THE IMPACT OF AGRICULTURAL RESEARCH ON EXPORTS

By

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The Impact of Research on the Export of U.S. Agricultural Products

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Abstract

Agricultural exports is one of the few areas where the United States (U.S.) enjoys positive trade balances. Agricultural exports account for over 21 percent of the cash receipts from all farm products. They also account for about 20 percent of total U.S. exports. Although the U.S. continues to dominate the world trade in wheat, corn, and soybeans, the U.S. share of the total world's market for wheat and soybeans has declined during the past 20 years.

Market shares for the U.S. agricultural products and the long-run competitiveness of the U.S. on the world market is influenced by many factors. These factors may be classified into five major groups: (1) marketing institutions, (2) trade policies, (3) exchange rates, (4) natural resource endowments, and (5) technological development. Marketing institutions, trade policies, and exchange rates have been the major barriers to U.S. agricultural exports. With trade liberalization in regional markets (NAFTA) and global markets (GATT), the comparative advantage of the U.S. in the international markets will largely depend upon production efficiency.

United States agriculture is a research intensive "high technology" enterprise which could remain a critical element in the U.S. trade balance. The impact of research on increasing agricultural productivity and the resulting benefits to producers, as well as domestic and foreign consumers of agricultural products, have been empirically analyzed by many studies. However, the relationships between research, productivity, and export of U.S. agricultural products have not been analyzed.

The overall objective of this study is to examine the impact of technological change on agricultural exports. The dynamic relationships among research, production, prices, and exports are estimated. The dynamic relationships among the variables are estimated in a vector autoregression (VAR) model using panel data for three commodities -- corn, soybeans, and wheat.

The results show that a one standard deviation innovation in research expenditures ($.386 million) would increase exports by 15.7 million bushels. A one standard deviation shock in production would reduce price by 8.3 cents per bushel.

THE IMPACT OF AGRICULTURAL RESEARCH ON EXPORTS

ARAJI, A. A. AND F. C. WHITE

Introduction

Agricultural exports constitute one of the few areas where the United States (U.S.) enjoys positive trade balances that offset deficits occurring in other areas. During the past thirty years, agricultural exports accounted for over 21 percent of the cash receipts from all farm products. They also accounted for about 20 percent of total U.S. exports. The percentage of total U.S. exports accounted for by agriculture, however, has declined in recent years reaching a low of 12 percent in 1988. Although the U.S. continues to dominate the world trade in wheat, corn, and soybeans, the U.S. share of the world market for these crops has fluctuated over the past 30 years. The U.S. share of the total world's market for wheat and soybeans has declined significantly during the 1960-1988 period, while the U.S. share of the total world's corn market has increased significantly during this period (U.S. Department of Agriculture).

Market share for the U.S. agricultural products and the long-run competitiveness of the U.S. on the world market is influenced by many factors. These factors may be classified into five major groups: (1) marketing institutions, (2) government policies, (3) exchange rates, (4) natural resource endowments, and (5) technological development. The affect of marketing institutions and governments policy on U.S. agricultural trade was discussed by Schmitz (1986), a technical memorandum prepared by the Office of Technology Assessment of the U.S. Congress (1986), and Sharples (1990). The role of exchange rates has been analyzed by Schuh (1974), Greenshield (1974), Machlup (1980), Chambers and Just (1982), Longmire and Morey (1983), Chambers (1984), Ruppel (1984), and Bessler and Babula (1987). The affect of natural resource endowment on agricultural trade was analyzed by Valentini (1974), Vollrath (1983), Haley and Abbot (1986), and Vollrath and Vo (1990). The impact of technology on U.S. agricultural exports, however, has not been adequately evaluated.

