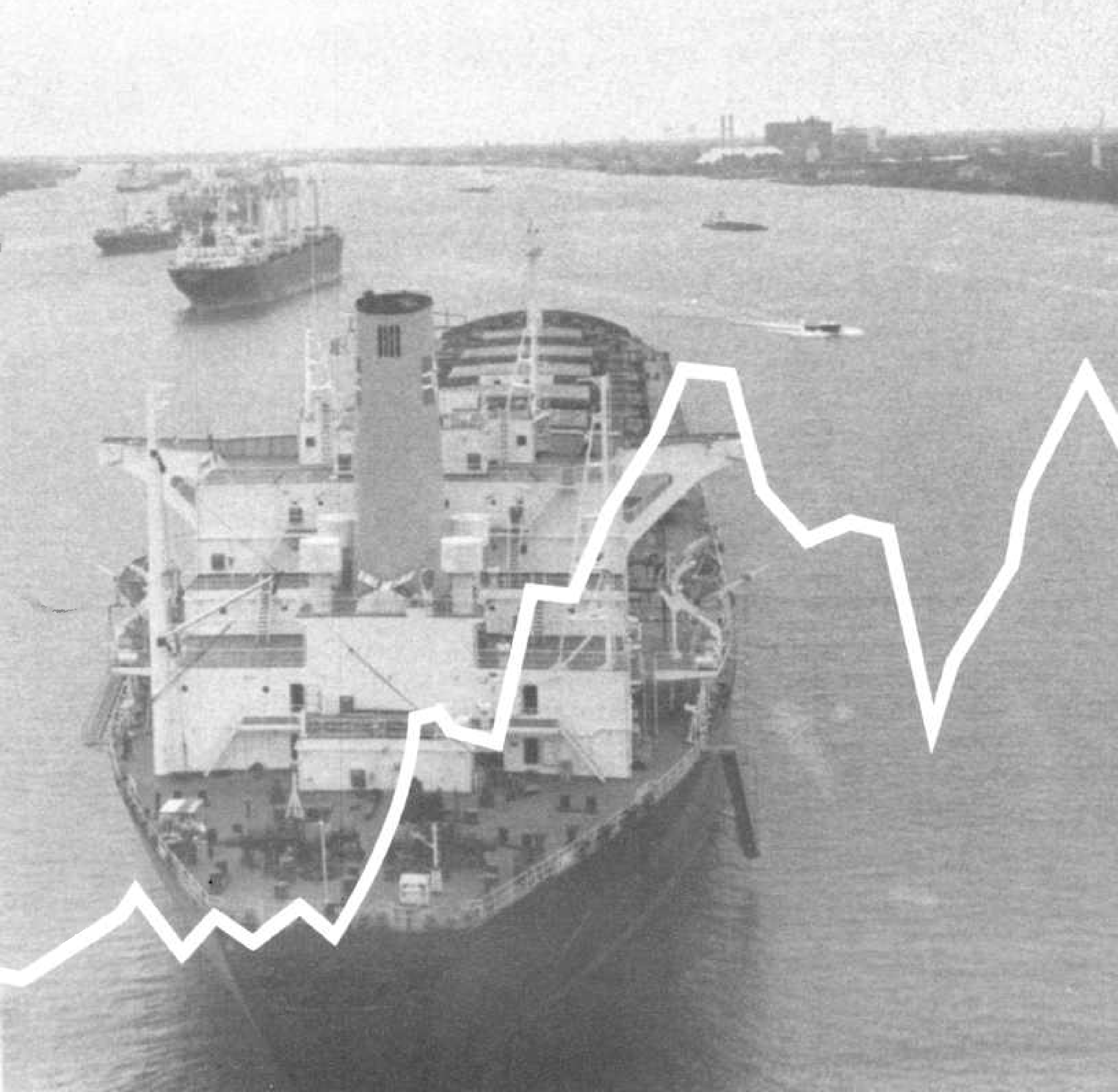
Export Demand for U.S. Corn, Soybeans, and Wheat

Cecil W. Davison
Carlos A. Arnade



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Export Demand for U.S. Corn, Soybeans, and Wheat. By Cecil W. Davison and Carlos A. Arnade, Commodity Economics Division and Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1784.

Abstract

An econometric analysis of demand for U.S. corn, soybean, and wheat exports for 1961-83 produced price, income, and exchange rate elasticity estimates that ranged from inelastic to elastic across major markets. Shortrun elasticity estimates for most corn markets were elastic for price but inelastic for income and exchange rates. Estimates for most soybean markets were inelastic for price and exchange rates, but half the soybean markets were elastic for income. Estimates for most wheat markets were inelastic for price, income, and exchange rates. This individual-market approach provides information that could help policymakers and exporters tailor longer run export-marketing strategies to fit specific markets.

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

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Contents

Summary

Our multi-market econometric analysis of price and income demand elasticities for U.S. corn, soybean, and wheat exports during the 1961-83 period produced elasticity estimates ranging from inelastic to elastic across major markets. This individual-market approach provides information that could help policymakers and exporters tailor export-marketing strategies to fit specific markets.

If corn exports are price elastic in the short run, exporters can increase sales revenues by lowering the export price. If exports are price inelastic in the short run, exporters will lose sales revenues by lowering the export price. If exports are inelastic for income in the importing country, export sales will not rise as fast as income in the short run. If exports are elastic for income in the importing country, export sales will rise faster than income in the short run. Shortrun elasticity estimates for most U.S. corn markets were elastic for price but inelastic for income and exchange rates. Estimates for most U.S. soybean markets were inelastic for price and exchange rates, but half the soybean markets were elastic for income. Estimates for most U.S. wheat markets were inelastic for price, income, and exchange rates.

We approximated aggregate U.S. export elasticities by summing share-weighted individual market elasticity estimates. The aggregate approximations suggest that shortrun price, income, and exchange rate elasticities are inelastic for each commodity export. This suggests that U.S. exporters could not increase revenues in the short run with price cuts.

Export Demand for U.S. Corn, Soybeans, and Wheat

Cecil W. Davison
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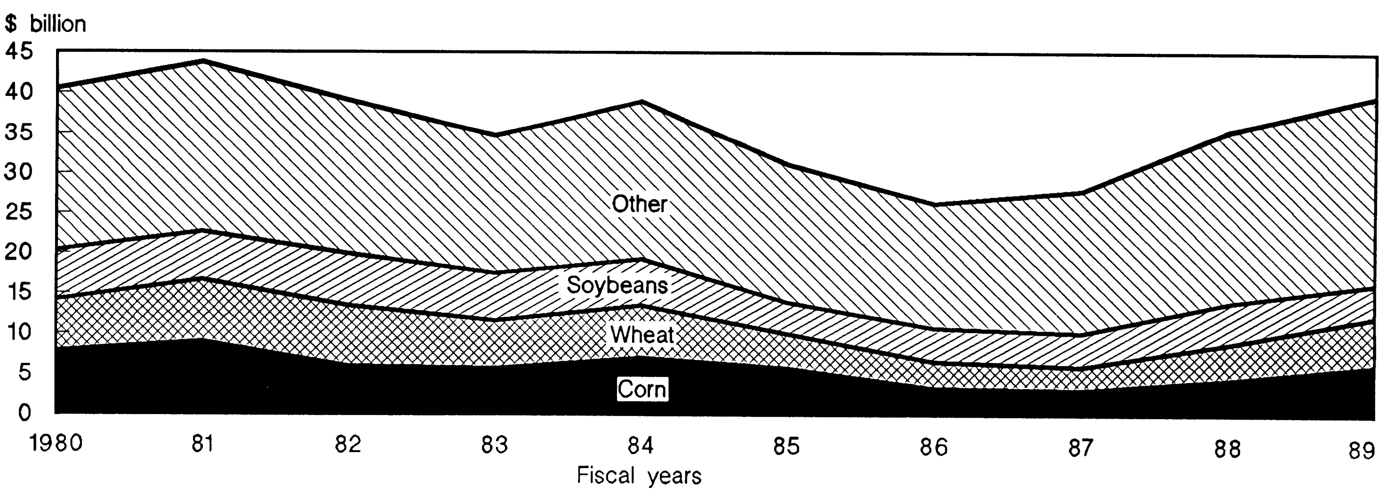
Introduction

The Nation's agricultural sector has become increasingly dependent on foreign markets. Agricultural exports climbed from nearly $15 billion (fiscal 1973) to almost $44 billion (fiscal 1981), receded to $26 billion in fiscal 1986, then recovered to nearly $40 billion in fiscal 1989. Corn has been the leading agricultural commodity exported, in terms of value, over the last 10 years, while wheat and soybean exports were second and third (fig. 1).

