# Testing for Disequilibrium in the Demand for Agricultural Inputs

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A dynamic system of cost-share equations for agricultural inputs is used to test for the presence of input disequilibrium. This dynamic system incorporates a disequilibrium adjustment process into input-share equations derived from a translog cost function. The disequilibrium process is represented as a generalized partial adjustment model where disequilibrium in one input may affect other inputs. Results from this analysis suggest applications of translog share systems to agriculture under static equilibrium assumptions are inappropriate.

Systems of equations derived from cost functions are commonly used to estimate input demand (Binswanger; Berndt and Wood; Ray). The popularity of using cost functions is attributed to the widespread application of duality theory to economic problems (Fuss and McFadden) and the development of flexible functional forms for econometric modeling (Diewert).

Cost functions are formed in a static equilibrium framework where inputs are assumed to adjust instantaneously to long-run cost minimizing levels. Although static equilibrium is an important conceptual framework and comparative statics is a powerful analytical tool, there is no reason to expect econometric models based on static foundations to accurately represent behavior which is inherently dynamic. In an econometric context, this means there is no a priori reason to assume that each observation in a data set represents a production technology fully adjusted to current prices and output.

Since the work of Marshall, economists have acknowledged the presence of disequilibrium and have distinguished between short-run and long-run economic behavior. Distinctions between these types of behavior are motivated by the fixed nature of durable consumer goods and capital equipment, the presence of habits and imperfect information, and the recognition that producers' and consumers' expectations are not static.

Input adjustments, closely associated with some of the major problems of market economics, have received serious attention only in the last two to three decades. During this period, input adjustments in agriculture, particularly those associated with the use of labor (Barton; Schuh; and Bryant), fertilizer (Huffman, 1972, 1974, and 1977), and equipment (Edwards), have been examined. The works of Edwards and Huffman illustrate the inadequacy of neoclassical static equilibrium concepts for addressing agricultural input adjustment. Huffman, for example, shows that changes in the use of fertilizer during a 5-year period in the 1960s are only a fraction of the changes necessary to achieve an optimum and, in addition, these changes cannot be explained solely in terms of relative prices. Both conclusions contradict static equilibrium assumptions.

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This analysis formally tests for disequilibrium in the demand for agricultural inputs. To achieve this objective, a dynamic system of cost-share equations for agricultural inputs is specified and estimated. A similar model is used by Norsworthy and Harper to derive short-run and long-run demand elasticities for inputs in the manufacturing sector. This dynamic system incorporates a disequilibrium adjustment process into input-share equations derived from a translog cost function (Christensen, *et al.*, 1971, 1973). The disequilibrium model is a unified framework for examining input demand which includes the equilibrium model as a more restrictive case. The disequilibrium process is represented as a generalized partial adjustment model (Cagan; Nerlove) where disequilibrium in one input may affect adjustment of other inputs.

The disequilibrium hypothesis is tested by comparing the disequilibrium model to the static equilibrium model through use of a likelihood ratio test. The translog input cost-share system can be used to test the disequilibrium hypothesis because disequilibrium in the input cost shares necessarily implies input quantity disequilibrium. Results from this analysis support the disequilibrium hypothesis and suggest that applications of translog share systems to agriculture under assumptions of static equilibrium in input demand are inappropriate.

The remainder of the paper is composed of four parts. The theoretical nature of the disequilibrium process is discussed in the next section. Estimated forms of the equilibrium and disequilibrium models are specified and results of the estimation are presented in the third and fourth sections. Major findings are summarized in the last section.

## Disequilibrium as Dynamics

There are two distinct types of disequilibrium models: (1) dynamic equilibrium models exhibiting short-run adjustment paths to long-run equilibrium positions and (2) disequilibrium models in which markets are not assumed to clear continually. In the latter case, disequilibrium means that market transactions occur at prices which do not lead to equilibrium. Under these conditions, either consumers or suppliers are not able to trade desired quantities at prevailing prices (Fair and Jaffee; Ziemer and White). Several reasons are advanced for the existence of this type of disequilibrium, including unusual weather, population shifts, and government constraints. However, the notion that incomplete or imperfect information flow can lead to disequilibrium price behavior is probably the most common reason given (Smith; Lancaster). A more sophisticated explanation for dynamic price behavior combines incomplete information with uncertainty regarding the knowledge of supply and demand schedules (Gordon and Hynes).

In this analysis, we adopt the first definition which describes disequilibrium as a temporary position in a process of long-run dynamic optimization. During the 1960s and 1970s, in reaction to the *ad hoc* macro-dynamics being practiced, some researchers attempted to derive aggregate dynamic relations from rational optimizing behavior (Phelps). Optimizing behavior was set in an environment where changes from the current situation are costly and disruptive and imperfect information and uncertainty exist. This framework was used to examine search behavior (Stigler; Alchian), transactions costs (Barro; Rothschild), and expectations formation (Cagan; Muth). For the purposes of this analysis, however, applications of the dynamic framework to examine input adjustments in production are the most relevant.

Economists have sought a theoretical framework for the partial adjustment or flexible accelerator model since Nerlove's (1956, 1958) early applied work because the simplicity of the accelerator has proved to be a valuable econometric tool. Many economists recognized the gap in economic theory where an elaborate theoretical structure, which existed for determining the level of an input, was combined with an *ad hoc* theory of adjustment. Eisner and Strotz developed a more rigorous theory of adjustment by casting the firm in a dynamic optimization framework. The present value or net worth maximized by the firm depends on the optimal level of the input selected by the firm, usually capital, and on the path of approach of the current stock to the optimal level. More recently, Lucas, Gould, and Treadway have extended the work of Eisner and Strotz.