Marketing institutions, trade policies, and exchange rates are major determinants of a country's competitiveness in the international market in the short-run. In the long-run, productivity and cost efficiency may become a more dominant factor. With a successful negotiation under the General Agreement on Tariffs and Trade (GATT), the comparative advantage of a country in the international market for a particular agricultural product will then largely depend upon production efficiency or return per unit of fixed input (Capalbo et al., 1990; Ahearn et al., 1990). United States agriculture is a research intensive enterprise. It has become a "high technology" enterprise which could remain a critical element in the U.S. trade balance (Congress of the United States, 1986). Investment in research and evolving technologies is generally believed to increase aggregate resource productivity, and higher productivity is generally believed to be a key element in increasing agricultural exports (Capalbo et al., 1990; Finn, 1987).

The impact of research on increasing agricultural productivity and the resulting social benefits to producers, as well as domestic and foreign consumers of agricultural products, have been empirically analyzed by many studies (Araji, 1980; Norton and Davis, 1981; Ruttan, 1982; Edwards and Freebairn, 1984; White, 1986; White, 1987; Araji, 1989; Araji and White, 1990; Araji, 1990). Despite the importance of research and evolving technologies to increasing agricultural productivity and its potential impact on trade, little progress has been made in introducing technology into trade theory. Consequently, there has been little empirical work on the relationships between research, productivity, and the exports of U.S. agricultural products.

Objectives

The overall objective of this study is to examine the relationships among agricultural research, exports, production, and prices for major crops. The dynamic relationships among the variables are estimated in a vector autoregression (VAR) model using panel data for three commodities -- corn, soybeans, and wheat.

Related Literature

Trade theory is cast in either one or the other of two basic streams of thought: the Ricardian tradition of comparative cost and the Heckscher-Ohlin theory of factor endowments. The focus of the Ricardian model is on relative cost and technology differences. The Heckscher-Ohlin explanation of comparative advantage is based upon differences in factor proportion, with technology assumed to be stable and universally available. The two conventional theories are brought together in Kenen's framework (1965). Kenen's perception of a fixed natural endowment of factor of production conforms to the Heckscher-Ohlin view. Kenen's allowance for capital investments which generates service flows from the resource endowment makes technological differences that exist among countries, a characteristic of the Ricardian model lacking in the conventional Heckscher-Ohlin version.

The development of models of induced technical change provided the basis for introducing technology into trade theory. Hayami and Ruttan (1970) adopted the Hicks' micro level factor-price inducement model to the aggregate agricultural sector, and argued that changing factor-price relations induced a particular kind of technical change. This obviously makes production technology an endogenous variable within the system, rather than a variable that is determined exogenously. Hayami and Ruttan estimated a meta production function across countries and thereby identified the importance of supply shifters in world agriculture. The meta production function is based upon the theory of induced innovations.

Thompson and Schuh (1975) explored the theoretical basis for the existence of a meta demand function. They argue that such a function could be estimated with cross-country data in the same way the meta production function has been estimated. Valentini and Schuh (1974) estimated a meta function for trade that transcends national boundaries in an attempt to gain an improved understanding of economic factors that affect the pattern of trade in agricultural commodities among countries. The meta trade function expresses agricultural production in terms of the inputs used in the generation of domestic output. Consumption is represented by a sector of variables that affect agricultural demand.

Empirical studies to explain the relationships between technology and agricultural trade have been very few. Four notable efforts have been undertaken by Valentini (1974), Vollrath (1983), Haley and Abbot (1986), and Vollrath and Vo (1990). Each of these studies has emphasized that agricultural technology is important in explaining the direction and magnitude of agricultural trade. In addition to these studies, the center for Agricultural and Rural Development at Iowa State developed several trade models where technology was used as an exogenous shock.

Valentini introduced induced technical changes into a more general growth model, with the results that technology became an endogenous variable in the trade theory. He argues that, other things being equal, the capability to produce and distribute new production technology will alter a country's natural comparative advantage, and make it a more effective competitor in the world market. His model provides a means of analyzing the role of natural factor endowments, domestic demand conditions, and variables representing technological capability in determining a country's comparative advantage in the world market. Valentini used ordinary least-square to express net exports as a function of labor, land, livestock, fertilizer, machinery, general education (school enrollment ratio) to represent human capital, technical education (number of agricultural college graduates per 10,000 farm workers) to represent capability to produce and distribute new production technology, per capita income, population, and a policy variable. General education and technical education were used as proxy variables to measure the effect of technological changes on exports.

