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Estimation of Aggregate U.S. Demands for Fertilizer, Pesticides, and Other Inputs

A Model for Policy Analysis

C. Matthew Rendleman

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Abstract

The method often proposed to meet environmental goals such as water quality improvement is input restriction, such as reduced fertilizer or pesticide use. Computable general equilibrium (CGE) models are potentially valuable tools to analyze the economic impact of such programs. However, to be useful, such models must approximate reality in the way they deal with input substitution. This report presents elasticity estimates that are consistent both with data on input use and with the assumptions of commonly used CGE models. The report describes the estimation of elasticities of substitution among nine outputs and six inputs, including pesticide and fertilizer. A nested production structure is assumed. The nesting structure employed allows the effects of price changes in agricultural inputs to be broken into stages. An effective 10-percent charge on pesticides goes further toward reducing its use (-17.46 percent) than does a 10-percent charge on fertilizer use (-1.0 percent). However, most of the effect on pesticide use (99 percent) occurs in the bottom nest, while the greatest effect on fertilizer (63 percent) occurs in the higher nests. The report ends with a partial equilibrium analysis of a 10-percent fertilizer charge and a 10-percent pesticide charge.

Keywords: Economywide analysis, input policy, computable general equilibrium (CGE) models, nested production functions, input substitution, elasticities of substitution, pesticides, fertilizer

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Introduction

One method to improve water quality is input restrictions. To be useful in analyzing input policy, analytical models must account for interactions among a range of inputs as well as output effects over a disaggregated mix of agricultural products. Such models necessarily incorporate estimates of economic parameter values. Input demand and substitution elasticities are especially important when modeling input restrictions. Preferably, these parameters should be estimated econometrically under the same assumptions incorporated in the policy model. This report explores these parameters and provides elasticity values that can be used in computable general equilibrium (CGE) models with nested production functions.[1]

This report examines the nature of fertilizer and pesticide interactions in various farm sectors and gives first-round effects of chemical price or input quantity disturbances. The final section of the report demonstrates that these estimates, when used in a partial equilibrium framework, have immediate use for understanding the response of the agricultural sectors to input reductions.

These elasticities also provide parameters for applied general equilibrium models that can be used to answer economywide questions. These estimates, which are compatible with general equilibrium assumptions, can add credibility to a type of model that often uses "reasonable" rather than estimated elasticities because of the number of parameters needed. Of particular importance are input substitution elasticities for fertilizers (nitrogen and phosphorus) and pesticides. The results should prove useful to policy modelers seeking to incorporate estimates of substitutability into larger models of the economy.

In the past, estimates of elasticities of substitution between fertilizers, chemicals, and other inputs (such as land and labor) have been too limited for this broader purpose. Earlier studies often include a "chemicals" category (as Ball's study does) without accounting for cross effects between fertilizer and pesticides. Thus, no differentiated policy analysis is possible. For example, what happens to the use of pesticides if fertilizer use is controlled by policy? An opposite problem has been too narrow a focus. In this case, for example, a study of the reduction of a particular chemical (with possible close substitutes) may not consider the broader class of chemicals of which that input is a part.

Estimates in this report were made with the following factors in mind in order to make the results useful for economywide policy analysis.

(1) The model must embody sufficiently detailed output categories. Crops that intensively use chemical inputs, such as tobacco, those that use the greatest quantities overall, such as feed grains, and other farm products likely to be affected by chemical reduction should be included.

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[1]Ballard, Fullerton, Shoven, and Whalley; Dervis, deMelo, and Robinson; Hertel, Thompson, and Tsigas; and Shoemaker, Anderson, and Hrubovcak all use nested functions for both production and utility.

(2) Input disaggregation must be sufficient to allow policy analysis in some detail. A minimum specification for inputs includes fertilizers, pesticides, and the other major inputs in serviceable categories.[2]

(3) The number of parameters must be kept small enough to be tractable in a larger economywide model. An estimation technique that is consistent with the nested input structure commonly used in CGE models will allow the estimates obtained to be used in a readily available modeling framework, such as Rutherford's MPS/GE.[3]

(4) The parameters estimated must have an interpretation consistent with single-industry models. Though a multioutput translog function is estimated in this report, output nonjointness is imposed to allow each output to be modeled in a single production function in later policy models.

(5) A cost function approach should be used to be consistent with a policy goal of limiting input use without changing output and also to provide the compensated elasticity values needed for the later CGE model.

Both own and cross partial elasticities of demand are estimated for fertilizers, pesticides, and other input categories, such as land and labor. This report first develops the model and discusses the relevance of the restrictions. Then, the data used in estimation are reviewed. The results and some of their implications are next discussed. This is followed, in the last section, by a partial equilibrium analysis of a 10-percent fertilizer charge and a 10-percent pesticide charge.

Procedure and Theory

The elasticities are found using a dual approach, estimating a cost function for agriculture with nine outputs and six inputs. Besides the usual neoclassical properties, nonjointness is imposed in the outputs and, also, input separability is imposed on groups of inputs.[4] [5] Output nonjointness is imposed to make the parameters estimated consistent with the report's goal of describing single-output technology (Hertel, Ball, Huang, and Tsigas) and to reduce the number of parameters estimated.[6] Input separability involves estimating separate stages of input demand, paralleling Fuss's work on the demand for energy. Fuss first estimated substitution parameters among energy types and then estimated the substitution parameters between energy as a whole and other inputs (Fuss; Pindyck).

In the general case, production can be represented by a transformation function, $T\left(Y;X\right) = 0$, where **Y** and **X** are output and input vectors. In the case of the specific outputs and inputs considered here,

$$T\left(Y_1 \ldots Y_9; Labor, Kap, Pest, Land, Fert, Matl\right) = 0, \tag{1}$$

where the inputs are labor, capital (Kap), pesticide (Pest), land, fertilizer (Fert), and materials (Matl). Equivalent technology would be embodied in the dual cost function,

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[2]Serviceable means that the category is disaggregated enough to be useful for more than making broad policy generalizations but not so detailed that consistent data cannot be found or that the final model computations become burdensome.

[3]MPS/GE is a FORTRAN-based system for general equilibrium analysis. It facilitates the formulation and analysis of CGE models.

[4]Nonjointness of the outputs implies that change in the marginal cost of producing one good does not affect the choice of output level for another.

[5]Input separability, as Fuss (p. 91) points out, allows the creation of aggregates that can each be dealt with as suboptimization problems.

[6]The number of parameters is reduced because the (Allen partial) elasticity of substitution between inputs in different subgroups is constrained to be equal. Therefore, as becomes apparent in subsequent sections, the elasticity of substitution between fertilizer and labor must be the same as between land and capital.

$$C = C(Y_1 \ldots Y_9; P_{Labor}, P_{Kap}, P_{Pest}, P_{Land}, P_{Fert}, P_{Matl}). \quad (2)$$

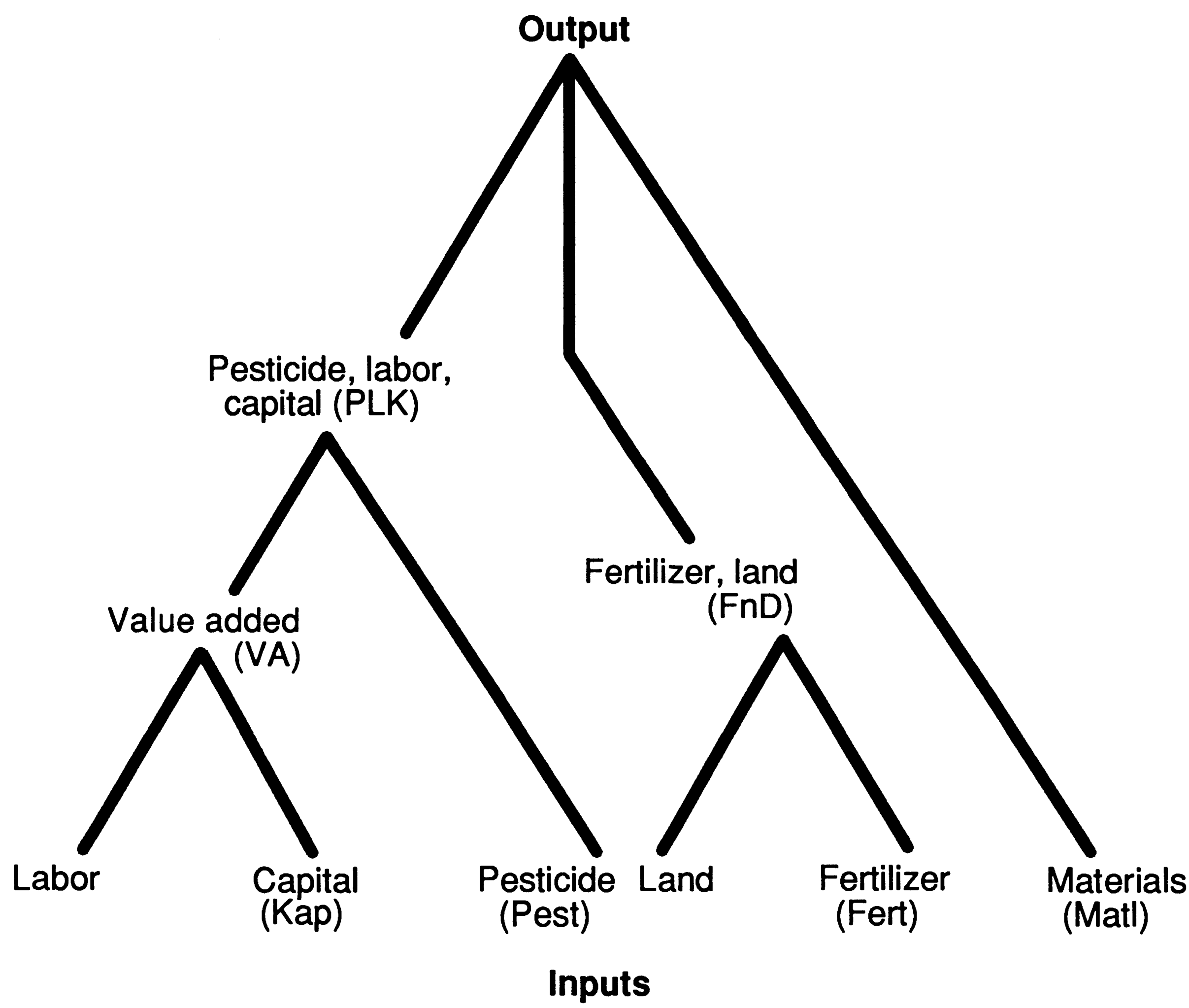
Once a functional form is chosen, the cost function can be estimated directly from the data.

