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DERIVING SUPPLY ELASTICITIES FROM COST OF PRODUCTION ESTIMATION: THE EFFECT OF FERTILIZER POLICY ON U.S., FRENCH, and U.K. WHEAT AND CORN PRODUCTION

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Fertilizer

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Introduction

By encouraging farm activity beyond what the market would induce, agricultural policy has distorted the value of resources, the cost of inputs, and the prices of commodities. Encouraging agricultural production has increased the demand for chemical inputs, especially fertilizers. Greater application rates of fertilizers in agricultural production have caused ground and surface water pollution through residual spillover and leaching. If the intensity of agricultural production results in water pollution without requiring producers to internalize the cost of pollution, then there exists a difference between social and private costs.

The water contamination problem arising from runoff of chemical inputs from agricultural production has attracted the attention of policy makers in both the U.S. and the EC over the last decade. Concurrently, the Environmental Protection Agency of the U.S. and the Directorate of Agriculture of the EC Commission are undertaking assessments of this problem.

The purpose of this study is to investigate how input policies (i.e., a tax or a quantitative restriction) aimed at reducing the use of fertilizer affect the marginal cost, MC, (and therefore supply) of wheat in the U.S., France, and the U.K., and corn in the U.S. and France. The translog (Tlog) cost function for each crop is estimated and the MC function is derived. Supply responses of wheat and corn are calculated from MC functions via the estimation of cost functions, and used for comparison across countries. In addition, price elasticities of factor demand, elasticities of substitution, input and output price elasticities of supply, and input price elasticities of MC are computed from the estimation of the cost functions. These estimates will be used as the basis for simulation modeling of unilateral and multilateral country policy scenarios designed to reduce agricultural intensity. Simulation exercises using these estimates permit investigation of the effect of input policy on input demand, production, consumption, export supply, and prices. This study is organized in three parts, model specification, results, and conclusions and potential policy implications.

Model Specification

Comparing costs of production of crops across countries raises several conceptual and econometric issues. These issues include (1) international comparability of cost concepts, definitions, and data collection methods, (2) the time period of the sample, (3) the relevance of various theoretical production/cost properties (adding-up, homogeneity, symmetry, negativity, monotonicity, duality).

Duality in production economics, linking production and cost relationships, has permitted researchers to estimate parameters of a cost function and relay the information to the underlying production function. Since production data (input quantities) by crop are difficult to obtain and expenditure data (input prices and expenditures on inputs) are more readily available, cost estimation is often feasible where direct estimation of production functions is not. Cost function estimation in the past has generally been limited to computation of input demand elasticities and elasticities of substitution (Binswanger; Ray). Marginal analysis has been applied to data on supply and demand elasticities, prices, quantities, and estimated cost and yield effects of input policy (Lichtenberg, Parker, and Zilberman). This study attempts to directly estimate supply shifts from a MC function through the estimation of a cost function, and to discuss the theoretical consistency of the model (Capalbo and Antle).

The Tlog cost function approximates the true minimum cost function with a second order logarithmic Taylor series expansion around variable levels of output, Q, and input prices, P_i. Expressed mathematically a cost function, C, in logarithms is of the form: $\ln C = f(\ln P_1, \ldots, \ln P_n; \ln Q)$. The second order Taylor series expansion of this function generates the Tlog cost function:

$$\ln C = \alpha_o + \alpha_Q \ln Q + .5\alpha_{QQ}(\ln Q)^2 + \sum_i \alpha_i (\ln P_i)$$
$$+ .5 \cdot \sum_i \sum_j \beta_{ij} (\ln P_i)(\ln P_j) + \sum_i \delta_{Qi} (\ln Q)(\ln P_i)$$

where C is cost of production, Q is output, P_i are input prices, ln is the natural log, and the α, β, and δ are parameters to be estimated.