Valentini used cross-sectional data from 23 countries for an average of 1957-1961 and cross-sectional data for 21 countries for an average of 1962-1966. Valentini assumed the existence of a meta production function incorporating general education and technical education as shift variables. His statistical results indicate that technological factors are at least partially associated with international comparative advantage, but these results do not have uniformly strong statistical support. Valentini's finding is consistent with other research which found that the same or comparable variables are important determinants of agricultural output (Hayami and Ruttan, 1970; Grilicher, 1964; and Evenson and Kislev, 1973). His finding is also consistent with findings of other researchers who have studied trade in industrial goods (Keesing, 1968; Ball, 1966; and Morral, 1972).

Vollrath (1983) specified a meta trade model similar to that of Valentini and Schuh (1974) to examine the extent to which fundamental production and consumption determinants could explain variations in the net exchange of agricultural commodities. Ordinary least square was used to express net agricultural exports as a function of land, agricultural labor, fertilizer-land ratio, tractor horsepower-agricultural labor ratio, number of graduates from agricultural colleges-agricultural labor ratio, income-population ratio, population, and value of total merchandise exports minus debt service payments plus or minus changes in reserve. Vollrath used data from 57 exporting countries for three time periods (1960, 1965, 1970). The proxy measure of technological changes is the number of college graduates in agriculture. His results show that land and population are the two most important factors in explaining net agricultural trade. The focus of Vollrath's study, neither country not commodity specific, was on identification of the relative importance of selected variables in determining net agricultural trade. His empirical results suggest that the pattern of comparative advantages, which changes over time, is determined not only by the natural resource endowment, but also by technological development and capital investments in all kinds of economic activities.

Haley and Abbot's empirical model extended the Hayami and Ruttan (1970) meta production function concept and the Thompson and Schuh (1975) meta demand function concept. The production model was estimated using translog specification for pooled time series and cross-sectional data from four periods (1960, 1965, 1970, and 1977) for 98 countries. The use of a translog functional form permits the productivity of each factor to be dependent on the levels of other factors. Capital served not only as a factor of production, but also as a shift variable reflecting the capacity of a nation to adopt modern, research-intensive agricultural techniques. Haley and Abbot assumed that technology is exogenously given. Their results show that the effect of estimated production on trade is significantly positive, the effect of estimated consumption is significantly negative, and the effect of the variable which measures the under-evaluation of the exchange rate is significantly negative. Basic problems in their study included the reconciliation of technological and factor-endowment explanation of trade and measurement of the contribution of natural resources to agricultural trade.

The Center for Agriculture and Rural Development (CARD) at Iowa State University developed trade models for feed grains (Bahrenian et al., 1986), for soybeans (Meyers et al., 1986), and for wheat (Devadoss et al., 1990). The models were developed to examine the impact of domestic and foreign farm policy changes and exogenous shocks on agricultural trade. The analysis of impacts of exogenous shocks include technology shocks, such as yield changes; changes in macroeconomic variables, such as income growth; inflation rate or exchange rates; and external shocks, such as those involving tariffs and subsidies. The models, using simultaneous equation systems, are non-spatial partial equilibrium models. They are non-spatial because they do not identify trade flows between specific regions, and partial equilibrium because only one commodity is considered.

Vollrath and Vo (1990) analyzed the economic factors that affected export behavior. The results of their study show that export behavior is affected by relative land productivity, agricultural labor productivity, tractor-labor ratio, irrigation-cropland ratio, and non-agricultural labor productivity. They argue that the relevance of Ricardo's concept of comparative costs is evident given that agricultural labor productivity, land productivity, and non-agricultural labor productivity are directly related to country export share. The impact of capital on exports, as indicated by the positive coefficients for irrigation-cropland ratio and tractor-labor ratio, lends support to the Heckscher-Ohlin explanation of trade. The direct relationship between the intensity of capital usage and competitiveness in agriculture is consistent with the Heckscher-Ohlin factor proportion theorem.