Falling farm prices in the early 1980's triggered large Federal outlays in producer support payments. Interest in expanding agricultural exports grew in this environment of farmers' concern about income, and policymakers' and taxpayers' concern about large treasury costs. This report identifies the major markets for U.S. exports of corn, soybeans, and wheat, and estimates price and income elasticities for those markets to broaden the understanding of factors that affect the demand for U.S. exports.

Figure 1
Value of U.S. agricultural exports



Method

We ranked U.S. corn, soybean, and wheat export markets for 1961-82, 1965-83, and 1961-83, respectively, based on volume of U.S. exports. Exports to the top 11 corn markets--the European Community (EC-9), Japan, the Soviet Union (USSR), Spain, Mexico, South Korea, Portugal, China, Poland, Taiwan, and Egypt--were almost 75 percent of all U.S. corn exports during the 1961-82 period. Exports to the top five soybean markets (the EC-9, Japan, Mexico, Spain, and Taiwan) exceeded 80 percent of all U.S. soybean exports during the 1965-83 period. Exports to the top 17 wheat markets (Japan, the USSR, the EC-9, China, Egypt, Brazil, India, South Korea, Venezuela, Nigeria, the Philippines, Mexico, Taiwan, Peru, Chile, Portugal, and Morocco) were approximately 80 percent of all U.S. wheat exports during the 1961-83 period. We estimated country-specific export demand functions for each country and for a rest-of-world residual.

Gardiner and Dixit's review of published estimates of demand price elasticities ranged from -0.16 to -1.31 for corn, from -0.14 to -2.8 for soybeans, and from -0.14 to -6.72 for wheat (*8*).[1] Each elasticity estimate 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 export demand equations for U.S. corn, soybeans, and wheat, using U.S. Department of Agriculture (USDA) commodity data and International Monetary Fund (IMF) macroeconomic data (*9*, *20*).

Specification

We postulate that an importer's (j) demand for a U.S. commodity (i) export (XP) is a function of six variables:

$$XP_{i,j} = f(EX_j,\ P_e,\ PI_j,\ GNP_j,\ PR_j,\ Z_j) \qquad (1)$$

where
- EX_j = the exchange rate between importer j and the United States,
- P_e = a vector of prices for U.S. and competing crop exports,
- PI_j = a domestic price index in importing country j,
- GNP_j = nominal domestic income in country j,
- PR_j = domestic production of the commodity in country j, and
- Z_j = country-specific variables in country j that influence domestic demand.

For many countries, we used real gross national product (GNP) (nominal GNP divided by a domestic price index). Although domestic demands are typically written to be homogenous degree zero, this may not be so for import demands (*2*). Therefore, we did not normalize all price variables on the domestic price index.

Estimation

To identify the most appropriate exponents for variables in our equations, we specified the country-specific equations with both linear and quadratic terms. The estimation process was refined by the following procedures:

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[1]Italicized numbers in parentheses refer to items cited in the References section.

1. We checked for multicollinearity in various subperiods: 1961-68, 1969-76, and 1977-83. We dropped competitors' prices that were collinear with the U.S. gulf price.

2. We tested for simultaneous equation bias by replacing U.S. prices with an instrumental variable [ordinary least squares (OLS) estimate of the U.S. price] and by applying the Wu test (details in Appendix).

3. We 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 seemingly unrelated regression (SUR) estimates. Zellner's SUR estimators are considered efficient relative to OLS estimators (*22*). Similarly, three-stage estimators are considered efficient relative to two-stage estimators.

4. We used the Wu test to see if our SUR (and OLS) estimates were significantly different from the three- (and two-) stage estimates (*3*, p. 314). For each country equation, they were not significantly different at the 5-percent level, implying that two-stage least squares (2SLS) estimation of U.S. exports to each of these markets is not required (details in Appendix). Thus, we report only the SUR estimates.

5. We used dummy variables and the *F*-test to test two hypotheses: price elasticities changed significantly from 1961-79 to 1979-83, and models with quadratic terms were significantly different from models containing only linear terms.

6. Finally, we searched for the best representative of an income variable. In some countries, total reserves minus gold gave a better fit than real GNP or real gross domestic product (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 and choosing 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.

We estimated seven country-specific export demand equations for U.S. corn in two SUR systems using annual data from 1961 to 1982. We estimated equations for the USSR, Poland, Egypt, China, and the rest-of-world outside the SUR systems using OLS because the data periods were not equal for all the variables (the microcomputer software required equal observations of all equations in an SUR system).

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

Eleven country-specific export demand equations for U.S. wheat were estimated in three SUR systems using annual data from 1961 to 1983. We estimated equations for the USSR, EC-9, China, India, Venezuela, Portugal, and the rest-of-world as single equations outside the SUR systems, using generalized least squares (GLS) or OLS, because their respective data periods were not equal for all the variables. To obtain adequate fits for the USSR equation, we broke it into a total import equation and an import share equation, a procedure described in Sirhan and Johnson (*14*).

Results

Results of our equations are reported in tables 1, 2, and 3. Since *F*-tests indicated that the functions with quadratic terms were rarely significantly better than functions with linear terms, we reported the latter for most export demand functions in this study.

Some results need explanation. Although corn and soybean meal are complementary ingredients in U.S. feed rations (corn for energy and meal for protein), feed use of these ingredients varies in other countries, ranging from complements to substitutes. We consequently used a two-tailed test of significance for the corn price in the soybean export equations, the soybean price in the corn export equations, and the constants in all equations. One-tailed tests were applied to the other variables in the equations.

Our calculated *F*-statistic for the equation of USSR demand for U.S. wheat was not significant at the 5-percent level. The price elasticity of demand for U.S. exports equals the price elasticity from an equation explaining total imports plus the price elasticity from an equation explaining the U.S. share of those imports (*14*). Therefore, we estimated a demand equation for total USSR wheat imports and a U.S. share equation. Neither dollar reserves nor real GNP produced significant wheat export equations for the Philippines and Egypt. A second hypothesis was that domestic demand in these countries was a function of nominal GNP, which performed better than real GNP in these two equations.

Parameter estimates for PL-480 wheat shipments consistently reflected an inverse relationship, one of substitution for commercial U.S. wheat exports, and the variable was significant in over half of the equations. However, the substitution effect applies to commercial and PL-480 shipments within the same year, and does not address the longer run market-development effects of PL-480 shipments.

Elasticities

We calculated elasticity estimates (E) from the equations with linear variables as the product of the parameter estimates ($\hat{b}$) times the mean of the independent variable ($\bar{x}$) divided by the mean of the corn, soybean, or wheat exports ($\bar{y}$), $E = \hat{b}\bar{x}/\bar{y}$. Elasticity estimates 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 approximate aggregate U.S. elasticity estimates with respect to the world. We similarly aggregated elasticity estimates from the 12 corn equations and 18 wheat equations.

Elasticity estimates from the equations with nonlinear terms required taking the first derivative of the equation with respect to the variable of interest, calculated at its mean. We then multiplied this parameter estimate by the mean of the independent variable and divided by the mean of the exports. For example, the elasticity estimates for equations with quadratic terms were:

$$E = (\hat{b}_{1i} + 2\hat{b}_{2i}\bar{I})\bar{I}/\bar{y}$$

where $\hat{b}_{1i}$ is the estimate of the parameter on variable I, and $\hat{b}_{2i}$ is the estimate of the parameter on the quadratic variable I^2.