Input Separability

Hertel points out that more than 12 types of separability have been identified and named by economists. Here, input separability as explained by Fuss is used to justify treating groups of inputs together. Input use is assumed to follow the model illustrated in figure 1. This arrangement of nested aggregates is similar to several subsequently cited models and is believed to approximate the farm-level decisionmaking structure. The use of aggregates reduces the number of parameters needed when constructing a CGE model and is employed here for that purpose. The aggregation implies weak separability, as noted above. This separability assumption is taken to be a part of the production structure for model tractability and convenience rather than as a proposition to be tested.

The particular structure chosen is as follows. Labor and capital are often considered together as a "value-added" (VA) component of production and are so treated here (see, for example, Kawagoe, Otsuka, and Hayami). It is also reasonable to assume that pesticide would substitute for this aggregate, for example when herbicide is used rather than mechanical cultivation. Therefore, value added and pesticide come together to form the intermediate input

Figure 1
Cost minimization in stages showing input aggregation scheme



PLK (pesticide, labor, capital). This structure is illustrated in figure 1. Again following Kawagoe, Otsuka, and Hayami, land, the other possible value-added component, substitutes for fertilizer at this first level of input choice, making FnD (Fert'n'Dirt). Though evidence is mixed, other studies have shown this pair to be strong net substitutes (for example, Binswanger).

The separability assumption implies that the marginal rate of substitution between the components of VA are unaffected by the mix of the components of FnD (see fig. 1). Farmers would be able to choose the relative proportions of labor and capital without regard to the price of fertilizer or land rent. Or, to change the example slightly, the relative quantities of Pest and VA are independent of the Land/Fert mix chosen. This is true even though the overall level of PLK is not independent of the level of FnD. This structure also implies sequential decisionmaking by farmers or multistage cost minimization. Thus, the cost function can be rewritten as:

$$C = C\left(Y_1 \ldots Y_9; C_{PLK}\left(P_{Pest}, C_{VA}\left(P_{Labor}, P_{Kap}\right)\right), C_{FnD}\left(P_{Land}, P_{Fert}\right), P_{Matl}\right). \tag{3}$$

C_{VA}, C_{PLK}, and C_{FnD} are aggregate price indexes created from unit cost functions (see Fuss). Details of the procedure are explained in the next section.

Output Nonjointness

The planned end use of the model dictates much of its structure. For this reason, the production of each commodity is treated as an independent activity. In the absence of commodity-specific time-series data on input use, parameters for individual farm sectors are developed by estimating an aggregate multiproduct cost function and imposing nonjointness on the outputs (Denny and Pinto).[7] Commodity-specific cost shares available for 1988 were then used to develop nine separate input price elasticity-of-demand matrices, one for each output category. These are used in the final section and are included in appendix C in their entirety. This individual treatment enables tax or input restriction policies to be studied on a commodity-by-commodity basis (for example, a nitrogen charge on feed grains). It also enables examination of commodity transactions within agriculture, such as purchases of feed grain for livestock production.

The Econometric Model

The econometric model requires the formation of submodels first. Composite price indexes for the aggregate inputs were estimated first. These were then used to estimate the final cost function.

<u>The Submodels</u>

As an example, consider the value-added subfunction:

$$C_{VA}\left(P_{Labor}, P_{Kap}\right). \tag{4}$$

The unit cost function in transcendental logarithmic (translog) form is

$$\ln C_{VA} = \gamma_0 + \sum_{i=1}^{2}\gamma_i \ln P_i + \tfrac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}\gamma_{ij}\ln P_i \ln P_j\ , \tag{5}$$

where the summation is over labor and capital.[8] Cost-minimizing behavior implies that the demand functions for labor or capital, in terms of shares of the cost of VA, take the form

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[7]Even though there is only one Allen elasticity estimate between any two inputs for all the agricultural sectors, this does not imply the same input price elasticities of demand across all producing sectors. This is true because the price elasticities are equal to the Allen partials weighted by the cost share of the relevant input. For example, as Hertel, Ball, Huang, and Tsigas note, "the demand elasticity for feed in the crops sector will be zero due to a zero cost share for feed in those activities."

[8]The translog is employed because it is useful in analyzing substitution possibilities among inputs.

$$S_{VA_i} = \gamma_i + \sum_{j=1}^{2}\gamma_{ij}\ln P_j \; . \tag{6}$$

When the constraints implied by neoclassical production theory are employed along with only two inputs in the function, one share equation is left to estimate, in this case the following:

$$S_{VA_\ell} = \gamma_\ell + \gamma_{\ell,\ell}\ln\left\{\frac{P_\ell}{P_c}\right\}, \tag{7}$$

where ℓ represents labor and c capital. The parameters γ_ℓ and $\gamma_{\ell\ell}$ are estimated using ordinary least squares. The remaining parameters (with the exception of γ_0) in equation 5 are then recovered via the constraints, as shown below.

C_{VA}, the unit cost for value added, is then simulated from the price data over the time range of the estimate. This results in an instrumental variable, a price index for C_{VA} (up to an arbitrary scaling factor γ_0), which is used in the estimation of the next level, PLK.

The Final Model

The final cost function itself is approximated by the translog function. (The arguments of the function now include T, the year, as a proxy for technological change.) Equation 8 is the translog cost function as estimated for the top level (now with three inputs, two aggregates, and materials), as follows:

$$\begin{aligned} \ln C = {} & \alpha_0 + \sum_{i=1}^{9}\alpha_i\ln Y_i + \tfrac{1}{2}\sum_{i=1}^{9}\sum_{j=1}^{9}\alpha_{ij}\ln Y_i\ln Y_j + \sum_{i=1}^{3}\sum_{j=1}^{9}\beta_{ij}\ln P_i\ln Y_j + \sum_{i=1}^{3}\gamma_i\ln P_i \\ & + \tfrac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\gamma_{ij}\ln P_i\ln P_j + \sum_{i=1}^{9}\delta_{iT}\ln Y_i T + \sum_{i=1}^{3}\epsilon_{iT}\ln P_i T + \theta_T T + \tfrac{1}{2}\theta_{TT}T^2 . \end{aligned} \tag{8}$$

Some restrictions apply. Symmetry requires equality of the cross partial derivatives in input prices and outputs so that equation 9 must hold:

$$\alpha_{ij} = \alpha_{ji}, \; \gamma_{ij} = \gamma_{ji} \; . \tag{9}$$

Linear homogeneity of the cost function in factor prices requires that equation 10 must hold:

$$\sum_{i=1}^{3}\gamma_i = 1, \; \sum_{i=1}^{3}\gamma_{ij} = \sum_{i=1}^{3}\beta_{ij} = \sum_{i=1}^{3}\epsilon_{iT} = 0. \tag{10}$$

Constant returns to scale were assumed throughout the time period of the study. The imposition of constant returns to scale requires equation 11 to hold:

$$\sum_{i=1}^{9}\alpha_i = 1, \; \sum_{i=1}^{9}\alpha_{ij} = \sum_{j=1}^{9}\beta_{ij} = \sum_{i=1}^{9}\delta_{iT} = 0. \tag{11}$$

Nonjointness in outputs requires equation 12 to hold:

$$\alpha_{ij} = -\alpha_i\alpha_j, \; \forall \; i{\neq}j. \tag{12}$$

The number of parameters to be estimated is reduced from 42 to 23 by substituting the restrictions into the system. (These are one γ_i from equation 10, three γ_{ij}'s from equation 9 and three from equation 10, nine β_{ij}'s from equation 11 and two more from equation 10, and one ε_{iT} from equation 10.)

The share equations are estimated directly. They are derived from the translog via Shephard's lemma,

$$\frac{\delta \ln C}{\delta \ln P_i} = \frac{P_i X_i}{C} = S_i\,, \tag{13}$$

or from equation 8,

$$S_i = \gamma_i + \sum_{j=1}^{3} \gamma_{ij} \ln P_j + \sum_{j=1}^{9} \beta_{ij} \ln Y_j + \epsilon_{iT} T,\ i = 1 \ to\ 3. \tag{14}$$

Eight share equations were estimated. The materials share was dropped, since one equation was redundant. The seemingly unrelated regression technique was used because of contemporaneous correlation of the error terms across the share equations.

The Allen-Uzawa (AU) partial elasticities of substitution are calculated from the estimated parameters as follows:

$$\sigma_{ij} = \frac{\gamma_{ij} + \gamma_i \gamma_j}{\gamma_i \gamma_j},\ i \neq j, \tag{15}$$

$$\sigma_{ii} = \frac{\gamma_{ii} + \gamma_i(\gamma_i - 1)}{\gamma_i^2}. \tag{16}$$

Data

The data, which cover 1948-89, are from Ball, based on national data developed for Economic Research Service productivity estimates. Ball constructed Tornqvist price and implicit quantity indexes for the nine outputs and six inputs. The output indexes are based on value to the producer; direct payments to producers under government programs are included in the value of production.