Gardiner and Dixit reviewed published estimates of demand price elasticities for major U. S. agricultural products. The price elasticities for corn, soybeans, and wheat ranged from highly inelastic to elastic. Inconsistencies among these estimates point to the need for further empirical analysis in this general area.

Davison and Arnade conducted a multi-market econometric analysis of price and income demand elasticities for U. S. corn, soybean, and wheat exports for 1961-83. Their aggregate price elasticities of export demand were -0.77 for corn exports, -0.15 for soybean exports, and -0.17 for wheat exports. The Davison and Arnade study considered income growth and exchange rates as demand shifters, without explicitly accounting for the impact of technological change on exports.

Procedures

Model Specification

In the VAR model, current values of exogenous variables are modeled as functions of past values of endogenous variables. A VAR model with panel data, which involves both time series and cross sectional data, requires special features. In particular, individual effects associated with each cross section have to be taken into account. However, these individual effects are unobservable. It is possible to develop a VAR model for panel data, which accounts for the individual effects, and then manipulate the model so that the individual effects do not have to be estimated (Chamberlain and Holtz-Eakin, Newey, and Rosen).

The VAR model used in this study assumes (a) that the intercept is random, (b) that the slope coefficients are stationary over time, and (c) that individual effects exist. Let **m** denote the number of variables, **n** denote the lag length, **N** denote the number of cross sections, and **T** denote the number of periods. The variables have three subscripts: **i** (or **k**) indicates the variable's number; **j** indicates the cross section; and t indicates the period. Following this notation, the VAR model can be simply expressed as

$$(1) \qquad Y_{ijt} = \alpha_t + \sum_{k=1}^{m} \sum_{h=1}^{n} \beta_{ik(t-h)} Y_{kj(t-h)} + \Psi_i f_{ijt} + \varepsilon_{ijt}$$

$$(i = 1, \ldots, m; j = 1, \ldots, N; t = (n + 1), \ldots, T)$$

where y is a variable,

f is the individual effect,

ε is an error term, and

α, β, and Ψ are parameters.

The error terms and explanatory variables are assumed to be orthogonal. It is not possible to estimate all of the parameters in this model, because the individual effects, f_{ijt}, are unobservable. Hence, the model must be transformed to eliminate the unobservable effects.

Subtracting equation (1) at time period t-1 from equation (1) at time period t will eliminate the unobservable effects. The transformed model can be expressed as

$$(2) \qquad Y_{ijt} - Y_{ij(t-1)} = \alpha_t - \alpha_{t-1} + \sum_{k=1}^{m} \sum_{h=1}^{n} \beta_{ik(t-h)}(Y_{kj(t-h)} - Y_{kj(t-h-1)}) + v_{ijt}$$

$$(i = 1, \ldots, n; j = 1, \ldots, N; t = (n + 2), \ldots, T)$$

where $v_{ijt} = \varepsilon_{ijt} - \varepsilon_{ij(t-1)}$. The conglomerate error term creates some problems which must be accounted for in estimation. In particular, the error term and some explanatory variables are no longer orthogonal:

$E(Y_{kj(t-1)}\, \varepsilon_{ij(t-1)}) \neq 0$ and hence

$E(Y_{kj(t-1)}\, v_{ijt} \neq 0.$

Model Estimation

Most of the original parameters in equation (1) can be obtained by estimating equation (2) using first differences of the data. Parameters which are not recovered are the constant term α_i and the impact of individual effects Ψ_{ij}. Failure to recover these parameters would make individual forecasts infeasible. However, other types of analysis such as impulse responses for average situations are possible with estimates of equation (2).