We calculated *t*-statistics for the combined linear and quadratic terms of a single variable as:

Table 1--Estimation results for U.S. corn export equations[1]

Variables/data	EC-9[2,3]	Japan	USSR	Spain	Mexico	South Korea
Constant	-140,500** (-7.12)	4,670 (1.44)	-44,290 (-0.93)	2,066* (2.82)	1,818 (1.60)	-788** (-4.04)
Real GNP	--	.658 (.71)	--	--	110* (2.18)	--
Total reserves minus gold	-.201 (-2.95) -.000001 (-3.61)	--	--	.312** (4.45)	--	.325* (2.23)
Livestock[4]	--	.405 (1.20)	--	-.25 (-1.13)	--	--
Swine inventory	5.44 (7.06) -.00005 (-6.48)	--	.253 (1.08)	--	--	.164* (2.52)
U.S. corn price, gulf	17.3 (.77)	-123* (-2.37)	66.8 (.69)	-38.2* (-2.40)	-28.8 (-1.15)	-39.1* (-1.87)
U.S. soybean price, gulf	-5.93 (-.61)	-4.26 (-.48)	-5.25 (-.12)	7.81 (1.55)	--	6.93 (1.75)
U.S. wheat price, gulf	--	--	--	--	26.9 (1.64)	--
U.S. sorghum price, gulf	--	96.5* (1.83)	--	--	--	26.2 (1.37)
South African corn price	80.2** (4.14)	84.9** (6.38)	--	--	--	13.9 (1.62)
Argentine sorghum price	--	--	--	47.2** (3.92)	--	--
Corn production Own	-.894** (-4.09)	--	-.518 (-1.73)	-.845 (-1.14)	-.457* (-2.56)	--
EC-9	--	--	-1.86 (-1.75)	--	--	--
Population	--	--	231 (1.13)	--	--	--
Exchange rate[5]	-3,620 (-1.15)	-15.5* (-2.15)	--	1.72 (.20)	-6.37 (-.39)	.0003 (1.58)
$\bar{R}^2$	.86	.95	.56	.83	.65	.91
Durbin-Watson	2.031	1.875	2.380	1.955	1.726	1.902
F[6]	13**	58**	3.1	14**	7.7**	31**
Estimator[7]	SUR	SUR	OLS	SUR	SUR	SUR
Data period	1964-82	1961-82	1970-82	1964-82	1964-82	1961-82

See footnotes at end of table.

Continued--

Table 1--Estimation results for U.S. corn export equations[1]--Continued

Variables/data	Portugal	China	Poland	Taiwan	Egypt	Rest of world[3]
Constant	-961** (-4.71)	868 (.58)	-2,161 (-1.57)	13,720** (4.48)	737 (1.58)	166,000 (2.04)
Nominal GNP[8]	--	--	22.4 (.43)	--	.094** (4.58)	--
Total reserves minus gold	.095 (.73)	--	--	.252** (7.20)	--	.421 (1.56) -.000005 (-1.48)
Swine inventory[9]	--	--	.251* (2.01)	-.225 (-1.92)	1.57 (1.69)	--
U.S. corn price, gulf	-22.1** (-3.07)	-7.51 (-.48)	-58.8* (-2.47)	-11.7 (-.90)	3.56 (2.62)	-385 (-.55) 1.72 (.55)
U.S. soybean price, gulf	8.15** (4.04)	--	12.2 (1.88)	4.81* (2.67)	--	--
U.S. sorghum price, gulf	--	--	--	-19.5 (-1.44)	--	--
South African corn price	13.8** (3.29)	--	--	18.0** (5.53)	--	--
Argentine sorghum price	10.9* (1.97)	--	25.7 (1.61)	--	--	-66.2 (-.17) .082 (.05)
Corn production Own[10]	--	28,200 (.66)	2.43 (.93)	--	-.632** (-3.70)	-1.13 (-1.86) .000005 (2.57)
USSR	--	--	-.094 (-1.35)	--	--	--
Exchange rate[5]	7.57 (1.70)	--	--	-319** (-4.61)	151 (1.03)	-1,520 (-1.13) 6.03 (1.45)
Dummy[11]	--	-1,410* (-2.67)	--	--	-84.2 (-1.05)	--
$\bar{R}^2$	.93	.53	.63	.94	.94	.91
Durbin-Watson	1.870	1.900	1.849	2.126	2.071	1.899
F[6]	41**	4.7*	5.0*	42**	38**	21**
Estimator[7]	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-statistics in parentheses. Significance levels (two-tailed test on constant and soybean price, one-tailed test on other variables): * = 5 percent, ** = 1 percent. [2]Minus the Netherlands because of transshipments. [3]Contains quadratic terms, with coefficients and t-statistics beneath the first-degree variable. [4]0.9 swine inventory and 0.1 poultry production. [5]Foreign currency units per U.S. dollar. Year-to-year changes used in Korean exchange rate. [6]Test of significance of equation, $F_{k-1,N-k} = [R^2/(1-R^2)]*[(N-k)/(k-1)]$ (*11*, p. 81). [7]SUR = seemingly unrelated regression; OLS = ordinary least squares. [8]Change in real GNP for Poland. [9]Poultry production in Egypt. [10]Per capita in China. [11]Cultural revolution in China; 1967 war in Egypt.

Table 2--Estimation results for U.S. soybean export equations, 1965-83[1]

Variables/data	EC-9[2]	Japan	Mexico[3]	Spain	Taiwan	Rest of world
Constant	-7,185** (-4.93)	1,873* (2.97)	-89.2 (-.68)	28.1 (.08)	-2,514* (-2.69)	1,336* (2.44)
Real GNP	--	.717** (4.58)	--	--	.122** (6.31)	--
Total reserves minus gold	.026** (3.70)	--	.342** (3.24)	.085** (3.65)	--	.065** (6.79)
Swine inventory	-.016 (-2.84)	--	--	2.00** (3.76)	-.116 (-2.43)	--
Poultry production	--	2.35** (9.57)	-1.14 (-.79)	--	--	--
U.S. soybean price, gulf	-4.94 (-.89)	-4.05** (-2.97)	1.76 (1.06)	-9.12** (-4.86)	-2.71* (-2.54)	-7.47 (-1.73)
U.S. corn price, gulf	-3.17 (-.32)	5.06 (2.15)	--	9.99** (3.48)	4.19* (2.54)	15.4 (2.14)
U.S. sorghum price, gulf	--	--	-5.86 (-1.21)	--	--	--
Soybean production	--	--	1.07 (2.28)	--	2.46 (.86)	--
Soybean production, Brazil and Argentina	--	--	--	.012 (.44)	--	-.290** (-3.53)
Exchange rate[4]	8.21 (7.01)	-3.71** (-2.71)	2.08 (.47)	5.99 (2.07)	59.4 (3.22)	-3.40 (-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[5]	69**	177**	9.6**	31**	28**	27**
Estimator[6]	SUR	SUR	OLS	SUR	SUR	SUR

-- = Variable not in equation. [1]*t*-statistics in parentheses. Significance levels (two-tailed test on constants, corn price, and sorghum price; one-tailed test on other variables): * = 5 percent, ** = 1 percent. [2]Minus the Netherlands because of transshipments. [3]Data for 1965-82. [4]Foreign currency units per U.S. dollar. [5]Test of significance of equation, $F_{k-1,N-k} = [R^2/(1-R^2)]*[(N-k)/(k-1)]$ (*11*, p. 81). [6]SUR = seemingly unrelated regression; OLS = ordinary least squares.

Table 3--Estimation results for U.S. wheat export equations[1]

Variables/data	Japan	USSR	EC-9[2]	China	Egypt	Brazil
Constant	-1,735 (-1.17)	-76,260* (-2.61)	-5,471 (-1.95)	-10,690 (-0.82)	-43.2 (-.04)	-755 (-1.58)
Wheat production	-1.17 (-2.38) .0004 (1.46)	-.158** (-2.67)	-.057* (-1.79)	.040 (.40)	.130 (.27)	-.621** (-3.93)
Population	--	591** (3.04)	--	.010 (.51)	--	--
Real GNP[3]	7.57 (5.74) -.003 (-5.39)	--	--	--	.077** (2.95)	8.62** (3.85)
Total reserves minus gold	--	--	.014 (1.23)	--	--	--
U.S. wheat price, gulf[4]	-656 (-1.60) 129 (2.22)	-81.5* (-1.82)	-3.28 (-1.12)	260 (.13)	-7.34* (-1.98)	2.30 (.24)
Australian wheat price	20.5 (2.76) -.092 (-3.79)	--	--	27.3 (.68)	--	--
Argentine wheat price	--	--	--	--	--	.078 (.01)
Exchange rate[5]	-1.42 (-.85)	--	1,820 (2.29)	--	300 (.98)	-1.47 (-1.05)
PL-480	--	--	--	--	-.0002 (-1.20)	-.0005* (-2.10)
Livestock	--	--	.080** (3.39)	--	--	--
Freight rates	25.0 (2.13)	303 (1.10)	-42.6 (-1.06)	--	30.0 (1.23)	16.0 (.86)
Dummy[6]	--	--	--	-2,130 (-.75) -2,880 (-1.67)	-878** (-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[7]	34**	8.5**	10**	3.2*	7.7**	27**
Estimator[8]	SUR	GLS	GLS	OLS	SUR	CSUR
Data period	1962-83	1965-83	1961-82	1965-82	1961-82	1962-83

See footnotes at end of table.