Labor input and cost data are developed as documented in Hertel, Ball, Huang, and Tsigas. The outputs are (1) animals, including all livestock, dairy, and poultry, (2) food grains, (3) feed grains, (4) cotton, (5) tobacco, (6) fruits, vegetables, and tree nuts, (7) oilseeds, (8) sugar, and (9) other farm-level products not otherwise classified (hereafter referred to as Y_1 through Y_9, respectively). These groups were chosen to give enough sectoral detail to be relevant for possible policy scenarios (for example, pesticide restrictions in fruits, vegetables, and tree nuts). As noted previously, the six inputs are (1) labor, (2) capital, (3) pesticide, (4) land, (5) fertilizer, and (6) materials, a residual category.

A few data points appeared to be influential in estimating the sublevel cost functions, but none of them was discarded. Capital rent reached a local high point in 1952 that made that observation influential in the estimation of the labor/capital aggregate. Although 1974 and 1989 were influential in estimating PLK, there was otherwise no reason for dropping the observations. The payment in kind (PIK) year 1983 was the most influential in the estimation of FnD because of the decrease in fertilizer use. Since the other PIK years were not unusual, it did not seem consistent to discard 1983.

Results

The elasticity estimates for the first level of aggregation are reported in tables 1 and 2. In each of the tables, individual cells are the elasticities of demand for the input in the row after a price change in the column. The elasticities of substitution are symmetric (noted as Allen-Uzawa elasticities to maintain consistency throughout all tables, even though this distinction is unnecessary for the two-input case). These elasticities represent substitution possibilities at any point in time, holding technology and the nine outputs constant. As noted in the previous section, these numbers were estimated from the unit cost function, subject to adding-up and symmetry constraints. Numbers in parentheses are approximate standard errors. (Standard errors are not computed for the last row and column, since those are determined as residuals. The standard errors reported are computed as a first-order Taylor series approximation to the true standard errors.)

Analysis of the residuals showed the time-series data and the error term to be a first-order autoregressive process. This pattern held consistently in each of the three submodels. When the model was specified as a first-order autoregressive process, the residuals appeared to be normally distributed. Each of the submodels and the final model met the expected curvature conditions: concavity in input prices (for method of calculation see Diewert and Wales). All tables use the abbreviations established in figure 1.

Because these aggregates contain only two inputs and because of the adding-up constraint, we have the result that in the price elasticity table, each row element is the negative of the other. Both labor and capital are demanded inelastically, consistent with other studies (Pollak and Wales; Fuss; Shoemaker; and Hertel, Ball, Haung and Tsigas).

Table 1--Elasticity and share estimates for labor and capital (VA aggregate constant)

	AU elasticities		Price elasticities of demand	
Factor	Labor	Kap	Labor	Kap
Labor	-0.369 (0.081)	0.559	-0.222	0.222
Kap		-0.849	0.337	-0.337
Shares	0.603 (0.018)	0.397		

Note: AU elasticity matrix is symmetric.

Table 2--Elasticity and share estimates for land and fertilizer (FnD aggregate constant)

	AU elasticities		Price elasticities of demand	
Factor	Land	Fert	Land	Fert
Land	-0.028 (0.033)	0.056	-0.018	0.018
Fert		-0.112	0.037	-0.037
Shares	0.668 (0.027)	0.332		

C_{VA} in equations 3 and 4 was used to produce an aggregate price series from the labor and capital estimation. This series was used as an instrumental variable in the estimation of the next sublevel. The second-stage estimation yields the results of table 3.

The only price-elastic demand in the system shows up here with the demand for pesticide. Conventional wisdom holds the demand to be inelastic; however, this result agrees in relative magnitude with Hertel, Ball, Haung, and Tsigas, who found their most elastic response from the similar category "chemicals."

These elasticities show the substitution of inputs when the aggregate input level (the PLK group) is constant. To assess the overall response of labor or capital demand to a change in its price, we must also consider the effect on the level of PLK. For example, the overall change in labor with respect to a change in the price of capital includes not only the labor/capital substitution in the value-added component (table 3) but also the effect the price change has on the total level of value added purchased. The total effect is determined as shown by Fuss in equation 17 below, as:

$$E_{L,K}^{PLK} = E_{L,K}^{VA} + S_K^{VA} E_{VA,VA}^{PLK} . \tag{17}$$

$E_{L,K}^{PLK}$ is the total elasticity with PLK at a constant level, $E_{L,K}^{VA}$ is the elasticity with the value-added sector at a constant level, S_K^{VA} is the cost share of capital in the value-added sector, and $E_{VA,VA}^{PLK}$ is the own-price elasticity of value added in the larger PLK aggregate. The results are recorded in table 4.

Table 3--Elasticity and share estimates for pesticide and the labor-capital aggregate (PLK aggregate constant)

	AU elasticities		Price elasticities of demand	
Factor	VA	Pest	VA	Pest
VA	-0.097 (0.008)	1.826	-0.092	0.092
Pest		-34.563	1.735	-1.735
Shares	0.950 (0.003)	0.050		

Table 4--Elasticity and share estimates for pesticide, labor, and capital (PLK aggregate constant)

	AU elasticities			Price elasticities of demand		
Factor	Labor	Kap	Pest	Labor	Kap	Pest
Labor	-0.484	0.492	1.826	-0.277	0.186	0.092
Kap		-0.990	1.826	0.282	-0.374	0.092
Pest			-34.563	1.046	0.689	-1.735
Shares	0.573	0.377	0.050			

The complete system was estimated, subject to the constraints detailed above, using the previously generated composite prices P_{PLK} and P_{FnD}. The estimated elasticities for the aggregates, with output held constant, is presented in table 5. The elasticities for each component are presented in tables 6 and 7.

Own-price responses have the expected sign but are quite small in magnitude. The only complementarity in the system appears here between the soil/fertilizer aggregate and the materials component. A drop in the price of a component of one aggregate (say, the price of fertilizer) is associated not only with an increase in use of its own aggregate, FnD, but also with an increase in use of the components of the other, such as energy and seed. Though the magnitude of the complementarity is small, it seems reasonable that more land use (part of FnD) would be associated with more seed use (Matl) or that more fertilizer use (FnD) would be associated with more energy use (Matl).

The most elastic price response comes from pesticides, which show the only elastic response in the system. Though weak, the land/fertilizer/materials complementarity shows clearly in the final system. With the exception of the labor/fertilizer substitution, the strongest quantity response from each input is always to its own price.

Comparisons with previous studies are difficult because the input categories and often the assumptions imposed vary. Even when they are based on the same theoretical foundation and employ the same input categories, past

Table 5--Elasticity and share estimates for all aggregates (output constant)

	AU elasticities			Price elasticities of demand		
Factor	PLK	FnD	Matl	PLK	FnD	Matl
PLK	-0.459 (0.126)	0.459 (0.344)	0.467	-0.231	0.101	0.130
FnD		-0.862 (0.246)	-0.147	0.231	-0.190	-0.041
Matl			-0.728	0.235	-0.032	-0.202
Shares	0.502 (0.030)	0.220 (0.034)	0.278			

Table 6--AU elasticity and share estimates for each element in the final system (output constant)

	AU elasticities					
Factor	Labor	Kap	Pest	Land	Fert	Matl
Labor	-1.423	0.521	3.176	0.459	0.459	0.467
Kap		-2.430	3.176	0.459	0.459	0.467
Pest			-69.248	0.459	0.459	0.467
Land				-0.987	-0.610	-0.147
Fert					-1.369	-0.147
Matl						-0.728
Shares	0.288	0.190	0.025	0.147	0.073	0.278

studies are not in agreement. For example, consider labor. In one of the early duality studies, Binswanger found almost unitary (-0.911) own-price elasticity for labor. However, more recently, Shoemaker found the own-price elasticity for labor to be only -0.337. Hertel found labor even less elastic (-0.133), and Lopez, who distinguished between hired and family labor, found both to be inelastic (-0.377 and -0.036, respectively) when estimated as net of output effects. All these results contrast with the present study, which estimates the own-price elasticity of labor at -0.409.

Conclusions

These results may help predict the effectiveness of various policy approaches to reducing pesticide and fertilizer use. For example, the slight response of other inputs to pesticide price and the stronger own-price response would seem to make pesticides a candidate for effective input charges. That is, pesticide use could be effectively reduced without greatly distorting the use of other inputs. Though the cross effects of a change in fertilizer price are also small, the own-price response is itself quite small, -0.1. Among other inputs, only the wage rate and capital rent would seem to have much of an effect on pesticide use, indicating that cheap labor and low interest may help to reduce pesticide use.

The nesting structure employed here allows the effects of price changes in agricultural inputs to be broken into stages. We can look again at potential pesticide and fertilizer charges to find an example. An effective 10-percent charge on pesticides goes further toward reducing its use (-17.46 percent) than does a 10-percent charge on fertilizer use (-1.0 percent). However, most of the effect on pesticide use (99 percent) is in the bottom nest (or first round), while the greatest effect on fertilizer use (63 percent) occurs at the top nest (or in the second round). That is, in the case of a fertilizer charge, land first substitutes for fertilizer: the 10-percent charge reduces fertilizer use by 0.37 percent as land takes its place. This demonstrates some "extensification" of land use (per unit of FnD). However, at this level, we cannot say that more land will be used in production; we can say only that relatively more land will be used in the FnD component of production. In the second round, fertilizer use is reduced another 0.63 percent as FnD use declines. The second effect reinforces the first with regard to fertilizer use, but reverses the extensification effect as less land overall is used per unit of output. In the case of a 10-percent charge on pesticides, a 17.35-percent (first round) drop occurs as the labor/capital aggregate takes the pesticide's place, but only an additional 0.12-percent drop takes place as substitution of other inputs is made for PLK.

A Policy Experiment

In this section, the output nonjointness properties referred to earlier and the 1988 cost shares are exploited in an input charge policy experiment. By employing the nonjointness property and the 1988 information, we can arrive at

Table 7--Input price elasticity of demand for each input in the final system (output constant)

	Price elasticities of demand					
Factor	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.409	0.099	0.080	0.067	0.034	0.130
Kap	0.150	-0.461	0.080	0.067	0.034	0.130
Pest	0.914	0.602	-1.746	0.067	0.034	0.130
Land	0.132	0.087	0.012	-0.145	-0.045	-0.041
Fert	0.132	0.087	0.012	-0.090	-0.100	-0.041
Matl	0.134	0.088	0.012	-0.022	-0.011	-0.202

the responses of individual producing sectors to changes in input cost. In tables 8 and 9, response by sector to a 1-percent change in the cost of pesticide and fertilizer, respectively, is given. (Elasticity tables included in the appendix include the whole range of input substitution possibilities.)