For empirical estimation, a three input (E, energy; F, fertilizer; and K, capital) Tlog cost function is estimated simultaneously with two cost share equations using seemingly unrelated regression (SUR). The simultaneous system of equations to be estimated, imposing homogeneity (deflating by the price of energy) and symmetry ($\beta_{FK} = \beta_{KF}$) is the following:

$$\ln C = \alpha_o + \alpha_Q \ln Q + .5\alpha_{QQ}[\ln Q]^2 + \alpha_F \ln(\frac{P_F}{P_E}) + \alpha_K \ln(\frac{P_K}{P_E})$$
$$+ .5\beta_{FF}\left[\ln(\frac{P_F}{P_E})\right]^2 + \beta_{FK}\ln(\frac{P_F}{P_E}) \cdot \ln(\frac{P_K}{P_E}) + .5\beta_{KK}\left[\ln(\frac{P_K}{P_E})\right]^2$$
$$+ \delta_{QF}\ln Q \cdot \ln(\frac{P_F}{P_E}) + \delta_{QK}\ln Q \cdot \ln(\frac{P_K}{P_E})$$
$$S_F = \alpha_F + \beta_{FF}\ln(\frac{P_F}{P_E}) + \beta_{FK}\ln(\frac{P_K}{P_E}) + \delta_{QF}\ln Q$$
$$S_K = \alpha_K + \beta_{FK}\ln(\frac{P_F}{P_E}) + \beta_{KK}\ln(\frac{P_K}{P_E}) + \delta_{QK}\ln Q$$

where P_E, P_F, P_K are the prices of energy, fertilizer, and capital respectively; S_F and S_K are the cost shares of fertilizer and capital.

The adding-up condition implies $\Sigma\, \alpha_i = 1$ and $\Sigma\, \delta_{Qi} = 0$; the homogeneity condition implies $\Sigma\, \beta_{ij} = \Sigma\, \beta_{ji} = 0$; and the symmetry condition implies $\beta_{ij} = \beta_{ji}$. Degrees of freedom limitations do not permit a statistical test of the homogeneity restriction; however, the expectation that a cost function is homogeneous of degree one in input prices justifies the restriction. The adding-up condition is effectively imposed with homogeneity. From Young's Theorem the order of differentiation does not matter and, since the β coefficients represent partial derivatives with respect to P_i and P_j, the coefficients β_{ij} and β_{ji} are symmetric. The symmetry restriction is tested statistically as are restrictions on the values of parameters.

Relying on Shephard's Lemma, input demand functions can be derived and the own-price and cross-price input demand elasticities can be computed as follows:

$$\xi_{ii} = (\beta_{ii}/S_i) + S_i - 1 \qquad \xi_{ij} = (\beta_{ij}/S_i) + S_j.$$

The elasticities of substitution, measuring the proportionate change in the ratio of inputs i and j relative to the change in the marginal rate of technical substitution between inputs i and j along an isoquant, can be computed. The value of the elasticity of substitution provides insight into the relationship among inputs. Although there exist several alternative substitution elasticities (Debertin and Pagoulatos; Blackorby and Russell), the Allen partial (own and cross), Shadow, and Morishima elasticities of substitution are computed respectively as follows:

$$\sigma^A_{ii} = [\beta_{ii} + S_i \cdot (S_i - 1)]/S_i^2, \qquad \sigma^A_{ij} = (\beta_{ij} + S_i \cdot S_j)/S_i \cdot S_j;$$

$$\sigma^S_{ij} = S_i \cdot S_j/[(S_i + S_j) \cdot (2\sigma^A_{ij} - \sigma^A_{ii} - \sigma^A_{jj})]; \quad \sigma^M_{ij} = S_j(\sigma^A_{ij} - \sigma^A_{jj}).$$

The emphasis of this study is on measuring the effect of input policy (a fertilizer tax or quantitative restriction) on cost of production, particularly cost at the margin. Taking the appropriate derivative, the Tlog MC function is expressed as:

$$\frac{\partial C}{\partial Q} \equiv MC = AC\{\alpha_Q + \alpha_{QQ}\ln Q + \sum_i \delta_{Qi}\ln P_i\}$$

where AC is average cost and is a function of quantity and input prices, i.e., $[AC(Q;P_i)]$. The estimated parameters from the cost function (α_Q, α_{QQ}, and δ_{Qi}) can be substituted into the MC function. Clearly, for MC to be greater than (less than) AC, $\{\alpha_Q + \alpha_{QQ}\ln Q + \Sigma\ \delta_{Qi}\ln P_i\}$ must be greater than (less than) one. Minimum AC occurs when the above expression in brackets is equal to one. Input price elasticities of MC, computed by taking the partial derivative of MC with respect to input prices, are:

$$\xi_{MC}^{P_i} = \frac{AC}{MC}\left\{S_i(\alpha_Q + \alpha_{QQ}lnQ + \sum_i \delta_{Qi}lnP_i) + \delta_{Qi}\right\}.$$