Violation of the orthogonality condition between $Y_{kj(t-1)}$ and v_{ijt} requires a modification to the traditional least squares approach. In the present study, an instrumental variables approach is used for this purpose. For equation (2), let **Y** represent a vector of first differences for one endogenous variable and **X** represent the matrix of first differences of the predetermined variables, including the constant. A matrix of instruments **Z** can be developed by lagging variables in **X** one period. The variables in **Z** would be orthogonal to the error term and are used as the instrumental variables. The coefficient estimates, $\hat{\beta}$, using the instrumental variables approach can be obtained as follows:

$$(3) \qquad \hat{\beta} = (X'Z\,(Z'Z)^{-1}Z'X)^{-1}(X'Z(Z'Z)^{-1}Z'Y$$

This is a two-stage least squares approach.

VAR Order

Following Hsiao, the appropriate VAR order is determined for each equation separately. Let the number of own lags be varied over a range **0, 1, ... n^{max}** (maximum number of lags). The lag length that minimizes Akaike's final prediction error (FPE) criterion is the appropriate choice for the initial estimate of own lags.

$$(4) \qquad FPE_{(p)} = (N^*T + p + c)/(N^*T - p - c)\ SSE_{(a,b)}/(N^*T)$$

where p is the number of lags, c is the number of constants and SSE is the sum of squared errors. An increase in the number of parameters, **(p + c)**, should increase the first term but reduce the second term by lowering SSE. Hence the minimum FPE would occur where enough parameters are included in the model to have a small SSE but not so many parameters as to inflate the first term.

Given **p** own lags, a second variable is added to the equation. The appropriate number of lags for the second variable is identified by considering a range of lags **0, 1, ..., n^{max}**. The lag with the lowest FPE is selected as the appropriate lag for the second variable. Similarly, appropriate lags on additional variables are identified by minimizing the FPE criterion.

After the initial lag lengths are identified in the first loop, the process is repeated in a second loop. The appropriate lag length for the first variable is identified given the lag lengths on the other variables. Similarly, the appropriate lag length is identified for each variable. If these lag lengths are the same as the initial lag lengths, the process ends. If the lag lengths changed, then the process is continued until the lag lengths stabilize.

The above process assumed that the initial starting values for all lags were zero. The process was repeated by using different starting points. In particular, initial lag lengths were also assumed to be one. The process that yielded the lowest FPE was used to identify the appropriate lags. If any final lags were at the boundary, $\mathbf{n^{max}}$, then $\mathbf{n^{max}}$ was lengthened and the process repeated until all identified lags were less than the maximum allowable lag.

Orthogonalization

The covariance matrix constructed from the residuals, $\mathbf{v_{ijt}}$, of the VAR model can be used to analyze contemporaneous relationships among the endogenous variables. Let **V**, which is $\mathbf{[v_{ijt}\ v_{2jt} \ldots v_{mjt}]}$, **for j = 1, ..., N and t = (n + 2), ..., T**, be a white noise process called an innovation process. Since these variables may have moved together, historically, the covariance matrix includes nonorthogonal innovations if the covariance matrix is not diagonal.

It is helpful to consider orthogonalized innovations, because they are uncorrelated both across time and across equations. Applying Choleski decomposition to the covariance matrix yields, a unique lower triangular matrix **H** of rank **m** such that

$$(5) \qquad \Sigma = \mathbf{HH'}$$

A square-root method can be used to calculate **H** (Graybill).

Impulse Responses

The contemporaneous model derived by decomposing the covariance matrix and the dynamic VAR model are used to compute impulse responses, which measure the responses of the endogenous variables in the system to an initial shock in the errors. It traces the effects of an initial shock on current and future values of the endogenous variables. By multiplying the original VAR model by the Choleski decomposed matrix, $\mathbf{H^{-1}}$, the impulse response is specified as follows (Sims, 1980)

$$(6) \qquad \mathbf{H^{-1}Y_{it} = H^{-1}\beta Y_{it-1} + H^{-1}\beta Y_{it} + \ldots + H^{-1}v_{it}}$$

where $\boldsymbol{\beta}$ is a matrix of estimated parameters. The impact of an innovation on all endogenous variables in subsequent periods can be measured by moving the system of endogenous variables ahead one time period at a time.