Table 8--Change in input use by sector in response to a 1-percent increase in pesticide price

Factor	Animal	Food grain	Feed grain	Cotton	Tobacco	Fruit, nuts, and vegetables	Oilseeds	Sugar	Other farm
Labor	0.002	0.136	0.081	0.105	0.063	0.100	0.124	0.222	0.109
Kap	0.002	0.136	0.081	0.105	0.063	0.100	0.124	0.222	0.109
Pest	-1.824	-1.690	-1.745	-1.721	-1.763	-1.726	-1.702	-1.604	-1.717
Land	N/A	0.014	0.006	0.009	0.007	0.012	0.014	0.017	0.013
Fert	N/A	0.014	0.006	0.009	0.007	0.012	0.014	0.017	0.013
Matl	0.000	0.014	0.006	0.009	0.007	0.012	0.014	0.017	0.014

N/A = Not applicable.

Table 9--Change in input use by sector in response to a 1-percent increase in fertilizer price

Factor	Food grain	Feed grain	Cotton	Tobacco	Fruit, nuts, and vegetables	Oilseeds	Sugar	Other farm
Labor	0.013	0.040	0.046	0.021	0.020	0.030	0.009	0.009
Kap	0.013	0.040	0.046	0.021	0.020	0.030	0.009	0.009
Pest	0.013	0.040	0.046	0.021	0.020	0.030	0.009	0.009
Land	-0.004	0.003	-0.003	-0.009	-0.018	-0.021	0.001	0.012
Fert	-0.059	-0.052	-0.058	-0.064	-0.073	-0.076	-0.054	-0.067
Matl	-0.004	-0.013	-0.015	-0.007	-0.006	-0.010	-0.003	-0.003

References

Ball, V.E. (1985). "Output, Input, and Productivity Measurement in U.S. Agriculture, 1948-1979," *American Journal of Agricultural Economics* 67: 475-86.

Ballard, C., D. Fullerton, J. Shoven, and J. Whalley (1985). *A General Equilibrium Model for Tax Policy Evaluation.* Chicago: Univ. of Chicago Press.

Belsley, David A., Edwin Kuh, and Roy E. Welsch (1980). *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity.* New York: John Wiley and Sons.

Binswanger, H. (1974). "A Cost Function Approach to the Measurement of Factor Demand and Elasticities of Substitution," *American Journal of Agricultural Economics* 56: 377-86.

Denny, Michael, and Cheryl Pinto (1978). "An Aggregate Model with Multi-Product Technologies," *Production Economics: A Dual Approach to Theory and Application.* Ed. M. Fuss and D. McFadden. Amsterdam: North-Holland Publishing Co.

Dervis, K., J. deMelo, and S. Robinson (1982). *General Equilibrium Models for Development Policy.* Cambridge, England: Cambridge Univ. Press.

Diewert, W.E., and T.J. Wales (1987). "Flexible Functional Forms and Global Curvature Conditions," *Econometrica* 55: 43-68.

Fuss, Melvyn A. (1977). "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs," *Journal of Econometrics* 5: 89-116.

Hertel, Thomas W. (1984). *Applications of Duality and Flexible Functional Forms: The Case of the Multiproduct Firm.* Research Bulletin 980. Dept. Agr. Econ., Purdue Univ. Sept.

______________, E. Ball, K.S. Huang, and M.E. Tsigas (1988). *Farm-Level Demand Elasticities for Agricultural Commodities.* Research Bulletin 988. Agr. Experiment Station, Purdue Univ.

______________, R.L. Thompson, and M.E. Tsigas (1989). "Economywide Effects of Unilateral Trade and Policy Liberalization in U.S. Agriculture," *Macroeconomic Consequences of Farm Support Policies.* Ed. Andrew Stoeckel, David Vincent, and Sandy Cuthbertson. Durham, NC: Duke Univ. Press.

Kawagoe, Toshihiko, Keijiro Otsuka, and Yujiro Hayami (1986). "Induced Bias of Technical Change in Agriculture: The United States and Japan, 1880-1980," *Journal of Political Economy* 94: 523-44.

Knutson, Ronald D., C. Robert Taylor, John B. Penson, and Edward G. Smith (1990). *Economic Impacts of Reduced Chemical Use.* College Station, TX: Knutson and Associates.

Lopez, R.E. (1984). "Estimating Substitution and Expansion Effects Using a Profit Function Framework," *American Journal of Agricultural Economics* 66: 358-67.

Pindyck, Robert S. (1977). "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison," *The Review of Economics and Statistics* 61(2): 169-79.

Pollak, Robert A., and Terence J. Wales (1987). "Specification and Estimation of Nonseparable Two-Stage Technologies: The Leontief CES and the Cobb-Douglas CES," *Journal of Political Economy* 95(2): 311-33.

Reiss, Peter C. (1990). "Detecting Multiple Outliers with an Application to R&D Productivity," *Journal of Econometrics* 43: 293-315.

Rutherford, Thomas F. (1989). *General Equilibrium Modelling With MPS/GE.* Dept. of Economics, Univ. of Western Ontario, London, Canada. Mar.

Shoemaker, Robbin (1986). *Effects of Changes in U.S. Agricultural Production on Demand for Farm Inputs.* TB-1722. U.S. Dept. of Agr., Econ. Res. Serv. Nov.

______________, Margot Anderson, and James Hrubovcak (1990). *U.S. Farm Programs and Agricultural Resources.* AIB-614. U.S. Dept. Agr., Econ. Res. Serv. Sept.

Appendix A: Commodity Prices, Output Quantities, Input Prices, and Input Quantities

Commodity Prices

Date	Panimal	Pfoodgn	Pfeedgn	Pcotton	Ptobacco	Pvegftnt	Poilseed	Psugar	Pother
1948	0.51052	0.58834	0.59904	0.48311	0.51936	0.42097	0.51097	0.30524	0.49744
1949	0.43262	0.56895	0.53874	0.43648	0.46570	0.36420	0.45695	0.29021	0.45737
1950	0.43736	0.53684	0.52454	0.61501	0.54006	0.36911	0.41687	0.29402	0.46778
1951	0.51831	0.53062	0.52767	0.55537	0.51286	0.39045	0.49697	0.34875	0.46986
1952	0.46891	0.53918	0.53710	0.54211	0.50174	0.44539	0.49365	0.32420	0.46383
1953	0.42124	0.54831	0.48925	0.50505	0.52183	0.38020	0.50727	0.32234	0.43384
1954	0.39087	0.55676	0.49258	0.50760	0.52138	0.36581	0.47344	0.30199	0.41094
1955	0.36443	0.51304	0.48237	0.46878	0.52727	0.37737	0.42713	0.32099	0.39852
1956	0.35604	0.51480	0.47194	0.49034	0.53537	0.40275	0.43155	0.33196	0.39932
1957	0.38097	0.52197	0.43998	0.50113	0.56340	0.36513	0.38089	0.30883	0.42028
1958	0.41351	0.47846	0.45111	0.52750	0.59222	0.39318	0.36557	0.36803	0.41980
1959	0.38487	0.47291	0.40860	0.47870	0.59174	0.38716	0.36050	0.31210	0.40911
1960	0.38147	0.46779	0.39598	0.43836	0.60840	0.40130	0.36424	0.33269	0.40813
1961	0.37784	0.49700	0.49720	0.47649	0.64218	0.37983	0.45019	0.32128	0.40364
1962	0.38244	0.58443	0.56228	0.47076	0.60076	0.38083	0.42234	0.35426	0.40500
1963	0.36774	0.56395	0.54929	0.47277	0.57883	0.39574	0.45240	0.36413	0.41087
1964	0.35341	0.47700	0.61324	0.43897	0.58695	0.44772	0.45509	0.33860	0.43453
1965	0.38574	0.48763	0.58379	0.46123	0.64829	0.46692	0.48370	0.35448	0.45249
1966	0.43727	0.56278	0.65092	0.59152	0.64591	0.44311	0.52197	0.36509	0.47606
1967	0.41016	0.51918	0.50901	0.70912	0.65868	0.44116	0.46348	0.39267	0.48675
1968	0.42824	0.50584	0.54212	0.55377	0.69258	0.47142	0.44847	0.39399	0.50991
1969	0.47772	0.49591	0.57913	0.50004	0.71791	0.45508	0.42997	0.38386	0.52480
1970	0.48555	0.59633	0.70908	0.58062	0.71894	0.45770	0.48141	0.42794	0.51069
1971	0.47280	0.51237	0.53064	0.59892	0.77819	0.48358	0.52724	0.44064	0.54103
1972	0.54479	0.66664	0.61650	0.55911	0.83108	0.55017	0.60158	0.45902	0.58747
1973	0.71435	1.13680	0.84814	0.73155	0.88222	0.67612	0.95252	0.71887	0.62836
1974	0.66384	1.20555	1.14259	0.79712	1.06346	0.76129	1.19879	1.38356	0.63410
1975	0.70062	0.98412	1.01682	0.71908	1.01531	0.72001	0.91979	0.91770	0.66013
1976	0.72355	0.82769	0.94972	0.93283	1.11884	0.72787	0.98664	0.58495	0.72872
1977	0.71786	0.75868	0.80928	0.79418	1.18214	0.78870	1.10935	0.61937	0.77830
1978	0.87308	0.90402	0.87059	0.93911	1.32733	0.90136	1.11269	0.67440	0.84885
1979	1.02349	1.00082	0.93549	0.95167	1.37486	0.92994	1.15519	0.83313	0.91060
1980	0.99364	1.06198	1.08689	1.10975	1.49181	0.95051	1.21338	1.16676	0.94982
1981	0.99848	1.07062	1.11844	0.94603	1.69411	1.06398	1.17467	0.89771	0.98012
1982	1.00000	1.00000	1.00000	1.00000	1.77444	1.00000	1.00000	1.00000	1.00000
1983	0.97618	1.22495	1.88621	1.43607	1.68955	0.98330	1.25178	0.98319	1.05612
1984	1.02240	1.13191	1.27035	1.14782	1.77156	1.05764	1.20930	0.94355	1.07112
1985	0.96048	1.09986	1.05623	1.01636	1.68168	1.00261	0.95223	0.93876	1.10534
1986	0.97405	1.07687	0.97561	1.08207	1.53401	1.03709	0.89738	0.97675	1.11189
1987	1.01891	1.02866	1.14233	1.10719	1.55177	1.05426	0.92432	0.99110	1.12710
1988	1.03216	1.21842	1.63108	1.02219	1.59621	1.09977	1.28814	1.06763	1.13903
1989	1.09615	1.14588	1.11920	1.20131	1.67153	1.19659	1.12100	1.08788	1.16658