Recall from microeconomic theory that the MC function is the inverse supply function in the region where producers would choose to operate, i.e., at all points above minimum average variable cost. If there is no fixed factor, then average variable cost is AC. Since it is assumed the market is competitive, producers supply a level of output (where the MC is greater than AC) such that MC is equal to the output price (P_Q), i.e., $[MC(P_i;Q) = P_Q]$.

Using the MC function and taking the appropriate derivatives with respect to input price and input quantity and output price, one can verify that the input price elasticities of supply (the effect of the tax), the input quantity elasticities of supply (the effect of the quantitative restriction), and the output price elasticity of supply are respectively:

$$\xi_S^{P_i} = \frac{-(MC \cdot S_i + AC \cdot \delta_{Qi})}{\frac{MC^2}{AC} - MC + AC \cdot \delta_{QQ}}; \quad \xi_S^{X_i} = \frac{AC \cdot S_i}{MC \cdot S_i + AC \cdot \delta_{Qi}}; \quad \xi_S^{P_Q} = \frac{MC \cdot AC}{MC^2 - MC \cdot AC + AC^2 \cdot \alpha_{QQ}}.$$

Data

U.S. cost of production (COP) data by crop are published on a yearly basis from USDA Cost of Production publications (USDA-ERS). Input price data are reported in various issues of Agricultural Statistics (USDA) as are crop acres planted and crop quantity produced. The COP data for the U.K. are published in the Report on Farming in the Eastern Counties of England 1988/89 (Murphy). Input price data are published in The Agricultural Situation in the Community (EC Commission) annual reports. The French COP data are published in a report produced by Unigrains entitled Couts de Production du Ble Tendre et du Mais en France (Le Stum and Camaret). In addition, cost share coefficients by input category for major commodities were made available by the Commission of the EC. The initial data analysis was performed by the INRA, Institut National des Recherches Agronomiques, of France. Production data, yield, and hectare harvested are published in Production Yearbook (U.N.-F.A.O.). Aggregated yearly data are used for the period 1975-89 for the U.S., 1979-89 for France, and 1975-88 for the U.K.

Cost Function Estimation Results

The results of the regression of the cost functions and the fertilizer and capital cost share equations for U.S., French, and U.K. wheat are reported in Table 1, and for U.S. and French corn in Table 2. The estimated coefficients are used to derive the Tlog MC function. It is expected that output varies positively with cost of production both for the first order (α_Q) and second order coefficient on quantity (α_{QQ}). A multicollinearity problem consistently appeared between the quantity coefficients, affecting the theoretical consistency of the model. In each case, neither coefficient was statistically significant and one of the signs was negative. As one of the quantity coefficients was dropped from the estimation, the regressed quantity coefficient was always positive and significant. By dropping one of the quantity coefficients, however, the translog cost function may be misspecified as a result of omitting a relevant explanatory variable. The chosen set of estimates were based on those from restricting α_{QQ} to be a small positive number (0.001), while letting the α_Q take on its estimated value. Although both coefficients appear in the MC function, it is critical that the value of α_Q be positive because it is the constant in the MC function. Convexity requires that the two coefficients be positive; therefore, a suitable check was not permitted (Capalbo and Antle).

Homogeneity was required for the estimation of the cost function, but statistical tests of significance were possible for symmetry. At the five percent level, the restrictions for symmetry were statistically significant, implying that the restrictions were necessary for the theoretical condition to be satisfied. The tests were conducted using the Chi-square test by the likelihood ratio method (Lopez). Negativity is satisfied for each crop as the own-price Allen partial substitution elasticities are negative. Monotonicity in input prices, requiring that the share equations are positive, is satisfied. Monotonicity in output, requiring that MC be positive, is satisfied by restriction.