Continued--

Table 3--Estimation results for U.S. wheat export equations[1]--Continued

Variables/data	India[9]	South Korea	Venezuela	Nigeria	Philippines	Mexico
Constant	7,714** (6.19)	-947* (-2.46)	-417 (-1.05)	-1,936** (-3.90)	896** (4.11)	125 (.38)
Wheat production	-103,550* (-1.85)	2.98 (2.30)	--	--	--	-.711** (-7.71)
Wheat stocks	142,500 (1.13)	--	--	--	--	--
Rice stocks	-872,500** (-2.73)	--	--	--	--	--
Real GNP[3]	--	25.0** (5.28)	1,381 (3.50) -355 (-2.67)	8.62 (3.05) -.014 (-3.67)	7.33 (5.78) -.010 (-4.38) **	55.6 (2.68) -.387 (-.90) *
Total reserves minus gold	.906** (2.63)	--	--	--	--	--
U.S. wheat price, gulf[4]	-1,197 (-1.55)	185 (1.35)	-4.39 (-.71) .0035 (.14)	-5.37 (-.78) .0250 (.95)	-534 (-2.72) 94.57 (3.07)	2.09 (.29) -.0166 (-.55)
Australian wheat price	39.7* (2.11)	2.52 (.71)	--	--	5.45 (1.31) -.035 (-2.42)	--
Argentine wheat price	--	--	--	--	--	6.23 (1.19)
U.S. rice price, gulf[10]	--	--	--	5.50 (3.73) -.005 (-4.23) **	--	--
Exchange rate[5]	-91.1 (-.30)	-2.88* (-1.96)	-99.4 (-.98)	-84.2 (-.50)	-54.6** (-3.30)	2.88 (.73)
PL-480	--	-.00002 (-.11)	--	--	--	--
Freight rates	--	-5.49 (-.34)	19.3 (1.89)	27.4 (4.52)	-6.46 (-1.03)	--
Dummy[6]	--	-3.02* (-2.12)	--	--	--	--
$\bar{R}^2$	.74	.91	.70	.91	.84	.83
Durbin-Watson	2.377	1.980	1.955	1.404	2.331	2.475
F[7]	9.7**	27**	8.8**	27**	15**	16**
Estimator[8]	OLS	SUR	OLS	SUR	SUR	SUR
Data period	1961-83	1962-83	1962-83	1961-82	1962-83	1962-83

See footnotes at end of table.

Continued--

Table 3--Estimation results for U.S. wheat export equations[1]--Continued

Variables/data	Taiwan	Peru	Chile	Portugal	Morocco	Rest of world
Constant	2,772 (1.86)	57.3 (.66)	-541* (-3.00)	874 (.69)	-1,219* (-2.85)	11,310** (6.62)
Wheat production	--	--	-.059 (-.65)	--	.246 (3.47)	-.051** (-3.52)
Real GNP[3]	.095 (3.52) -.000003 (-1.64) **	--	--	-265 (-.97) 16.1 (1.00)	.748* (1.97)	--
Total reserves minus gold	--	.365** (3.21)	.220 (2.47) -.00004 (-2.13) *	--	--	.04* (2.43)
U.S. wheat price, gulf[4]	-826 (-5.73) 130 (5.97)	7.81 (1.67)	13.7 (4.46) -.047 (-3.40)	3.65 (.69) -.016 (-.67)	2.59 (1.81)	-6.33 (-.98)
Argentine wheat price[11]	6.34 (1.70) -.025 (-1.94)	-6.88 (-1.38)	-.359** (-3.04)	--	--	2.50 (.53)
Exchange rate[5]	-33.4 (-1.54)	-.017 (-.10)	--	2.19 (1.48)	304 (3.71)	-17.8* (-1.76)
PL-480	--	-.002** (-2.88)	-.001** (-5.48)	-.0004 (-.83)	-.001** (-4.54)	--
Freight rates	-5.62 (-.55)	7.32 (.97)	13.2 (1.83)	10.5 (1.16)	-14.7 (-1.65)	-10.5 (-.24)
Dummy[6]	--	--	-124** (-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[7]	21**	14**	57**	14**	7.2**	10**
Estimator[8]	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]USSR equation for total wheat imports. *t*-statistics in parentheses. Significance levels (two-tailed test on constants, one-tailed test on other variables): * = 5 percent, ** = 1 percent. Quadratic terms shown with coefficients and *t*-statistics beneath the first-degree variable, and the significance level of the combined terms at the bottom. [2]Minus the Netherlands because of transshipments. [3]Nominal GNP in Egypt and the Philippines. [4]Western White wheat price at Portland for Japan, China, Korea, and Taiwan. Weighted average of Hard Red Spring and Western White wheat for Philippines. [5]Foreign currency units per dollar. Year-to-year changes used in Korean exchange rate. [6]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. [7]Test of significance of equation, $F_{k-1,N-k} = [R^2/(1-R^2)]*[(N-k)/(k-1)]$ (*11*, p. 81). [8]SUR = seemingly unrelated regression; GLS = generalized least squares; OLS = ordinary least squares; CSUR = SUR corrected for serial correlation, Cochrane-Orcutt procedure (4). [9]Production and stocks on per capita basis. [10]Weighted average of Houston and Thai rice prices. [11] Canadian wheat price in Taiwan. Wheat stocks in Chile.

$$t = \frac{\hat{b}_{1i} + 2\hat{b}_{2i}\bar{I}}{[\mathrm{var}(\hat{b}_{1i}) + 4\bar{I}^2\mathrm{var}(\hat{b}_{2i}) + 4\bar{I}\mathrm{cov}(\hat{b}_{1i}\hat{b}_{2i})]^{.5}}$$

where var denotes variance and cov denotes covariance. Elasticity estimates from the corn equations are listed in tables 4 and 5, from the soybean equations in tables 6 and 7, and from the wheat equations in tables 8 and 9.

Our estimates of the price elasticity of export demand are short run, reflecting export responses to prices within the same year. For corn, our aggregate price elasticity approximation of -0.77 is closer to 1.0 than other shortrun price elasticity estimates that range from -0.16 to -0.60 in the review by Gardiner and Dixit (*8*). Our price elasticity approximation of -0.15 for soybean exports lies within the -0.14 to -2.00 range of estimates in that review. Our -0.17 approximation of the aggregate wheat price elasticity also lies within the wider range of -0.14 to -3.13 estimates in the Gardiner and Dixit review (80 percent of the wheat elasticities in the review were inelastic).

Comparing elasticity estimates in the literature raises the question of which estimates are considered better than others. Should a policymaker use a world demand elasticity estimated from a single equation, or a weighted total from numerous country or regional equations? Should one expect these estimates to be different? To address these questions, we aggregated our country and regional data and specified a single equation to represent the 80 percent of our export markets that we previously estimated with individual market equations (table 10). We then added the elasticity estimates to those from the rest-of-world equation to approximate world elasticities based on two equations.

Although our approximations of price and income elasticities derived from the two equations often differ from the weighted totals from multiple equations, they all remain inelastic (table 11).

One- or two-equation world models present several difficulties. 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, countries have specific elasticities. High-income countries like Japan are less likely to spend more income on food imports than middle-income countries like Mexico. A rise in total world income does not reveal the countries that benefited and may lead to unrealistic income elasticity estimates. Third, simultaneous-equation bias is probable 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. Fourth, aggregating data across countries for an aggregate-data equation subjects the estimates to aggregation bias (*1*). Finally, a one- or two-equation world model does not reflect the unique and diverse economic relationships within countries, a major point of this study.

Our estimates of inelastic 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). Future increases of U.S. wheat or soybean exports to these regions will likely be due to factors other than rising incomes. Higher (elastic) income elasticities were estimated for Mexico, the Philippines, and Brazil. Income (which influences domestic demand) and production (which affects shortrun supply) were often statistically significant in our equations.