Output Quantities

Date	Qanimal	Qfoodgn	Qfeedgn	Qcotton	Qtobacco	Qvegftnt	Qoilseed	Qsugar	Qother
1948	34917.77	4658.14	6311.40	5402.64	1756.30	8663.52	2118.19	589.19	2144.56
1949	36824.71	3997.03	3151.45	5956.54	1997.43	8519.80	1947.88	619.86	2154.09
1950	38130.61	3714.12	4108.25	3638.45	1914.73	8418.16	2305.19	778.27	2595.72
1951	39923.02	3765.29	3713.83	5630.16	2312.34	8374.53	2077.79	623.14	2664.52
1952	40710.86	4908.66	4084.62	5547.57	2237.86	8134.59	2049.57	639.57	2704.95
1953	41343.12	4212.15	4160.03	6151.29	2041.56	8742.44	2018.03	717.92	2543.58
1954	42842.09	3964.60	5305.86	5082.39	2220.87	8946.07	2346.77	801.35	2276.73
1955	44121.63	3954.90	5738.70	5613.44	2189.61	9256.87	2570.75	719.46	2245.74
1956	44670.55	4105.16	5360.88	4963.33	2163.00	9304.59	3040.23	732.88	2536.24
1957	44176.86	3524.17	6983.52	4126.29	1667.91	9502.16	2977.03	847.88	2196.60
1958	45389.40	5348.04	6777.45	4306.12	1727.67	9118.00	3965.37	826.97	2294.69
1959	47353.98	4450.10	6647.41	5461.61	1784.76	9589.66	3307.82	918.74	2757.39
1960	47091.24	5511.94	7922.35	5463.71	1936.30	9503.14	3563.70	1114.87	2150.30
1961	49221.12	4890.47	6564.38	5397.91	2052.43	10185.38	4143.52	1254.14	2802.64
1962	49801.42	4719.43	6782.74	5608.01	2300.50	10138.15	4167.09	1287.03	2895.41
1963	51301.92	4920.46	8033.20	5754.57	2321.82	10001.32	4379.45	1595.81	2882.27
1964	52666.84	5323.51	6216.12	5752.17	2217.85	9569.17	4391.90	1629.55	2851.76
1965	51456.68	5313.14	10144.08	5595.16	1847.68	9836.01	5302.31	1488.16	2876.48
1966	52554.91	5546.14	8234.25	3539.94	1932.98	10446.32	5698.26	1489.19	2804.24
1967	54312.84	6076.10	11639.36	2885.65	1987.13	10603.68	5956.75	1445.68	2809.70
1968	54137.55	5524.17	10087.48	3867.34	1691.64	10849.32	6786.00	1698.07	2726.65
1969	54280.72	6160.48	10807.50	4634.68	1805.52	11310.82	6924.51	1711.41	2795.34
1970	56681.35	5602.52	8044.13	3678.04	1912.94	11104.19	6993.71	1666.17	2980.24
1971	57455.82	6678.97	13592.10	4077.87	1705.14	11370.43	7250.01	1704.61	2990.23
1972	58004.31	6281.61	12607.77	5354.76	1763.89	11046.05	7793.85	1792.52	3176.79
1973	58549.46	7175.10	14536.41	4419.76	1746.68	11769.39	9425.58	1670.91	3832.84
1974	57842.93	7637.95	10879.77	4200.30	1994.97	12227.66	7527.35	1533.74	4333.63
1975	54654.28	9171.42	14696.95	2799.06	2223.34	12602.75	9451.70	1814.18	4460.16
1976	57118.15	8857.90	13988.63	3689.68	2070.59	12644.04	7936.49	1864.78	4899.25
1977	58147.11	8299.16	15759.89	5106.83	1938.36	13172.65	10928.64	1683.35	4997.27
1978	58243.33	7696.20	16483.55	3803.14	1993.61	13476.04	11667.57	1691.68	4463.26
1979	59554.01	9193.55	17804.42	5412.36	1554.69	14093.63	14180.50	1539.06	4548.33
1980	62280.81	10029.98	13015.02	3935.48	1757.91	14726.35	10888.25	1611.46	4997.46
1981	63258.86	11959.78	19427.11	5798.64	2053.59	14786.75	12433.58	1800.66	5090.88
1982	62800.93	11638.07	18949.54	4157.09	1945.78	15114.11	13515.59	1587.84	5464.14
1983	63910.42	10257.23	5593.59	2697.15	1455.64	14752.11	10123.26	1616.70	5533.80
1984	62879.91	10863.30	20428.57	4800.52	1736.91	15283.12	11771.11	1585.80	6147.34
1985	64666.05	10182.09	23856.50	4837.50	1494.84	15605.10	12962.55	1608.17	6239.91
1986	65321.82	8971.47	22246.27	3528.22	1147.65	15632.80	11944.96	1700.12	6670.29
1987	66297.06	9005.83	18365.43	5482.49	1207.06	17104.04	11890.25	1865.17	7341.04
1988	67939.38	8098.46	11566.89	5714.22	1295.61	17188.52	9751.46	1784.43	7742.90
1989	68448.75	8868.93	21072.30	4514.16	1382.83	17101.96	11835.50	1788.06	7865.54

Input Prices

Date	Pland	Pfert	Ppest	Plabor	Pkap	Pmatl
1948	0.71806	0.48294	0.62510	0.13625	0.60240	0.28738
1949	0.45538	0.50235	0.64330	0.13755	0.43579	0.27208
1950	0.53934	0.46644	0.66400	0.12886	0.42006	0.27195
1951	0.58994	0.49062	0.82400	0.14394	0.52647	0.29187
1952	0.38503	0.48083	0.79370	0.14859	0.54625	0.30760
1953	0.37420	0.48290	0.62340	0.14944	0.42634	0.28654
1954	0.33629	0.47382	0.61030	0.14761	0.40725	0.30513
1955	0.29662	0.46249	0.62290	0.14765	0.38492	0.27235
1956	0.25871	0.44678	0.61440	0.15966	0.36971	0.27017
1957	0.21808	0.43775	0.56410	0.17295	0.35578	0.26928
1958	0.34723	0.44147	0.54590	0.17951	0.39590	0.29043
1959	0.18119	0.43362	0.57170	0.18867	0.35101	0.29253
1960	0.20737	0.42946	0.57960	0.19300	0.36598	0.28259
1961	0.25790	0.43138	0.55840	0.20549	0.38846	0.30148
1962	0.27325	0.42320	0.54740	0.21478	0.39263	0.31957
1963	0.26798	0.41565	0.51170	0.22294	0.39622	0.33002
1964	0.15872	0.40883	0.49640	0.24736	0.36928	0.32845
1965	0.36011	0.40214	0.50870	0.26628	0.41434	0.33421
1966	0.46940	0.40040	0.52600	0.28855	0.44489	0.35427
1967	0.33758	0.39556	0.54630	0.31067	0.42241	0.35393
1968	0.28972	0.35495	0.53630	0.33690	0.41480	0.35215
1969	0.42897	0.32580	0.51910	0.36534	0.44915	0.36215
1970	0.39646	0.33251	0.50240	0.38542	0.45576	0.38653
1971	0.47089	0.34565	0.49420	0.39298	0.48022	0.40029
1972	0.87633	0.35616	0.51050	0.41102	0.58153	0.43265
1973	1.91759	0.41359	0.53070	0.48163	0.80762	0.60914
1974	1.27967	0.72912	0.59200	0.53347	0.73905	0.61774
1975	1.14603	0.90363	0.68950	0.57531	0.67381	0.62374
1976	0.80040	0.69581	0.68240	0.64752	0.59933	0.68162
1977	0.74803	0.70450	0.69030	0.71630	0.69104	0.73315
1978	0.94216	0.69274	0.69800	0.79076	0.76201	0.74797
1979	1.37989	0.76086	0.71850	0.87038	0.89501	0.85396
1980	0.39014	0.96286	0.80330	0.93323	0.82041	0.95003
1981	1.49224	1.02795	0.90680	0.88106	1.03070	1.02019
1982	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1983	0.24422	0.94800	1.05500	0.98520	0.97530	1.04074
1984	1.62952	1.01667	1.06420	0.99011	1.20442	1.03943
1985	1.65201	0.90871	1.01030	1.04885	1.23547	0.98623
1986	1.48890	0.79403	0.95240	1.06242	1.23981	0.98523
1987	2.14834	0.79786	0.96460	1.10149	1.34873	1.00652
1988	2.25799	0.85213	1.00120	1.07734	1.44212	1.10130
1989	2.50198	0.86659	1.06790	1.16438	1.49994	1.12500