Monte Carlo integration can be used to compute means and variances of the posterior distribution of the impulse responses. The posterior distribution of $(\mathbf{B},\Sigma)$ is Normal-inverse Wishart (Zellner).

$$\Sigma^{-1} \sim \text{Wishart}\,((T\hat{\Sigma})^{-1},T)$$

and, given Σ,

$$\mathbf{B} \sim N(\hat{\mathbf{B}},\Sigma(X'Z(Z'Z)^{-1}Z'X)^{-1}).$$

Data

Data on three U. S. commodities--corn, soybeans, and wheat--were collected for the 1950-1988 period. The four variables included in the analysis were production, prices received by farmers, exports and research expenditures.

USDA publications prepared as background information for farm legislation were the sources of data for production, prices, and exports. Corn data were from Lin, Leath, and Paarlberg and Mercier. Soybean data were from Hacklander and Gardiner and Crowder and Davison. Wheat data were from Evans and Harwood and Young.

State Agricultural Experiment Station (SAES) research expenditure data for selected commodities for 1950-1982 have been compiled by Robert E. Evenson. These data cover 42 states, excluding Alaska, Connecticut, District of Columbia, Hawaii, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Using the same states, SAES research expenditure data were compiled from the USDA Current Research Information System (CRIS) for 1967-1988 to update the Evenson series. The CRIS data were used for the 1967-1988 period, and Evenson's data were used for the 1950-1966 period.

Production and exports were based on million bushels. Prices were on the basis of dollars per bushel. Research expenditures were based on million dollars. Prices and research expenditures were converted to constant 1970 dollars using the GNP implicit price deflator reported in the Economic Indicators of the Farm Sector (USDA). All variables were converted to logarithms for analysis.

Empirical Results

The relationships among the four endogenous variables were estimated using a panel VAR model. The optimal number of lags for each equation was determined separately, considering 0 to 10 lags. The combination of lags that gave the lowest FPE criterion was selected as the optimal number of lags. Optimal lag lengths for each equation are identified in Table 1. Eight years is the longest lag. With one observation lost for differencing and another observation lost for the instrumental variables, a VAR with eight lags actually requires ten observations prior to the period of analysis. Hence the period of analysis for this study covered the years 1950-88. With three cross-sections for corn, soybeans, and wheat, and 29 periods, the analysis was based on 87 observations.

With interactions among the variables, it is difficult to interpret VAR results directly. However, two types of analyses from the VAR results will be presented. First, the covariance matrix of the VAR residuals will be decomposed to identify contemporaneous relationships. Secondly, impulse responses which combine contemporaneous and dynamic relationships will be presented.

Contemporaneous relationships among the endogenous variables are identified by Choleski decomposition of the covariance matrix. For comparison, a covariance matrix based on the original differences from cross-sectional means is presented first in Table 2. Then the covariance matrix based on the residuals of the VAR model is reported in the lower half of Table 2. A covariance matrix from the VAR model was derived by converting predicted values from the logarithmic model back to original levels and calculating residuals between actual and predicted values. These two covariance matrices were orthogonalized by Choleski factorization. A comparison of these two covariance matrices reveals that the unexplained variation from the VAR model is a small percentage of the original variation in the data.

A one standard deviation innovation in research expenditures ($.386 million) would increase exports by 15.7 million bushels (Table 2). A one standard deviation shock in production would reduce price by 8.3 cents per bushel. For purposes of this study, the information from the covariance matrix is only a starting point for uncovering the dynamic relationships among the endogenous variables.

Means and standard deviations of the impulse responses are estimated with 1000 expenditures for selected years over the 100-year period are reported in Table 3. The results show the volatility of research expenditures. A given innovation in research expenditures is followed by a decline in research in the second year and then a sharp rise in research in the third year. After 100 years, the cumulative research response is $0.9 million, 125 percent greater than the initial innovation. In the long run, the increase in research expenditures of almost one million dollars increases exports 20.0 million bushels, increases production 36.6 million bushels, and increases price by 6.9 cents per bushel. These long-term impacts are statistically significant at the 5 percent level.