Simultaneous-Equation Bias

We used the Wu test to determine whether our equations with price variables were significantly different from versions with price estimates. That is, we tested for simultaneous-equation bias in each of our country-specific

Table 4--Price, income, and exchange rate elasticities for U.S. corn exports, 1961-82

Market	Elasticities: Price	Elasticities: Income	Elasticities: Exchange rate	Market share[1]	Weighted elasticities[2]: Price	Weighted elasticities[2]: Income	Weighted elasticities[2]: Exchange rate
EC-9[3]	0.16[4]	-0.42[4]	-0.44	0.238	0.038	-0.099	-0.105
Japan	-1.79	-.14[4]	-.77	.151	-.271	-.021	-.116
USSR	1.04[4]	--	--	.141	.147	--	--
Spain	-1.55	.69	1.71[4]	.054	-.084	.037	.092
Mexico	-2.27	2.72	-.12	.028	-.063	.076	-.003
South Korea	-3.39	.41	--	.026	-.088	.011	--
Portugal	-1.92	.03	.28[4]	.025	-.048	.001	.007
China	-.75	--	--	.022	-.016	--	--
Poland	-6.42	--	--	.020	-.129	--	--
Taiwan	-1.30	.52	-15.80	.020	-.025	.010	-.316
Egypt	.68[4]	1.49	.70[4]	.011	.007	.016	.008
Rest of world	-.89	-.02[4]	-1.97	.264	-.235	-.005	-.520
Total	NA	NA	NA	1.000	-.77	.03	-.95

-- = Data not available. NA = Not applicable. [1]Average share of U.S. export market, 1961-82. [2]Elasticities times market share, computed from unrounded data. [3]Minus the Netherlands because of transshipments. [4]Implausible sign.

Table 5--Cross-price elasticities for U.S. corn exports, 1961-82

Market	Variable	*t*-statistic[1]	Elasticity
EC-9[2]	U.S. soybean price, gulf	-0.61	-0.05
	South African corn price	4.14**	.67
Japan	U.S. soybean price, gulf	-.48	-.49
	South African corn price	6.38**	1.03
	U.S. sorghum price, gulf	1.83*	1.32
USSR	U.S. soybean price, gulf	-.12	-.20
Spain	U.S. soybean price, gulf	1.55	.74
	Argentine sorghum price	3.92**	1.64
Mexico	U.S. wheat price, gulf	1.64	2.16
South Korea	U.S. soybean price, gulf	1.75	1.44
	South African corn price	1.62	1.00
	U.S. sorghum price, gulf	1.37	2.15
Portugal	U.S. soybean price, gulf	4.04**	1.65
	South African corn price	3.29**	1.08
	Argentine sorghum price	1.97*	.81
China	Variables not in equation	--	--
Poland	U.S. soybean price, gulf	1.88	3.22
	Argentine sorghum price	1.61	2.40
Taiwan	U.S. soybean price, gulf	2.67*	1.30
	South African corn price	5.53**	1.78
	U.S. sorghum price, gulf	-1.44	-2.07[3]
Egypt	Variables not in equation	--	--
Rest of world	Argentine sorghum price	-.16	-.38[3]

-- = Data not available. [1]Significance levels (two-tailed test on soybean price, one-tailed test on other variables): * = 5 percent, ** = 1 percent. [2]Minus the Netherlands because of transshipments. [3]Implausible sign.

Table 6--Price, income, and exchange rate elasticities, U.S. soybean exports 1965-83

Market	Elasticities: Price	Elasticities: Income	Elasticities: Exchange rate	Market share[1]	Weighted elasticities[2]: Price	Weighted elasticities[2]: Income	Weighted elasticities[2]: Exchange rate
EC-9[3]	-0.17	0.18	0.001[4]	0.363	-0.062	0.065	0.0005
Japan	-.28	.30	-.36	.186	-.052	.056	-.066
Mexico[5]	1.37[4]	1.84	.21[4]	.156	.213	.287	.033
Spain	-1.42	.31	.38[4]	.080	-.114	.025	.030
Taiwan	-.82	1.93	3.42[4]	.041	-.034	.079	.140
Rest of world	-.60	1.36	-.07	.174	-.104	.237	-.013
Total	NA	NA	NA	1.000	-.15	.75	.13

NA = Not applicable. [1]Average share of U.S. export market, 1965-83. [2]Elasticities times market share, computed from unrounded data. [3]Minus the Netherlands because of transshipments. [4]Implausible sign. [5]1965-82 data.

Table 7--Cross-price elasticities, U.S. soybean exports, 1965-83

Market	Variable	*t*-statistic[1]	Elasticity
EC-9[2]	U.S. corn price, gulf	-0.32	-0.06
Japan	U.S. corn price, gulf	2.15	.18
Mexico[3]	U.S. sorghum price, gulf	-1.21	-2.56
Spain	U.S. corn price, gulf	3.48**	.79
Taiwan	U.S. corn price, gulf	2.54*	.64
Rest of world	U.S. corn price, gulf	2.14	.63

[1]Significance levels (two-tailed test): * = 5 percent, ** = 1 percent. [2]Minus the Netherlands because of transshipments. [3]1965-82 data.

Table 8--Price, income, and exchange rate elasticities, U.S. wheat exports, 1961-83

Market	Elasticities			Market share[1]	Weighted elasticities[2]		
	Price	Income	Exchange rate		Price	Income	Exchange rate
Japan	0.08[3]	0.32	-0.17	0.115	0.009	0.037	-0.019
USSR	-1.04	--	--	.109	-.113	--	--
EC-9[4]	-.17	.21	1.01[3]	.088	-.015	.018	.089
China	.44[3]	--	--	.083	.036	--	--
Egypt	-.54	.37	.45[3]	.060	-.033	.022	.027
Brazil	-.16	1.50	-.04	.053	-.008	.080	-.002
India	-1.28	.68	-.69	.044	-.056	.030	-.030
South Korea	.54[3,5]	1.15	--	.042	.022	.048	--
Venezuela	-.72	.92	-.75	.025	-.018	.023	-.018
Nigeria	-.02	.62	-.15	.022	-.0004	.014	-.003
Philippines	-.004	1.65	-.67	.022	-.0001	.036	-.014
Mexico	-1.15	1.95	.16[3]	.020	-.023	.039	.003
Taiwan	-.61	.96	-2.80	.020	-.012	.019	-.055
Peru	2.03[3]	.41	-.56	.018	.036	.007	-.010
Chile	1.20[3]	.26	--	.014	.017	.004	--
Portugal	.12[3]	.88	3.33[3]	.013	.002	.011	.043
Morocco	1.12[3]	.69	1.19[3]	.010	.011	.007	.012
Rest of world	-.12	.35	-.37	.242	-.029	.084	-.088
Total	NA	NA	NA	1.000	-.17	.48	-.06

-- = Data not available. NA = Not applicable. [1]Average share of U.S. export market, 1961-83. [2]Elasticities times market share, computed from unrounded data. [3]Implausible sign. [4]Minus the Netherlands because of transshipments. [5]After 1978.

Table 9--Cross-price elasticities for U.S. wheat exports, 1961-83

Market	Variable	*t*-statistic[1]	Elasticity
Japan	Australian wheat price	0.22	0.06
China	Australian wheat price	.68	1.71
India	Australian wheat price	2.11*	1.50
Korea	Australian wheat price	.71	.27
Philippines	Australian wheat price	-.46	-.32[2]
Brazil	Argentine wheat price	.01	.006
Mexico	Argentine wheat price	1.19	1.39
Peru	Argentine wheat price	-1.38	-1.70[2]
Taiwan	Canadian wheat price	.11	.11

[1]Significance level (one-tailed test): * = 5 percent. [2]Implausible sign.