In Tables 3, 4, and 5 all relevant elasticities are reported from the wheat COP estimation (computed at the sample means) for the U.S., France, and the U.K., respectively. The Hicksian own-price elasticities of input demand are all negative, implying an increase in the price of an input, holding output constant, results in a decrease in demand for the input. The fertilizer own-price elasticities are -0.3383, and -0.0771, -0.5227 for the U.S., France, and the U.K., respectively. The cross-price elasticities are generally positive, indicating that the inputs are substitutes.

The input price elasticities of MC are all positive indicating that an increase in the price of an input results in an increase in MC. The values of the MC elasticities with respect to the fertilizer price are 0.3304, 0.5102, and 0.2964 for the U.S., France, and the U.K. It was expected that the European countries would have larger changes in MC from a change in the price of fertilizers because wheat is more fertilizer intensive in Europe.

The input price (quantity) elasticities of supply, capturing the effect of a tax on an input (capturing the effect of quantitative restriction of the use of an input), are all negative (positive) as expected. The fertilizer price elasticities of supply for the U.S., France, and the U.K. are -0.2156, -0.4689, and -0.3134. The fertilizer quantity elasticity of supply for the three respective countries are 0.4011, 0.4814, and 0.5523. The output price elasticities of supply are positive, implying producers would be willing to increase supply in expectation of higher profits. The output price elasticities for wheat supply in the U.S., France, and the U.K. are 0.6265, 0.9091, and 1.0415.

The elasticities from the estimation of the U.S. and French corn cost functions are reported in Tables 6 and 7. The own-price Hicksian elasticities of fertilizer demand are negative, -0.0602 for the U.S. and -0.0798 for France. The U.S. elasticities of substitution for each pair of inputs are positive, suggesting the inputs are substitutes. For France, the only exception is the energy-fertilizer pair, the negative sign indicating a complementary relationship.

The marginal cost elasticities with respect to the price of fertilizer are similar for U.S. and French corn, 0.5108 and 0.5879. Although corn is the more fertilizer intensive crop relative to wheat in the U.S., it accounts for a smaller proportion of costs compared with French corn. The elasticities of MC for the indicate that changes in costs associated with changes in fertilizer prices have the most effect on the more fertilizer intensive crop, i.e. corn. For France, both crops are fairly fertilizer intensive, though wheat is the more intensive crop of the two. The MC elasticities suggest that changes in the MC of corn associated with fertilizer price changes are slightly larger than for wheat in France.

The input price elasticities of supply for the U.S. and France are -0.3949 and -0.4448. Given that French changes in MC associated with fertilizer price changes were larger, it is consistent for the supply changes to be larger for France as well. The input quantity elasticity of supply, however, is somewhat larger for U.S. corn than for French corn, 0.4418 compared with 0.4150.

The input price and quantity elasticities of supply are larger in magnitude for European wheat as expected. For corn, the effect of the tax has a larger effect on French supply, but the quantitative restriction has a larger effect on U.S. supply. The values of the elasticities support the hypothesis that policies aimed at reducing the use of a polluting input will adversely affect the producers that use the polluting input most intensively.

Conclusions and Potential Policy Implications

The results of the estimation of the wheat and corn cost functions permit meaningful economic interpretation. The input demand, MC, and supply elasticities are of the correct sign and generally reasonable in magnitude. Although this study is limited by the small sample periods, the results confirm it is a legitimate approach to compute supply responses by substituting the parameter estimates of a cost function and deriving a MC function and recalling that MC is the inverse of supply.

The wheat and corn supply elasticities with respect to output prices and fertilizer prices for the U.S., France and the U.K. estimated in this study are comparable with the results from other studies (Shumway; Henneberry and Tweeten; Koopmans; Helmers, Azzam, and Spilker). Although the input quantity elasticities of supply, derived via the cost function, are not comparable to those from other studies per se, the magnitudes across countries are consistent with the findings from the input price elasticities. Hence, it is useful to discuss these elasticities in terms of potential policy implications.