Input Quantities

Date	Qland	Qfert	Qpest	Qlabor	Qkap	Qmatl
1948	11011.72	1509.51	188.77	63493.12	13161.66	29281.35
1949	11052.10	1570.62	216.07	62015.99	14643.34	27984.66
1950	11071.19	1860.92	269.58	62269.38	15516.89	29192.84
1951	11061.97	1954.65	236.65	61742.48	16584.50	31966.78
1952	11070.80	2241.96	239.39	61288.62	17620.34	31830.20
1953	11081.07	2275.81	248.64	60818.91	18285.18	32271.43
1954	11086.48	2397.54	273.64	60133.13	18639.19	30472.29
1955	11089.17	2391.41	321.08	60126.93	19013.21	34921.79
1956	11050.32	2415.05	437.83	58583.11	19264.45	35866.96
1957	10922.91	2458.04	343.91	57184.02	18993.16	37681.80
1958	10949.46	2521.12	414.00	56931.87	19031.43	37843.61
1959	10903.12	2855.01	500.26	56655.13	19325.87	40918.28
1960	10845.39	2915.30	500.34	55612.32	19566.68	41876.23
1961	10650.68	3113.25	590.97	54906.61	19407.50	40198.07
1962	10567.97	3416.85	672.27	54466.71	19512.07	39838.38
1963	10493.47	3849.40	740.67	52503.09	19733.92	40582.65
1964	10534.92	4334.30	809.83	49532.70	20051.39	40340.51
1965	10475.21	4667.57	931.79	48310.82	20136.84	40938.11
1966	10409.48	5239.71	1068.44	43793.25	20815.68	41572.96
1967	10339.82	5857.47	1447.92	42182.95	21374.91	43067.91
1968	10259.39	6544.67	1542.05	42289.54	22146.49	43472.45
1969	10181.57	6780.26	1745.33	41299.23	22478.63	45105.53
1970	10108.77	7037.39	1910.83	40185.97	22729.31	45293.22
1971	10057.18	7415.03	2312.83	39743.26	23116.66	44987.53
1972	9993.27	7356.30	2677.77	39382.81	23494.44	43401.94
1973	9944.14	8225.52	2664.41	39380.67	23993.61	41530.61
1974	9947.81	8089.15	2555.74	38700.09	25254.43	47105.93
1975	9909.70	7199.84	2585.93	38459.92	25814.04	47436.52
1976	9711.52	8989.51	3089.10	37300.65	26762.23	48208.35
1977	9550.92	8953.83	2807.47	36188.87	27218.98	46713.23
1978	9489.43	9182.40	3805.16	36067.34	27953.09	54016.77
1979	9465.20	9281.55	4782.18	36072.04	28800.60	56189.74
1980	9432.09	9416.70	4405.57	36304.57	29901.65	55158.31
1981	9436.95	8723.15	4632.77	35483.63	29723.53	52956.61
1982	9380.40	7689.00	4282.00	33683.50	29936.16	51402.00
1983	9317.68	7006.36	3668.25	32147.98	29014.46	51310.64
1984	9298.93	8165.91	4405.19	32599.66	27693.25	53447.48
1985	9244.73	7896.88	4289.81	29937.87	27220.96	50894.77
1986	9188.46	8218.81	4540.11	29281.41	25883.07	49296.16
1987	9115.00	7625.44	4677.59	28434.26	24550.27	49558.89
1988	9034.39	7484.77	4437.68	27971.93	23563.79	48327.23
1989	8985.01	8214.93	5357.24	27859.56	22695.68	52554.64

Appendix B: Estimation Statistics

Labor/Capital Estimation

Ordinary least squares estimates
Durbin-Watson 0.3675

Estimates of the autoregressive parameters
Total R-square 0.7811

Lag	Coefficient	Standard error
1	-0.78396839	0.09940768

Variable	B Value	Standard error
Intercept	0.602839763	0.01790
P1	0.105512577	0.02082

Land/Fertilizer Estimation

Ordinary least squares estimates
Durbin-Watson 0.3308

Estimates of the autoregressive parameters
Total R-square 0.9219

Lag	Coefficient	Standard error
1	-0.79701850	0.09671018

Variable	B Value	Standard error
Intercept	0.668133926	0.02698
P1	0.209431509	0.01120

Labor/Capital and Pesticides Estimation

Ordinary least squares estimates
Durbin-Watson 0.5917

Estimates of the autoregressive parameters
Total R-square 0.9196

Lag	Coefficient	Standard error
1	-0.61995103	0.12564304

Variable	B Value	Standard error
Intercept	0.948740750	0.001684
P1	-0.043279042	0.002855

Final Estimation

Nonlinear SUR estimation

Equation	R-square	Adjusted R-square
S1	0.9197	0.8920
S2	0.9434	0.9239

Parameter	Estimate	Approximate standard error
B11	0.10935300	0.0405700
B12	-0.07187100	0.0452100
B21	-0.02673500	0.0157600
B22	0.04292600	0.0177000
B31	0.01353300	0.0086800
B32	-0.02721900	0.0097500
B41	0.01567800	0.0087285
B42	-0.02253100	0.0097900
B51	0.01305000	0.0170000
B52	-0.03154800	0.0177200
B61	-0.05729200	0.0400700
B62	0.01583500	0.0449100
B71	-0.02085400	0.0162900
B72	0.02300300	0.0182800
B81	-0.03538800	0.0145700
B82	0.04476300	0.0161700
C1	0.50243900	0.0299400
C11	0.13418700	0.0275200
C12	-0.05983200	0.0074561
C2	0.21998700	0.0336600
C22	0.12988900	0.0080077
E1T	-0.00057142	0.0008656
E2T	-0.00255137	0.0009730

Appendix C: Price and Allen-Uzawa Elasticities by Sector Computed from 1988 National Income and Product Account Data

Livestock, Dairy, and Poultry

	Sigma		Price elasticities	
	Labor	Kap	Labor	Kap
Labor	-0.570	0.559	-0.282	0.282
Kap	0.559	-0.549	0.277	-0.277

	Sigma		Price elasticities	
	VA	Pest	VA	Pest
VA	-0.002	1.826	-0.002	0.002
Pest	1.826	-1835.180	1.824	-1.824

	Allen elasticities Labor and Kap in KLP			Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest	Labor	Kap	Pest
Labor	-0.572	0.558	1.826	-0.283	0.281	0.002
Kap	0.558	-0.551	1.826	0.276	-0.278	0.002
Pest	1.826	1.826	-1835.180	0.904	0.921	-1.824

	Sigma		Price elasticities	
	PLK	Matl	PLK	Matl
PLK	-0.599	0.467	-0.262	0.262
Matl	0.467	-0.364	0.205	-0.205

PRICE	Labor	Kap	Pest	Matl
Labor	-0.413	0.149	0.002	0.262
Kap	0.146	-0.410	0.002	0.262
Pest	0.774	0.788	-1.824	0.262
Matl	0.101	0.103	0.000	-0.205
Shares	0.217	0.221	0.000	0.562

ALLEN	Labor	Kap	Pest	Matl
Labor	-1.904	0.674	3.568	0.467
Kap	0.674	-1.856	3.568	0.467
Pest	3.568	3.568	-4188.390	0.467
Matl	0.467	0.467	0.467	-0.364

Food grains

	Sigma			Price elasticities	
	Labor	Kap		Labor	Kap
Labor	-0.726	0.559		-0.316	0.316
Kap	0.559	-0.430		0.243	-0.243

	Sigma			Price elasticities	
	Land	Fert		Land	Fert
Land	-0.009	0.055		-0.008	0.008
Fert	0.055	-0.326		0.047	-0.047

	Sigma			Price elasticities	
	VA	Pest		VA	Pest
VA	-0.181	1.826		-0.164	0.164
Pest	1.826	-18.461		1.662	-1.662

	Allen elasticities Labor and Kap in KLP				Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest		Labor	Kap	Pest
Labor	-0.979	0.434	1.826		-0.387	0.223	0.164
Kap	0.434	-0.653	1.826		0.172	-0.336	0.164
Pest	1.826	1.826	-18.461		0.723	0.939	-1.662

	Sigma				Price elasticities		
	PLK	FnD	Matl		PLK	FnD	Matl
PLK	-0.933	0.459	0.467		-0.310	0.092	0.218
FnD	0.459	-0.420	-0.147		0.153	-0.084	-0.069
Matl	0.467	-0.147	-0.269		0.155	-0.029	-0.126

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.510	0.064	0.136	0.078	0.013	0.218
Kap	0.049	-0.495	0.136	0.078	0.013	0.218
Pest	0.600	0.779	-1.690	0.078	0.013	0.218
Land	0.060	0.078	0.014	-0.080	-0.004	-0.069
Fert	0.060	0.078	0.014	-0.025	-0.059	-0.069
Matl	0.061	0.080	0.014	-0.025	-0.004	-0.126
Shares	0.132	0.171	0.030	0.171	0.029	0.468

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-3.877	0.372	4.560	0.459	0.459	0.467
Kap	0.372	-2.898	4.560	0.459	0.459	0.467
Pest	4.560	4.560	-56.462	0.459	0.459	0.467
Land	0.459	0.459	0.459	-0.466	-0.144	-0.147
Fert	0.459	0.459	0.459	-0.144	-2.050	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.269

Feed grains

	Sigma		Price elasticities	
	Labor	Kap	Labor	Kap
Labor	-1.728	0.559	-0.422	0.422
Kap	0.559	-0.181	0.137	-0.137

	Sigma		Price elasticities	
	Land	Fert	Land	Fert
Land	-0.019	0.055	-0.014	0.014
Fert	0.055	-0.160	0.041	-0.041

	Sigma		Price elasticities	
	VA	Pest	VA	Pest
VA	-0.107	1.826	-0.101	0.101
Pest	1.826	-31.289	1.725	-1.725

	Allen elasticities Labor and Kap in KLP			Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest	Labor	Kap	Pest
Labor	-1.935	0.485	1.826	-0.447	0.346	0.101
Kap	0.485	-0.298	1.826	0.112	-0.213	0.101
Pest	1.826	1.826	-31.289	0.422	1.304	-1.725