Table 10--Estimation results for single-equation alternatives to multiple-equation estimates of U.S. corn, soybean, and wheat exports[1]

Variables/data	Corn	Soybeans	Wheat
Constant	29,540 (.86)	-22,330** (-3.13)	29,400 (-1.53)
Total reserves minus gold[2,3]	.151** (5.61)	.026** (2.62)	.115** (4.05)
U.S. corn price, gulf	-15.3 (-.20)	--	--
U.S. soybean price, gulf	53.5 (1.66)	-.75 (-.12)	--
U.S. wheat price, gulf	--	--	116 (3.22)
Swine inventory[3]	--	.20** (4.52)	--
Wheat production[3]	--	--	-.072* (-2.12)
Exchange rate[4]	-28,030 (-.92)	12,160 (2.54)	44,430 (2.48)
$\bar{R}^2$	.95	.92	.84
Durbin-Watson	1.707	2.618[5]	2.263
F[6]	95**	55**	29**
Estimator[7]	OLS	OLS	OLS
Data period	1961-82	1965-83	1962-83

-- = Variable not in equation. [1]*t*-statistics in parentheses. Significance levels (two-tailed test on soybean price in corn equation and on constants; one-tailed test on other variables): * = 5 percent, ** = 1 percent. [2]Minus China, Poland, and the USSR because of incomplete data. [3]Minus the Netherlands because of transshipments. [4]Special Drawing Rights (IMF) per U.S. dollar. [5]Correcting for serial correlation [Cochrane-Orcutt procedure (4)] changed the sign, *t*-statistic, and the $\hat{B}$ for soybean price, so we have no confidence that the price elasticity estimate calculated from this uncorrected equation is significantly different from zero. [6]Test of significance of equation, $F_{k-1,N-k} = [R^2/(1-R^2)]*[(N-k)/(k-1)]$ (*11*, p. 81). [7]OLS = ordinary least squares.

Table 11--Approximations of U.S. export price, income, and exchange rate elasticities, by number of contributing equations

U.S. exports/ equations	Number of equations	Elasticities: Price	Elasticities: Income	Elasticities: Exchange rate	Market share[1]	Weighted elasticities[2]: Price	Weighted elasticities[2]: Income	Weighted elasticities[2]: Exchange rate
Corn:								
Market equations	11	NA	NA	NA	0.736	-0.532	0.031	-0.433
Rest of world	1	-.89	-.02[3]	-1.97	.264	-.235	-.005	-.520
World	12	NA	NA	NA	1.000	-.77	.03	-.95
Single equation[4]	1	-.06	.45	-1.17	.736	-.043	.334	-.864
Rest of world	1	-.89	-.02[3]	-1.97	.264	-.235	-.005	-.520
World	2	NA	NA	NA	1.000	-.28	.33	-1.38
Soybeans:								
Market equations	5	NA	NA	NA	.826	-.049	.512	.138
Rest of world	1	-.60	1.36	-.07	.174	-.104	.237	-.013
World	6	NA	NA	NA	1.000	-.15	.75	.13
Single equation[4]	1	-.02	.22	1.20[3]	.826	-.014	.183	.992
Rest of world	1	-.60	1.36	-.07	.174	-.104	.237	-.013
World	2	NA	NA	NA	1.000	-.12	.42	.98
Wheat:								
Market equations	16	NA	NA	NA	.758	-.145	.395	.023
Rest of world	1	-.12	.35	-.37	.242	-.029	.084	-.088
World	17	NA	NA	NA	1.000	-.17	.48	-.06
Single equation[4]	1	.66[3]	.49	2.14[3]	.758	.502	.375	1.622
Rest of world	1	-.12	.35	-.37	.242	-.029	.084	-.088
World	2	NA	NA	NA	1.000	.47	.46	1.53

NA = Not applicable. [1]Average share of U.S. export market (corn, 1961-82; soybeans, 1965-83; wheat, 1961-83). [2]Elasticities times market share, computed from unrounded data. [3]Implausible sign. [4]Elasticities calculated from data means in app. table 3.

equations. In every case, we were not able to reject the null hypothesis at the 5-percent level that the OLS and the 2SLS estimates of the equations were the same. Based on this lack of evidence of simultaneous-equation bias, we conclude that 2SLS estimation of U.S. exports to each market is not required (details in Appendix).

Policy Implications

U.S. agricultural policymakers have some control over the U.S. export price of corn, a significant variable in some of the corn equations. Our approximation of an aggregate inelastic price elasticity (-0.77) suggests 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 trade policies. For example, lower U.S. prices over a sustained period might slow the expansion of corn production in customer countries, another variable significant in some of the corn equations.

For soybean exports, foreign income (represented as real GNP or nominal total reserves minus gold) was significant in all the soybean equations, more frequently significant than the soybean price. 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 managing foreign debt, which can affect foreign disposable income and total reserves minus gold, may also affect U.S. agricultural exports. Our approximation of an aggregate inelastic price elasticity (-0.15) suggests that U.S. soybean exporters could not increase revenues in the short run with price cuts.

For wheat exports, U.S. agricultural policymakers have little or no direct control over foreign income or foreign wheat production, variables that were significant in many of the country equations. Although lower U.S. prices over a sustained period might slow the expansion of wheat production in customer countries, our approximation of an inelastic aggregate price elasticity (-0.17) suggests 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 trade policies.

Policymakers need accurate estimates of current elasticities, not just historical averages. With the use of dummy variables, we found no significant change in the 1-year price elasticities after 1978, indicating that more recent elasticities may not significantly differ from those calculated for 1961-79.

This individual-market approach provides information, including price and income elasticity estimates, that could help policymakers and exporters tailor export-marketing strategies to fit specific markets. For example, arraying the U.S. export markets identified in this analysis in a matrix according to estimates of their shortrun price and income elasticities may illustrate which countries are price sensitive (more elastic than -1.00) and which are income sensitive in purchasing U.S. exports (fig. 2).

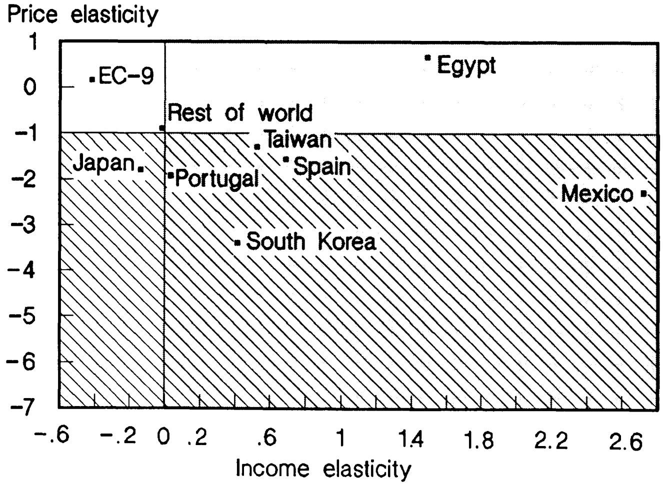
Income-sensitive markets may be more responsive to credit guarantee programs, such as the Commodity Credit Corporation (CCC) Export Credit Guarantee Program

Figure 2

Sensitivity of U.S. corn, soybean, and wheat exports to changes in export price and importer's income

Panel A: Corn

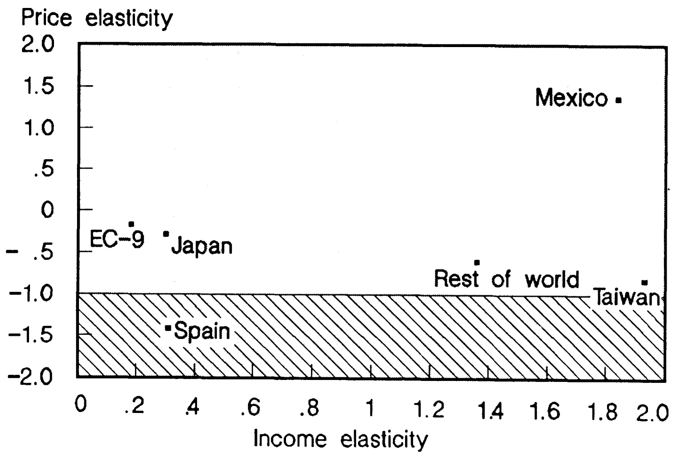
Most corn markets were elastic for price with positive income elasticities.



Source: Table 4.

Panel B: Soybeans

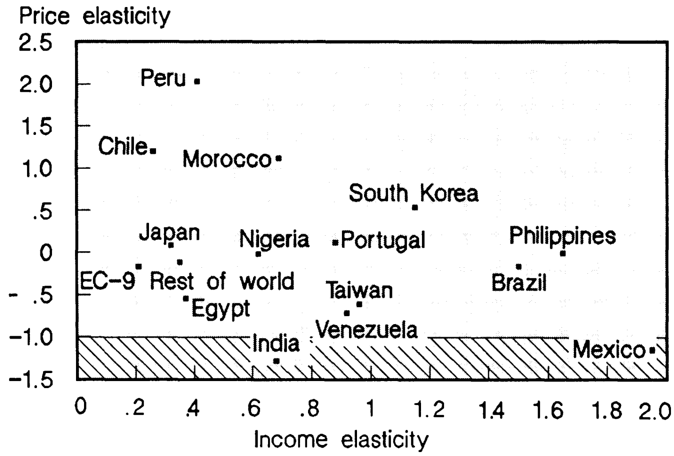
Most soybean markets were inelastic for price, but all had positive income elasticities.