Consider two policy instruments for the purposes of reducing the use of a polluting input: a fertilizer tax of 25 percent, and a quantitative restriction on its use by 20 percent. The input price elasticities suggest that a 25 percent tax on fertilizer in each country would result in reduced wheat supplies in the U.S., France, and the U.K. by 5.39 percent, 11.72 percent, and 7.84 percent. If a 20 percent reduction in fertilizer were desirable for the purposes of relieving environmental degradation, then the elasticities predict that supply would be reduced in each country by 8.02 percent, 9.63 percent, and 11.05 percent. Clearly, the U.S. wheat producers would benefit relative to their EC counterparts from agri-environmental policies when imposed multilaterally. For corn, the input price elasticities suggest that a 25 percent tax on fertilizer in the U.S. and France would result in reduced corn supplies by 9.87 percent and 11.12 percent, respectively. The 20 percent quantitative restriction, implied by the input quantity elasticities of supply, suggest that the U.S. supply would be reduced by 8.84 percent and the French supply by 8.30 percent.

Although the levels at which these policy instruments are selected is arbitrary, the elasticities serve as a indicator of the magnitude of the effect of potential policies. In the 25 (20) percent tax (quantitative restriction) policy, it is apparent that policies aimed at reducing fertilizer would tend to adversely affect French and U.K. crop supplies more than the U.S. supplies. According to the findings in this study, the losses to wheat producers would be greater relative to corn producers in Europe. In addition, the European producers would also be more adversely affected by such policy relative to their U.S. counterparts, particularly for wheat.

Future research will compare input policies designed to reduce fertilizer use with other EC member countries and other crops. The elasticities computed will be used as the basis for simulation modeling of potential input policy scenarios designed to reduce agricultural intensity. Different policy mixes will be considered under a unilateral, bilateral, and multilateral framework. In addition, trade policy simulations affecting crop production can be evaluated in terms of changes in input demands. For example, if decoupling agricultural policy were proposed, it is possible to determine how input demand will be affected from the changes in output supply.

Table 1. Wheat Cost of Production Estimation Results: the U.S., France, and the U.K. using SUR.[a]

	U.S. Wheat (1975-89)		French Wheat (1979-89)		U.K. Wheat (1975-88)	
	Coefficient	Std Error	Coefficient	Std Error	Coefficient	Std Error
α_O	0.002	0.026	- 0.001	0.034	0.000	0.048
α_Q	2.596	0.750	2.100	b	1.960	0.696
α_{QQ}	0.001	b	0.001	b	0.001	b
α_E	0.199	c	0.045	c	0.319	c
α_F	0.344	0.026	0.516	0.033	0.322	0.048
α_K	0.457	0.026	0.439	0.034	0.359	0.048
β_{EE}	0.124	c	0.022	c	0.116	c
β_{EF}	- 0.012	c	- 0.036	c	- 0.040	c
β_{EK}	- 0.113	c	0.014	c	- 0.075	c
β_{FF}	0.109	0.111	0.210	b	0.050	b
β_{FK}	- 0.098	0.086	- 0.174	b	- 0.010	0.219
β_{KK}	0.210	0.114	0.160	b	0.085	0.250
δ_{QE}	0.133	c	0.078	c	0.063	c
δ_{QF}	- 0.035	0.049	- 0.012	0.023	- 0.050	0.088
δ_{QK}	- 0.099	0.062	- 0.066	0.011	- 0.013	0.097

	U.S. Cost Function	French Cost Function	U.K. Cost Function
R-square:	0.901	0.852	0.945
Chi-square:	14.921	8.006	21.767
Sum of Squared Residuals:	0.092	0.097	0.161
Degrees of Freedom:	14.000	15.000	14.000

a Seemingly unrelated regression (SUR) estimation of 3 equations with homogeneity and symmetry imposed. Using a Chi-square test, restrictions were significant at 5 % level, implying that the restrictions were needed.

b Restricted coefficients in the system of equations were tested using an F-test at the 5 % level.

c Standard errors are not reported since the energy cost share is omitted from system of equations.