The impacts of a one standard deviation innovation in exports is shown in Table 4. In the long run, almost one million bushels in exports increases production by 34.5 million bushels, increases price by 17.2 cents per bushel, and increases research expenditures by $.07 million. These long-term impacts are statistically significant at the 5 percent level.

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Table 1. Optimal Lag Lengths

	Equations			
Variables	Research Expenditures	Exports	Production	Prices
Research Expenditures	3	0	7	0
Exports	0	2	8	4
Production	0	5	5	3
Prices	3	7	0	4

Table 2. Choleski Decomposition of Selected Covariance Matrices

	Research	Exports	Production	Price
Original Data				
Research	6.277			
Exports	315.983	331.349		
Production	647.323	447.067	667.731	
Price	-.562	.294	-.185	1.305
VAR Model				
Research	.386			
Exports	15.654	116.526		
Production	33.494	-44.915	298.333	
Price	-.091	.013	-.083	.403

Table 3. Impulse Responses for One Standard Deviation Innovation in Research

Period	Research	Exports	Production	Price
	(Mil. $)	(Mil. Bu.)	(Mil. Bu.)	($/Bu.)
1	0.398	24.921	40.850	-0.101
	(0.031)	(13.389)	(33.919)	(0.047)
2	0.038	-1.908	4.375	0.138
	(0.005)	(2.815)	(9.044)	(0.032)
3	0.237	-7.537	-20.101	0.081
	(0.019)	(2.998)	(22.811)	(0.012)
4	-0.004	-0.994	5.402	-0.047
	(0.008)	(1.471)	(6.996)	(0.013)
5	0.128	6.535	44.177	-0.020
	(0.011)	(1.967)	(8.279)	(0.016)
1-5	0.792	20.367	72.835	0.052
	(0.064)	(10.339)	(21.444)	(0.021)
1-10	0.866	21.866	36.939	0.071
	(0.077)	(11.680)	(20.013)	(0.027)
1-15	0.888	16.903	33.496	0.070
	(0.078)	(9.458)	(14.195)	(0.023)
1-20	0.906	20.310	40.111	0.086
	(0.081)	(10.773)	(18.389)	(0.031)
1-25	0.895	21.021	33.409	0.074
	(0.079)	(11.015)	(18.296)	(0.030)
1-100	0.900	19.975	36.579	0.069
	(0.079)	(10.972)	(18.300)	(0.030)

Standard deviations are in parentheses.

Table 4. Impulse Responses for One Standard Deviation Innovation in Exports

Period	Research	Exports	Production	Price
	(Mil. $)	(Mil. Bu.)	(Mil. Bu.)	($/Bu.)
1	0.000	116.645	-26.607	0.040
	(0.000)	(9.111)	(33.628)	(0.045)
2	-0.003	-1.083	52.718	0.234
	(0.004)	(2.846)	(7.990)	(0.022)
3	0.003	-25.432	117.282	-0.024
	(0.004)	(2.020)	(20.516)	(0.010)
4	0.014	-8.670	-53.528	-0.062
	(0.008)	(1.286)	(5.657)	(0.011)
5	0.026	7.824	40.203	-0.136
	(0.003)	(1.680)	(6.299)	(0.011)
1-5	0.040	90.388	132.080	0.054
	(0.015)	(7.515)	(18.089)	(0.019)
1-10	0.088	101.474	70.749	0.152
	(0.034)	(8.574)	(19.034)	(0.023)
1-15	0.036	82.487	40.657	0.116
	(0.033)	(6.931)	(13.583)	(0.019)
1-20	0.072	95.313	70.611	0.192
	(0.037)	(7.780)	(17.279)	(0.025)
1-25	0.050	96.726	36.539	0.181
	(0.035)	(.8066)	(17.879)	(0.025)
1-100	0.066	97.405	34.488	0.172
	(0.035)	(7.909)	(17.876)	(0.025)

Standard deviations are in parentheses.