	Sigma			Price elasticities		
	PLK	FnD	Matl	PLK	FnD	Matl
PLK	-1.551	0.459	0.467	-0.357	0.155	0.202
FnD	0.459	-0.125	-0.147	0.106	-0.042	-0.063
Matl	0.467	-0.147	-0.134	0.107	-0.050	-0.058

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.529	0.092	0.081	0.115	0.040	0.202
Kap	0.030	-0.467	0.081	0.115	0.040	0.202
Pest	0.339	1.049	-1.745	0.115	0.040	0.202
Land	0.024	0.075	0.006	-0.045	0.003	-0.063
Fert	0.024	0.075	0.006	0.010	-0.052	-0.063
Matl	0.025	0.077	0.006	-0.037	-0.013	-0.058
Shares	0.053	0.164	0.013	0.252	0.087	0.432

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-9.962	0.557	6.386	0.459	0.459	0.467
Kap	0.557	-2.847	6.386	0.459	0.459	0.467
Pest	6.386	6.386	-137.555	0.459	0.459	0.467
Land	0.459	0.459	0.459	-0.181	0.038	-0.147
Fert	0.459	0.459	0.459	0.038	-0.598	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.134

Cotton

	Sigma			Price elasticities	
	Labor	Kap		Labor	Kap
Labor	-3.355	0.559		-0.479	0.479
Kap	0.559	-0.093		0.080	-0.080

	Sigma			Price elasticities	
	Land	Fert		Land	Fert
Land	-0.026	0.055		-0.018	0.018
Fert	0.055	-0.118		0.037	-0.037

	Sigma			Price elasticities	
	VA	Pest		VA	Pest
VA	-0.139	1.826		-0.129	0.129
Pest	1.826	-23.966		1.697	-1.697

	Allen elasticities Labor and Kap in KLP				Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest		Labor	Kap	Pest
Labor	-3.750	0.462	1.826		-0.498	0.368	0.129
Kap	0.462	-0.239	1.826		0.061	-0.191	0.129
Pest	1.826	1.826	-23.966		0.242	1.454	-1.697

	Sigma				Price elasticities		
	PLK	FnD	Matl		PLK	FnD	Matl
PLK	-1.243	0.459	0.467		-0.338	0.146	0.192
FnD	0.459	-0.202	-0.147		0.125	-0.064	-0.060
Matl	0.467	-0.147	-0.195		0.127	-0.047	-0.080

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.542	0.099	0.105	0.099	0.046	0.192
Kap	0.017	-0.460	0.105	0.099	0.046	0.192
Pest	0.198	1.185	-1.721	0.099	0.046	0.192
Land	0.017	0.099	0.009	-0.061	-0.003	-0.060
Fert	0.017	0.099	0.009	-0.006	-0.058	-0.060
Matl	0.017	0.101	0.009	-0.032	-0.015	-0.080
Shares	0.036	0.216	0.019	0.216	0.101	0.411

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-15.052	0.460	5.481	0.459	0.459	0.467
Kap	0.460	-2.125	5.481	0.459	0.459	0.467
Pest	5.481	5.481	-89.493	0.459	0.459	0.467
Land	0.459	0.459	0.459	-0.283	-0.029	-0.147
Fert	0.459	0.459	0.459	-0.029	-0.573	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.195

Tobacco

	Sigma			Price elasticities	
	Labor	Kap		Labor	Kap
Labor	-2.411	0.559		-0.454	0.454
Kap	0.559	-0.130		0.105	-0.105

	Sigma			Price elasticities	
	Land	Fert		Land	Fert
Land	-0.028	0.055		-0.019	0.019
Fert	0.055	-0.108		0.036	-0.036

	Sigma			Price elasticities	
	VA	Pest		VA	Pest
VA	-0.079	1.826		-0.076	0.076
Pest	1.826	-42.330		1.750	-1.750

	Allen elasticities Labor and Kap in KLP				Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest		Labor	Kap	Pest
Labor	-2.593	0.504	1.826		-0.468	0.392	0.076
Kap	0.504	-0.214	1.826		0.091	-0.167	0.076
Pest	1.826	1.826	-42.330		0.330	1.421	-1.750

	Sigma				Price elasticities		
	PLK	FnD	Matl		PLK	FnD	Matl
PLK	-0.886	0.459	0.467		-0.305	0.062	0.243
FnD	0.459	-0.604	-0.147		0.158	-0.082	-0.077
Matl	0.467	-0.147	-0.271		0.161	-0.020	-0.141

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.523	0.155	0.063	0.041	0.021	0.243
Kap	0.036	-0.404	0.063	0.041	0.021	0.243
Pest	0.274	1.184	-1.763	0.041	0.021	0.243
Land	0.029	0.123	0.007	-0.073	-0.009	-0.077
Fert	0.029	0.123	0.007	-0.018	-0.064	-0.077
Matl	0.029	0.125	0.007	-0.013	-0.007	-0.141
Shares	0.062	0.268	0.014	0.089	0.046	0.521

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-8.418	0.579	4.417	0.459	0.459	0.467
Kap	0.579	-1.508	4.417	0.459	0.459	0.467
Pest	4.417	4.417	-123.818	0.459	0.459	0.467
Land	0.459	0.459	0.459	-0.812	-0.196	-0.147
Fert	0.459	0.459	0.459	-0.196	-1.402	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.271

Fruits, Vegetables, and Tree Nuts

	Sigma		Price elasticities	
	Labor	Kap	Labor	Kap
Labor	-1.342	0.559	-0.395	0.395
Kap	0.559	-0.233	0.164	-0.164

	Sigma		Price elasticities	
	Land	Fert	Land	Fert
Land	-0.027	0.055	-0.018	0.018
Fert	0.055	-0.110	0.037	-0.037

	Sigma		Price elasticities	
	VA	Pest	VA	Pest
VA	-0.126	1.826	-0.118	0.118
Pest	1.826	-26.417	1.708	-1.708

	Allen elasticities Labor and Kap in KLP			Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest	Labor	Kap	Pest
Labor	-1.561	0.471	1.826	-0.429	0.311	0.118
Kap	0.471	-0.375	1.826	0.130	-0.248	0.118
Pest	1.826	1.826	-26.417	0.502	1.206	-1.708

	Sigma			Price elasticities		
	PLK	FnD	Matl	PLK	FnD	Matl
PLK	-0.723	0.459	0.467	-0.283	0.059	0.224
FnD	0.459	-0.846	-0.147	0.180	-0.109	-0.070
Matl	0.467	-0.147	-0.342	0.183	-0.019	-0.164

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.507	0.124	0.100	0.040	0.020	0.224
Kap	0.052	-0.435	0.100	0.040	0.020	0.224
Pest	0.424	1.019	-1.726	0.040	0.020	0.224
Land	0.049	0.119	0.012	-0.091	-0.018	-0.070
Fert	0.049	0.119	0.012	-0.036	-0.073	-0.070
Matl	0.050	0.121	0.012	-0.013	-0.006	-0.164
Shares	0.108	0.259	0.025	0.086	0.043	0.479

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-4.707	0.481	3.939	0.459	0.459	0.467
Kap	0.481	-1.680	3.939	0.459	0.459	0.467
Pest	3.939	3.939	-68.160	0.459	0.459	0.467
Land	0.459	0.459	0.459	-1.059	-0.421	-0.147
Fert	0.459	0.459	0.459	-0.421	-1.699	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.342

Oilseeds

	Sigma		Price elasticities	
	Labor	Kap	Labor	Kap
Labor	-2.152	0.559	-0.444	0.444
Kap	0.559	-0.145	0.115	-0.115

	Sigma		Price elasticities	
	Land	Fert	Land	Fert
Land	-0.030	0.055	-0.019	0.019
Fert	0.055	-0.100	0.036	-0.036

	Sigma		Price elasticities	
	VA	Pest	VA	Pest
VA	-0.159	1.826	-0.147	0.147
Pest	1.826	-20.933	1.679	-1.679

	Allen elasticities Labor and Kap in KLP			Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest	Labor	Kap	Pest
Labor	-2.499	0.448	1.826	-0.474	0.327	0.147
Kap	0.448	-0.317	1.826	0.085	-0.232	0.147
Pest	1.826	1.826	-20.933	0.346	1.333	-1.679

	Sigma			Price elasticities		
	PLK	FnD	Matl	PLK	FnD	Matl
PLK	-0.743	0.459	0.467	-0.286	0.086	0.200
FnD	0.459	-0.610	-0.147	0.177	-0.114	-0.063
Matl	0.467	-0.147	-0.355	0.180	-0.027	-0.152

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.528	0.119	0.124	0.055	0.030	0.200
Kap	0.031	-0.440	0.124	0.055	0.030	0.200
Pest	0.292	1.125	-1.702	0.055	0.030	0.200
Land	0.033	0.129	0.014	-0.093	-0.021	-0.063
Fert	0.033	0.129	0.014	-0.038	-0.076	-0.063
Matl	0.034	0.131	0.014	-0.018	-0.010	-0.152
Shares	0.073	0.281	0.031	0.120	0.066	0.429

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-7.237	0.423	4.002	0.459	0.459	0.467
Kap	0.423	-1.567	4.002	0.459	0.459	0.467
Pest	4.002	4.002	-55.135	0.459	0.459	0.467
Land	0.459	0.459	0.459	-0.771	-0.314	-0.147
Fert	0.459	0.459	0.459	-0.314	-1.148	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.355

Sugar

	Sigma			Price elasticities	
	Labor	Kap		Labor	Kap
Labor	-4.492	0.559		-0.497	0.497
Kap	0.559	-0.070		0.062	-0.062

	Sigma			Price elasticities	
	Land	Fert		Land	Fert
Land	-0.004	0.055		-0.004	0.004
Fert	0.055	-0.748		0.051	-0.051

	Sigma			Price elasticities	
	VA	Pest		VA	Pest
VA	-0.323	1.826		-0.274	0.274
Pest	1.826	-10.324		1.552	-1.552