Table 2. Corn Cost of Production Estimation Results: The U.S. and France Using SUR.[a]

	U.S. Corn (1975-89) Coefficient	Std Error		France Corn (1978-89) Coefficient	Std Error
α_O	0.001	0.008	α_O	0.002	0.021
α_Q	1.440	0.691	α_Q	2.212	b
α_{QQ}	0.001	b	α_{QQ}	0.001	b
α_E	0.145	c	α_E	0.032	c
α_F	0.527	0.025	α_F	0.540	0.021
α_K	0.329	0.025	α_K	0.428	0.021
β_{EE}	0.087	c	β_{EE}	0.010	c
β_{EF}	- 0.071	c	β_{EF}	- 0.037	c
β_{EK}	- 0.013	c	β_{EK}	0.027	c
β_{FF}	0.218	0.108	β_{FF}	0.205	b
β_{FK}	- 0.147	0.088	β_{FK}	- 0.169	b
β_{KK}	0.160	0.123	β_{KK}	0.142	b
δ_{QE}	0.122	c	δ_{QE}	0.011	c
δ_{QF}	- 0.037	0.047	δ_{QF}	0.107	0.014
δ_{QK}	- 0.085	0.062	δ_{QK}	- 0.118	0.006

	Translog Cost Function		Translog Cost Function
R-square:	0.836	R-square:	0.736
Chi-square:	13.205	Chi-square:	12.582
Sum of Squared Residuals:	0.089	Sum of Squared Residuals:	0.059
Degrees of Freedom:	14.000	Degrees of Freedom:	15.000

a Seemingly unrelated regression (SUR) estimation of 3 equations, imposing homogeneity and symmetry. Using a Chi-square test, restrictions were significant at 5 % level, implying that the restrictions were needed.
b Restricted coefficients in the system of equations were tested using an F-test at the 5 % level.
c Standard errors are not reported since the energy cost share is omitted from system of equations.

Table 3. Input Demand, Output Supply, Marginal Cost, and Substitution Elasticities: U.S. Wheat Estimates.[a]

	Input Demand Price Elasticities			Marginal Cost Price Elasticities	Output Supply Elasticities	
	Quantity Demanded:			Marginal Cost:	Input Price:	Input Quantity:
	Energy	Fertilizer	Capital	Wheat		
Prices:						
Energy	-0.1764	0.2848	-0.1084	0.2504	-0.1248	0.3063
Fertilizer	0.1648	-0.3383	0.1735	0.3304	-0.2156	0.4011
Capital	-0.0472	0.1305	-0.0833	0.4192	-0.2867	0.4203
					Output Price:	
					0.6265	

Elasticities of Substitution

	Allen Partial Elasticities:			Morishima Elasticities:			Shadow Elasticities:		
	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital
Energy	-0.8864	0.0979	-0.0495	n/c	0.3720	0.0607	n/c	0.2605	0.1344
Fertilizer		-0.9839	0.0793	0.1959	n/c	0.1196		n/c	0.2600
Capital			-0.1822	0.1665	0.3656	n/c			n/c

[a] The supply and marginal cost elasticities are calculated at the arithmetic mean with other factors held constant at the geometric mean. Input demand and substitution elasticities are calculated using estimated parameters.

n/c Refers to values which are not computed.

Table 4. Input Demand, Output Supply, Marginal Cost, and Substitution Elasticities: French Wheat Estimates.[a]

	Input Demand Price Elasticities			Marginal Cost Price Elasticities	Output Supply Elasticities	
	Quantity Demanded:			Marginal Cost:	Input Price:	Input Quantity:
	Energy	Fertilizer	Capital	Wheat		
Prices:						
Energy	-0.4600	-0.2837	0.7437	0.0823	-0.0412	0.2617
Fertilizer	-0.0290	-0.0771	0.1020	0.5102	-0.4689	0.4814
Capital	0.0767	0.1198	-0.1966	0.4074	-0.3990	0.5136
					Output Price:	
					0.9091	

Elasticities of Substitution

	Allen Partial Elasticities:			Morishima Elasticities:			Shadow Elasticities:		
	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital
Energy	-10.1595	-0.1463	0.3264	n/c	0.0016	0.4534	n/c	0.4169	0.4621
Fertilizer		-0.1494	0.0448	0.4534	n/c	0.2162		n/c	0.1628
Capital			-0.4478	0.4748	0.1001	n/c			n/c

[a] The supply and marginal cost elasticities are calculated at the arithmetic mean with other factors held constant at the geometric mean. Input demand and substitution elasticities are calculated using estimated parameters.

n/c Refers to values which are not computed.