Source: Table 6.

Panel C: Wheat

Most wheat markets were inelastic for price, but all had positive income elasticities.



Source: Table 8.

Elastic for price
Positive income elasticity
Both

When the export demand for a commodity is price elastic, lowering the price will increase export sales revenues.

When the export demand is price inelastic, lowering the price will reduce export sales revenues.

When the importer's income elasticity is greater than zero, a rise in income will increase U.S. export sales revenues.

For panel C, U.S. wheat is both price and income elastic for Mexico, price inelastic and income elastic for Brazil, and both price and income inelastic for the EC-9.

(known as GSM-102). Credit-guarantee programs facilitate U.S. exports by guaranteeing repayment of private credit extended to importers. These programs maintain or expand the demand for U.S. exports in markets with tight foreign exchange constraints (*15*, *17*). If the IMF or commercial banks increase lending to developing countries, those countries that are income-sensitive might respond by boosting their imports of U.S. commodities.

If U.S. export expansion were desired, price-sensitive markets might be good candidates for export programs with strong price-subsidy elements, such as the Export Enhancement Program (EEP), designed to make U.S. exports more price-competitive in specific markets (*15*, *17*). If trade liberalization lowers world commodity prices, countries more sensitive to price changes may become faster growing export markets.

Other programs may help develop demand for American products by influencing tastes and preferences in markets that are relatively insensitive to price or income changes. For example, the Cooperator Program, a joint effort by the U.S. Government and producer groups, involves trade fairs and demonstration projects (*16*). The Targeted Export Assistance (TEA) Program attempts to influence consumer preferences by either creating product awareness and good-will or by establishing product differentiation (*17*). The TEA program promotes exports of a specific category or brand of American commodity or production in specified markets (*15*).

Study Limitations

Shortrun elasticity estimates are of limited value in U.S. policy analysis, where U.S. farm legislation applies for 4 years or more, and policymakers are concerned about even longer term policy effects on the U.S. agricultural sector. However, shortrun elasticities can generally be viewed as a lower limit to longer run elasticities, which would usually be more elastic as supplies and prices adjust over time. For example, in a recent Box-Cox estimation of both shortrun and longrun elasticities for U.S. soybean exports to seven major markets during 1969-84, an unweighted average of the shortrun price elasticity estimates was an inelastic -0.16 (*5*). The longrun price elasticity estimates averaged -0.26, more elastic, but still inelastic. Shortrun and longrun income elasticity estimates averaged 2.3 and 2.6, respectively, also reflecting a more elastic estimate for the longrun elasticity (*5*).

In the Gardiner and Dixit review, published estimates of shortrun price elasticities of U.S. corn exports range from -0.16 to -0.60, U.S. soybean exports range from -0.14 to -2.8, and U.S. wheat exports range from -0.14 to -3.13 (*8*). Such lack of robustness indicates that the results of any model must be viewed as conditional. Our results, and those from other studies, would be more useful for policy analysis when combined with other information, such as production response data for customers and competitors.

Comparing elasticities among markets would be more meaningful if the estimates were calculated from identical time periods. Data restrictions did not allow us to use the same time period in all our equations. However, we found no significant change in our elasticity estimates after 1978, which suggests that the elasticities may not have changed appreciably in recent years. If the elasticities have not changed appreciably, small differences in the time periods of the data are of little consequence in estimating the elasticities.

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 complements or substitutes for U.S. soybeans, which could be determined only by lengthy testing of other data.

We used nominal exchange rate variables in the equations. A real exchange rate variable may be more appropriate when exchange rates are fixed, because it adjusts continually for significantly different inflation rates in the two countries, rather than only at official realignments. However, a nominal exchange rate variable theoretically includes adjustments for inflation differences when exchange rates are flexible. We estimated the equations over periods of both fixed and flexible exchange rates. Since most of the movement in relative consumer price indexes among most of the 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.

We estimated the EC-9 equation without adjusting for the effects of the variable import levy system, which would affect the elasticity estimates for corn and wheat (soybeans enter duty-free). 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-9 system.

Additional Research

For public policy decisions, policymakers need the best estimates of current and future elasticities, and how they may be changing. Additional research is needed to determine if these elasticities have been changing in recent years.

Models that forecast U.S. exports to particular markets would also be useful. The 20-year models developed in this study can be contenders for forecasting purposes, but models using only the last 10 years of data may perform better. Also, models that forecast exports based on previous years' data would be easier for analysts to use than models that required forecasts of the independent variables.

Although one can compute the effects of U.S. price on foreign production from models in this study, that elasticity would represent the price effect on production in the same year only. Additional research is needed to estimate the effects of 2-4 years of price increases on foreign production, or 2-4 years of price declines. Since increased production abroad can only limit the expansion of U.S. exports, the price effects on output of both customers and competitors need to be examined.

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 Procedures

All estimation and most of the data transformation were done on a microcomputer using the <u>Regression Analysis of Time Series</u> (RATS) statistical package. RATS allows for correction of serial correlation before SUR estimation. 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 a problem if an iterative SUR procedure were used. However, we did not obtain iterative SUR estimators. Serial correlation should not affect the unbiasedness or consistency of our SUR estimators, although it would affect their efficiency.

Data for the equations can be divided into two components: macroeconomic data came mostly from the IMF's International Financial Statistics, and agricultural data from official USDA sources.

Exports

U.S. corn and soybean exports to specific countries, July 1 through June 30, were from USDA estimates and are listed in 1,000 metric tons (*20*). We obtained U.S. commercial wheat exports to specific countries by subtracting PL-480 shipments from USDA export estimates.

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, we used 1980 production data to explain U.S. exports from July 1980 through June 1981 (*20*).

Prices

Prices are f.o.b. (free on board) gulf and are listed in dollars-per-metric ton. We used Portland prices of Western White wheat, on a per-bushel basis, in the Asian wheat equations. The Philippine wheat equation contains a per-bushel price, which is a weighted average of Western White wheat and Hard Red Spring wheat 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. Thus, the annual price series represent a May 1 through April 30 average of monthly prices, 2 months ahead of July 1 through June 30 wheat exports and an August 1 through July 31 average price for October 1 through September 30 corn and soybean exports, allowing for time differences between sales and shipments.

Freight Rates

Freight rates to Asian markets are from Canadian and U.S. North Pacific ports (*7*). Freight rates to other markets are an average of rates from gulf and St. Lawrence ports to Europe (*7*). All rates were adjusted to match our May 1 through April 30 price year for wheat.

Stocks

We used domestic wheat stocks in 1,000 metric tons in the wheat equations for India and Chile, at the beginning of their respective marketing years (*20*).

PL-480

PL-480 data represent PL-480 shipments, in metric tons, during July 1 through June 30 for most of the data. However, recent PL-480 data represent an October 1 through September 30 year (*19*). Adjusted historical series were not available. Consistent data for other credit programs were not available for the time period used.

Livestock

Livestock variables in the corn and soybean equations were January 1 swine inventories (1,000 animals), and poultry production (1,000 metric tons) (*20*). The livestock variable used in the EC-9 wheat equation was a weighted average of January 1 swine and cattle inventories (1,000 animals), reflecting wheat used as feed in EC-9 pork, beef, and milk production (*10*, pp. 17-19; *20*).

Economic Data

Macroeconomic data, except Taiwan data, came from the IMF (*9*). Data for Taiwan came from that country's government publications (*12*, p. 23; *13*). GNP data are in own-currency calendar years and, in most equations, deflated by the Consumer Price Index (CPI). Thus, we used 1980 real GNP to explain U.S. exports from July 1980 through June 1981.

Total reserves minus gold are reported in millions of U.S. dollars as of the end of the calendar year (*9*).

Exchange rate data are 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 1 through June 30 year after 1970. Before 1970, exchange-rate data showed little monthly movement and are represented by calendar-year data.