	Allen elasticities Labor and Kap in KLP				Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest		Labor	Kap	Pest
Labor	-5.610	0.335	1.826		-0.528	0.253	0.274
Kap	0.335	-0.405	1.826		0.031	-0.306	0.274
Pest	1.826	1.826	-10.324		0.172	1.380	-1.552

	Sigma				Price elasticities		
	PLK	FnD	Matl		PLK	FnD	Matl
PLK	-1.407	0.459	0.467		-0.349	0.130	0.219
FnD	0.459	-0.159	-0.147		0.114	-0.045	-0.069
Matl	0.467	-0.147	-0.158		0.116	-0.042	-0.074

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.560	-0.011	0.222	0.121	0.009	0.219
Kap	-0.001	-0.570	0.222	0.121	0.009	0.219
Pest	0.139	1.116	-1.604	0.121	0.009	0.219
Land	0.011	0.086	0.017	-0.046	0.001	-0.069
Fert	0.011	0.086	0.017	0.009	-0.054	-0.069
Matl	0.011	0.088	0.017	-0.039	-0.003	-0.074
Shares	0.023	0.187	0.037	0.264	0.019	0.468

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-24.021	-0.056	5.955	0.459	0.459	0.467
Kap	-0.056	-3.039	5.955	0.459	0.459	0.467
Pest	5.955	5.955	-43.026	0.459	0.459	0.467
Land	0.459	0.459	0.459	-0.173	0.035	-0.147
Fert	0.459	0.459	0.459	0.035	-2.796	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.158

Other Farm Products

	Sigma			Price elasticities	
	Labor	Kap		Labor	Kap
Labor	-1.185	0.559		-0.380	0.380
Kap	0.559	-0.264		0.179	-0.179

	Sigma			Price elasticities	
	Land	Fert		Land	Fert
Land	-0.012	0.055		-0.010	0.010
Fert	0.055	-0.254		0.045	-0.045

	Sigma			Price elasticities	
	VA	Pest		VA	Pest
VA	-0.138	1.826		-0.128	0.128
Pest	1.826	-24.1575		1.698	-1.698

	Allen elasticities Labor and Kap in KLP				Price elasticities Labor and Kap in KLP		
	Labor	Kap	Pest		Labor	Kap	Pest
Labor	-1.413	0.463	1.826		-0.421	0.293	0.128
Kap	0.463	-0.422	1.826		0.138	-0.266	0.128
Pest	1.826	1.826	-24.158		0.544	1.154	-1.698

	Sigma				Price elasticities		
	PLK	FnD	Matl		PLK	FnD	Matl
PLK	-0.652	0.459	0.467		-0.272	0.049	0.223
FnD	0.459	-1.134	-0.147		0.191	-0.121	-0.070
Matl	0.467	-0.147	-0.375		0.194	-0.016	-0.179

PRICE	Labor	Kap	Pest	Land	Fert	Matl
Labor	-0.502	0.121	0.109	0.040	0.009	0.223
Kap	0.057	-0.438	0.109	0.040	0.009	0.223
Pest	0.463	0.982	-1.717	0.040	0.009	0.223
Land	0.057	0.121	0.013	-0.109	-0.012	-0.070
Fert	0.057	0.121	0.013	-0.054	-0.067	-0.070
Matl	0.058	0.123	0.014	-0.013	-0.003	-0.179
Shares	0.124	0.263	0.029	0.088	0.019	0.477

ALLEN	Labor	Kap	Pest	Land	Fert	Matl
Labor	-4.044	0.460	3.732	0.459	0.459	0.467
Kap	0.460	-1.665	3.732	0.459	0.459	0.467
Pest	3.732	3.732	-58.656	0.459	0.459	0.467
Land	0.459	0.459	0.459	-1.246	-0.619	-0.147
Fert	0.459	0.459	0.459	-0.619	-3.510	-0.147
Matl	0.467	0.467	0.467	-0.147	-0.147	-0.375

U.S. Department of Agriculture
Economic Research Service

SUMMARY OF REPORT

Restricting Chemical Use on the Most Vulnerable Cotton Acreage Can Protect Water Quality With Only Minor Effects on Cotton Yields and Prices

Number 6, January 1993

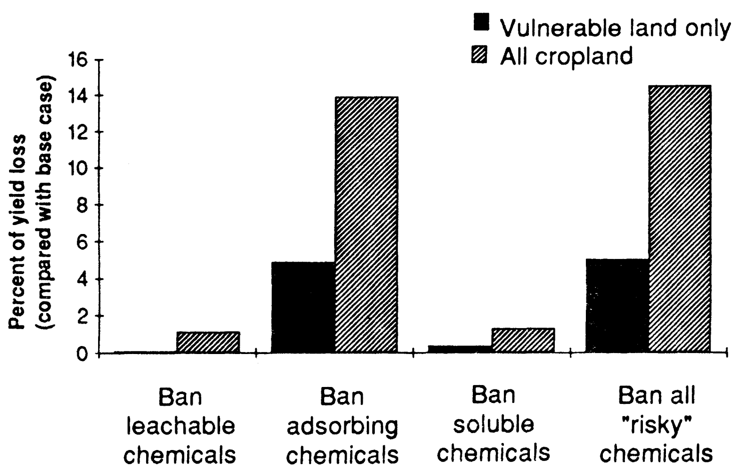
Contact: Stephen R. Crutchfield, (202) 219-0444.

Environmental damage to surface and ground water posed by cotton farming may be reduced, with only limited effects on yields and prices, if restrictions on agrichemical use or production are applied to just those acres most vulnerable to water-quality problems. The most widespread potential damage is from nitrates in fertilizer that can pollute ground water and pesticides that can contaminate surface water.

Production of cotton appears less likely than other crops to cause erosion-induced water-quality problems because cotton acreage is not the major source of cropland erosion in most regions. Widespread restrictions on the use of chemicals likely to leach, dissolve in cropland runoff, or attach to eroding soils may reduce the risk of water-quality degradation, but may also raise cotton prices by reducing yields. These conclusions flow from USDA's 1989 Cotton Water Quality Survey that gathered data on cotton agricultural chemical use and related production practices and resource conditions in 14 cotton States. Data gathered on the use of fertilizers, herbicides, insecticides, and other agricultural chemicals were analyzed to assess the potential water-quality problems that may be associated with cotton production.

Yield losses from chemical restrictions on cotton acreage

Yield losses are minimized if chemical restrictions are targeted to only cotton acreage at greatest water-quality risk.



Widespread Restrictions Could Raise Cotton Prices

The study's results highlight the importance of targeting pollution-prevention programs to attain the most cost-effective environmental protection strategies. Restricting the use of environmentally damaging chemicals on all cotton acreage could reduce the overall potential for water-quality impairment, but could raise cotton prices by as much as 31 percent. More specific chemical-use restrictions, targeted to acreage considered at greatest water-quality risk, could achieve nearly the same level of environmental protection, but would limit price increases and reduce yield losses. Modifying production practices to reduce soil erosion could generate $25 million in economic benefits by reducing sedimentation in surface water systems.

To Order This Report...

The information presented here is excerpted from ***Cotton Production and Water Quality: Economic and Environmental Effects of Pollution Prevention,*** AER-664, by Stephen R. Crutchfield, Marc O. Ribaudo, LeRoy T. Hansen, and Ricardo Quiroga. The cost is $8.00.

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U.S. Department of Agriculture
Economic Research Service

ERS SUMMARY OF REPORT

Production Costs for Ethanol to Drop as New Technology Comes On-Line

Number 7, February 1993

Contact: Neil Hohmann (202) 219-0428

The fuel ethanol industry is poised to adopt a wide range of technologies that would reduce costs at every stage of the production process. Adoption of improved enzymes, fermenter designs, membrane filtration, and other innovations in the next 5 years is expected in new ethanol plants constructed to meet new demand resulting from Clean Air Act stipulations for cleaner burning fuel. A new report, *Emerging Technologies in Ethanol Production*, examines the likelihood of near- and long-term cost reductions in producing ethanol, as well as the potential of biomass (agricultural residues, municipal and yard waste, energy crops like switchgrass) to supplement corn as an ethanol feedstock.

Ethanol Industry Expands, Reducing Costs

The use of ethanol as a fuel for vehicles in the United States grew from insignificance in 1977 to nearly 900 million gallons in 1991. The ethanol industry emerged through a combination of government incentives and new technologies, which enabled large-scale production of ethanol from domestic resources, particularly corn. Growing consumer acceptance of ethanol-blended fuels, incentives to gasoline blenders, and falling costs of production (from $1.35-$1.45 per gallon in 1980 to less than $1.25 per gallon in 1992) were responsible for the jump in ethanol production.

The construction of new ethanol production plants and the adoption of new technologies at existing plants is likely to lead to further cost reductions (5-7 cents per gallon over the next 5 years). Improved yeasts, which tolerate high concentrations of ethanol, can lower energy costs. A system of membranes can recycle enzymes and capture high-value coproducts at many steps in the production process.

Longer term technologies would save approximately 9-15 cents per gallon over present costs. Energy and feedstock savings will result from technology that can convert some of the nonstarch portions of corn to ethanol. Development of microorganisms that speed the process will contribute to long-term savings. Development of markets for coproducts of ethanol production will create additional savings. Cost savings may be less for smaller plants that serve niche markets, or in older plants that must replace inefficient equipment.

Ethanol From Biomass Reduces Costs and Environmental Waste

Biomass can also be converted to ethanol, although commercial-scale ventures are limited by current technology. While biomass requires more handling and sorting before conversion, those costs may be offset by the abundance of biomass relative to corn. Although the production of ethanol from biomass is presently constrained by technological difficulties, new developments in this decade may allow ethanol to be produced from biomass at or below the cost of corn-derived ethanol.

To Order This Report...

The information presented here is excerpted from ***Emerging Technologies in Ethanol Production,*** AIB-663, by Neil Hohmann and C. Matthew Rendleman. The cost is $9.00.

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