Table 5. Input Demand, Output Supply, Marginal Cost, and Substitution Elasticities: U.K. Wheat Estimates.[a]

	Input Demand Price Elasticities			Marginal Cost Price Elasticities	Output Supply Elasticities	
	Quantity Demanded:			Marginal Cost:	Input Price:	Input Quantity:
Prices:	Energy	Fertilizer	Capital	Wheat		
Energy	-0.3185	0.1954	0.1231	0.3512	-0.3666	0.4677
Fertilizer	0.1935	-0.5227	0.3292	0.2964	-0.3134	0.5523
Capital	0.1094	0.2954	-0.4047	0.3524	-0.3694	0.5224
					Output Price:	
					1.0415	

Elasticities of Substitution

	Allen Partial Elasticities:			Morishima Elasticities:			Shadow Elasticities:		
	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital
Energy	-0.9985	0.0629	0.0442	n/c	0.5430	0.4206	n/c	0.4402	0.3740
Fertilizer		-1.6229	0.1182	0.3385	n/c	0.4472		n/c	0.5070
Capital			-1.1275	0.3326	0.5607	n/c			n/c

[a] The supply and marginal cost elasticities are calculated at the arithmetic mean with other factors held constant at the geometric mean. Input demand and substitution elasticities are calculated using estimated parameters.

n/c Refers to values which are not computed.

Table 6. Input Demand, Output Supply, Marginal Cost and Substitution Elasticities: U.S. Corn Estimates.[a]

	Input Demand Price Elasticities			Marginal Cost Price Elasticities	Output Supply Elasticities	
	Quantity Demanded:			Marginal Cost:	Input Price:	Input Quantity:
Prices:	Energy	Fertilizer	Capital	Corn		
Energy	-0.2786	0.0390	0.2406	0.1971	-0.1087	0.3150
Fertilizer	0.0105	-0.0602	0.0497	0.5108	-0.3949	0.4418
Capital	0.1062	0.0796	-0.1859	0.2920	-0.2463	0.4825
					Output Price:	
					0.7500	

Elasticities of Substitution

	Allen Partial Elasticities:			Morishima Elasticities:			Shadow Elasticities:		
	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital
Energy	-1.9216	0.0200	0.0790	n/c	0.0707	0.2118	n/c	0.2360	0.2661
Fertilizer		-0.1143	0.0163	0.2815	n/c	0.1912		n/c	0.1442
Capital			-0.5659	0.2901	0.0688	n/c			n/c

[a] The supply and marginal cost elasticities are calculated at the arithmetic mean with other factors held constant at the geometric mean. Input demand and substitution elasticities are calculated using estimated parameters.

n/c Refers to values which are not computed.

Table 7. Input Demand, Output Supply, Marginal Cost, and Substitution Elasticities: French Corn Estimates.[a]

	Input Demand Price Elasticities			Marginal Cost Price Elasticities	Output Supply Elasticities	
	Quantity Demanded:			Marginal Cost:	Input Price:	Input Quantity:
	Energy	Fertilizer	Capital	Corn		
Prices:						
Energy	-0.6607	-0.5799	1.2406	0.0374	-0.0269	0.3942
Fertilizer	0.0350	-0.0798	0.1148	0.5879	-0.4448	0.4150
Capital	0.0945	0.1448	-0.2393	0.3747	-0.3527	0.5156
					Output Price:	
					0.8249	

Elasticities of Substitution

	Allen Partial Elasticities:			Morishima Elasticities:			Shadow Elasticities:		
	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital	Energy	Fertilizer	Capital
Energy	-28.2633	-0.3129	0.5308	n/c	-0.0890	0.4664	n/c	0.6084	0.6630
Fertilizer		-0.1478	0.0491	0.6505	n/c	0.2603		n/c	0.1922
Capital			-0.5594	0.6780	0.1063	n/c			n/c

[a] The supply and marginal cost elasticities are calculated at the arithmetic mean with other factors held constant at the geometric mean. Input demand and substitution elasticities are calculated using estimated parameters.

n/c Refers to values which are not computed.

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