Some adjustments in the data were required. Netherlands data are not included in EC-9 data because the Netherlands is a major transshipment country. In the absence of macroeconomic income or total reserves minus gold data for the USSR, we used population as an explanatory variable. We used changes in the Polish GNP in the Polish corn equation. Zero observations on the dependent variable occurred in a few cases, such as Mexico's corn equation. Rather than attempt a Tobit model (*3*, pp. 265-68), which involves high computational costs, we set zero observations equal to 0.1 and performed GLS. Missing observations did not pose a major problem. In the few cases where observations were absent, we averaged earlier and later observations. Finally, we used year-to-year changes in exchange-rate data in the South Korean corn and wheat equations to eliminate collinearity problems. Thus, a Korean exchange-rate elasticity is not calculated from these equations, but the variable is not entirely eliminated.

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Appendix

The Wu Test

The Wu test for small samples can be used to determine if two-stage least squares estimators (2SLS) are significantly different from OLS estimators and to test whether a variable is endogenous. (If all right-side variables in an equation are determined to be exogenous, the SUR estimators are consistent. If some right-side variables are endogenous, SUR estimators are not consistent, and we would instead use instruments to obtain three-stage estimators.)

Call $\hat{B}_{OLS}$ a rx1 vector of OLS or GLS estimators with an estimated VC matrix $\hat{V}_{OLS}$. Call $\hat{B}_{2SLS}$ a rx1 vector of 2nd stage estimators with a VC matrix $\hat{V}_{2SLS}$. Let:

$$\hat{q} = \hat{B}_{2SLS} - \hat{B}_{OLS}, \text{ and} \quad (1)$$
$$\hat{V} = N(\hat{V}_{2SLS} - \hat{V}_{OLS}) \quad (2)$$

where N is the number of observations. Wu has shown that $\hat{q}'N\hat{V}^{-1}\hat{q}$ follows a χ^2_r distribution with r degrees of freedom (*3, 21*). If $\hat{q}'N\hat{V}^{-1}\hat{q}$ is greater than the table value of χ^2_r, one can reject the null hypothesis that simultaneous-equation bias does not exist.

In our case, $\hat{q}$ just represented the difference in the OLS and two-stage estimators for price in the export demand equations and $\hat{V}$ only represented N times the difference in their variance.

For example, in the multiple-market soybean equation (table 10), we twice regressed imports of U.S. soybeans on total reserves minus gold, the U.S. gulf soybean price, swine inventories, and the exchange rate. The first regression was done by OLS. In the second regression (2SLS), we replaced the soybean price variable with an instrumental variable created by regressing the soybean price on exogenous variables in the equation (table 10) and the soybean price lagged 1 year (app. table 1).

The $\hat{B}$ on soybean price in the first (OLS) estimation of the soybean equation was -0.7510 (table 10), and its variance was 39.75 (app. table 2). The $\hat{B}$ on the price instrument in the 2SLS estimation of the soybean equation was 34.23 (app. table 1), while its variance was 251.6 (app. table 2). In this simple case of testing only one variable for simultaneous-equation bias, the term:

$$\hat{q}'N\hat{V}^{-1}\hat{q} = N(\hat{B}_{2SLS} - \hat{B}_{OLS})^2/N(\hat{V}_{2SLS} - \hat{V}_{OLS}) \quad (3)$$
$$= (34.23 - -.7510)^2/(251.6 - 39.75) = 5.78 \quad (4)$$

where $\hat{V}$'s represent estimates of the individual variances of the estimators. Our numerical answer is significant at the 5-percent level (from a chi-square table using 1 degree of freedom, which is equal to the number of variables being tested). Therefore, we conclude the soybean price variable is endogenous. Consequently, we assume the estimates in the multiple-market soybean equation (table 10) reflect simultaneous-equation bias. Wu test values for the OLS corn and wheat equations (table 10) were 1.95 and 0.12, not significant at the 5-percent level. (We performed Wu tests on OLS equations, not corrected for serial correlation, to be consistent with the literature cited.)

Appendix table 1--2SLS estimations for Wu tests for OLS equations in table 10[1]

Variables/data	Corn		Soybeans		Wheat	
Dependent variable	Gulf price	U.S. exports	Gulf price	U.S. exports	Gulf price	U.S. exports
Constant	290** (5.14)	-19,550 (-.37)	38.9 (.27)	-30,630** (-4.68)	6.56 (.17)	-500 (-.03)
Total reserves minus gold[2,3]	-.000009 (-.12)	.144** (5.29)	.0006 (1.41)	-.001 (-.09)	.0002 (1.16)	.087 (2.07
U.S. corn price, gulf, t-1	.342* (2.76)	--	--	--	--	--
Estimated U.S. corn price	--	128 (1.01)	--	--	--	--
U.S. soybean price, gulf	--	47.7 (1.61)	--	--	--	--
U.S. soybean price, gulf, t-1	--	--	.404 (1.55)	--	--	--
Estimated U.S. soybean price	--	--	--	34.2* (2.16)	--	--
U.S. wheat price, gulf, t-1	--	--	--	--	.553** (3.28)	--
Estimated U.S. wheat price	--	--	--	--	--	102 (1.89)
Swine inventory[3]	--	--	.0004 (.21)	.176** (4.39)	--	--
Wheat production[3]	--	--	--	--	.0001 (.59)	-.063 (-1.61)
Exchange rate[4]	-253** (-4.79)	13,920 (.31)	--	18,440** (4.13)	--	15,040 (.92)
$\bar{R}^2$	.92	.95	.73	.94	.82	.79
Durbin-Watson[5]	.89	1.911	--	2.624	2.58**	1.768
F[6]	81**	101**	17**	75**	33**	21**
Data period	1961-82	1961-82	1965-83	1965-83	1962-83	1962-83

-- = Variable not in equation. [1]The two equations for each commodity were estimated sequentially rather than simultaneously. t-statistics in parentheses. Significance levels (two-tailed test): * = 5 percent, ** = 1 percent. [2]Minus China, Poland, and the USSR because of incomplete data. [3]Minus the Netherlands because of transshipments. [4]Special Drawing Rights (IMF) per U.S. dollar. [5]Durbin h-statistic for gulf price equations, except soybeans, where we used a test suggested by Durbin (*6*) asymptotically equivalent to Durbin's h. Evidence was insufficient at the 5-percent level to reject the null hypothesis that the errors are not correlated in the corn and soybean price equations. Equations were not corrected for serial correlation because the Wu test was done with uncorrected estimates. [6]Test of significance of equation, $F_{k-1,N-k} = [R^2/(1-R^2)]*[(N-k)/(k-1)]$ (*11*, p. 81).

Appendix table 2--Covariance/correlation matrices for OLS and 2SLS soybean export equations

Variables	Constant	Total reserves minus gold	U.S. soybean price, gulf	Estimated U.S. soybean price	Swine inventory	Exchange rate[1]
			OLS equation			
Constant	51,016,000	0.472	-0.478	--	-0.733	-0.897
Total reserves minus gold	32.9	.00009	-.457	--	-.708	-.150
U.S. soybean price, gulf	-21,538	-.028	39.75	--	.046	.536
Estimated U.S. soybean price	--	--	--	--	--	--
Swine inventory	-233	-.0003	.013	--	.002	.371
Exchange rate[1]	30,651,000	-6.99	16,151	--	78.9	22,868,000
			2SLS equation			
Constant	42,936,000	.617	--	-.558	-.486	-.909
Total reserves minus gold	57.8	.0002	--	-.851	-.147	-.477
U.S. soybean price, gulf	--	--	--	--	--	--
Estimated U.S. soybean price	-58,023	-.193	--	251.6	-.284	.621
Swine inventory	-128	-.00008	--	-.181	.002	.132
Exchange rate[1]	26,583,000	-30.4	--	43,934	23.7	19,920,000

-- = Variable not in equation. [1]Special Drawing Rights (IMF) per U.S. dollar.

Appendix table 3--Data means used for single-equation elasticities in table 11

Variables	Corn	Soybeans	Wheat
U.S. exports (1,000 metric tons)	21,960	9,146	19,017
Total reserves minus gold (million dollars)	65,761	79,446	81,775
U.S. corn price, gulf (dollars per ton)	84.36	--	--
U.S. soybean price, gulf (dollars per ton)	--	200.7	--
U.S. wheat price, gulf (dollars per ton)	--	--	108.9
Exchange rate[1]	.9191	.9029	.9162
Data period	1961-82	1965-83	1962-83

-- = Variable not used to calculate elasticities. [1]Special Drawing Rights (IMF) per U.S. dollar.

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