Although these models differ in their complexity, they all have the same underlying structure postulated by Eisner and Strotz. In each, an objective function incorporating factor adjustment costs as well as the production function is specified. The firm is assumed to maximize net worth over a given time horizon. Adjustment costs are interpreted as foregone profits due to short-run rising supply prices in the capital-supplying industry or increasing costs associated with integrating new equipment into production: reorganizing production and training workers. These costs vary with the speed of capital adjustments. A firm maximizing its present value will introduce capital stock additions in a manner similar to that provided by the acceleration model. Furthermore, it is assumed that values of the expected input and output price variables do not change. This static or stationary expectations assumption is necessary if the dynamic optimization problem is to be well-defined (Nerlove). Because expectations are static, the firm adjusts to a fixed target considered to be the long-run equilibrium of neoclassical theory.

The disequilibrium framework applied in this analysis uses an approximation of Lucas' generalization of the Eisner and Strotz dynamic optimization model. This disequilibrium approach differs from Lucas in two important ways. First, in the Lucas framework, the adjustment matrix is endogenous allowing for nonconstant adjustment parameters. Following Nadiri and Rosen, it is assumed that the adjustment matrix is constant. Second, the Lucas approach allows for adjustment only in quasi-fixed inputs, while this specification extends the adjustment matrix to all inputs.

A generalized adjustment structure, which is the solution to the optimization problem, implies an interdependent system. Like Nadiri and Rosen, we allow disequilibrium in one input to influence use of other inputs. Inputs follow a disequilibrium path along which they are dynamically adjusted to compensate for deficiencies among the desired and actual levels of their respective inputs. Attempts to relax this assumption by estimating an internal cost of adjustment model following Treadway failed to produce statistically meaningful results. While this failure may be attributed to data aggregation or sampling problems, an alternative explanation for the poor results is the critical assumption of input and output price stationarity. To obtain the more theoretically attractive closed form solution suggested by Treadway, the dynamic optimization procedure assumes that input and output prices are constant indefinitely. The agricultural sector has been characterized by relatively volatile prices, making the assumption of constant prices inappropriate for this sector. Therefore, the theoretically less elegant but simpler adjustment model is presented here. The disequilibrium system implies two types of factor subtitution: (1) long-run substitution caused by changes in relative input prices, and (2) short-run substitution caused by slow adjustment to long-run input levels.

For a single input, adjustment to a long-run equilibrium using an accelerator framework can be written as:

$$x_t - x_{t-1} = b(x_t^* - x_{t-1}) \quad 0 < b \leq 1 \tag{1}$$

where $x_t$ is the observed level of an input at time t, $x_t^*$ is the long-run equilibrium level of the input, and b is an adjustment coefficient between zero and one.

This framework assumes that the long-run equilibrium input quantity cannot be observed. In the absence of changes in relative input prices or other exogenous variables, the input quantity demanded changes in proportion to the difference between the long-run equilibrium quantity and last period's observed input quantity. Equation (1) is generalized to n inputs by writing:

$$X - X_L = B'(X^* - X_L) \tag{2}$$

where X and $X_L$ are vectors of length n of current and lagged input quantities, respectively, B is an nxn dimensional matrix of adjustment coefficients, and $X^*$ is a vector of length n of current optimal input quantities. Although input disequilibrium exists, firms may remain on the production surfaces since the adjustment matrix includes feedback effects of the type $b_{ij}$. Output, however, need not be constant.

## Empirical Model Structure

The underlying structure of the equilibrium and disequilibrium models is a translog unit cost function. In this analysis, the translog function is viewed as an approximation to the agricultural producer's cost function. The translog is an attractive analytical form yielding input cost shares as functions of input prices. These cost shares are linear in parameters and therefore conducive to econometric estimation while readily yielding measures of input substitution and price sensitivity.

### *Equilibrium Model*

The equilibrium model uses a cost-share system derived from a translog cost function manifesting constant returns to scale and Hicksian neutral technological change. Under long-run equilibrium, the translog cost function implies a cost-share system of the form:

$$\partial \ln C/\partial \ln P_{it} = S_{it}^* = d_i + \sum_{j=1}^{n} d_{ij} \ln P_{jt} \quad (i = 1, 2, \ldots, n) \tag{3}$$

where C is total cost, $P_i$ is the price of the ith input in period t, $S_{it}^*$ is the optimal input share for the ith input in period t, and $d_i$ and $d_{ij}$ are parameters.

Symmetry and homogeneity of factor prices in equilibrium are imposed by:

$$\begin{aligned} &d_{ij} = d_{ji};\\ &\sum_{i=1}^{n} d_{ij} = \sum_{j=1}^{n} d_{ij} = \sum_{i=1}^{n}\sum_{i=1}^{n} d_{ij} = 0;\\ &\sum_{i=1}^{n} d_i = 1. \end{aligned} \tag{4}$$

The equilibrium own-price and cross-price elasticities, holding output constant, are:

$$(P_{it}/x_{it}^*)(\partial x_{it}^*/\partial P_{it}) = [(S_{it}^*)^2 - S_{it}^* + d_{ii}]/S_{it}^* \quad (i = 1, 2, \ldots, n) \tag{5}$$

$$(P_{jt}/x_{it}^*)(\partial x_{it}^*/\partial P_{jt}) = [S_{jt}^* S_{it}^* + d_{ij}]/S_{it}^* \quad (i \neq j = 1, 2, \ldots, n) \tag{6}$$

where $x_{it}^*$ is the optimal quantity of the ith input in period t and Q is output.

The symmetry conditions imposed in equation (4) imply only that:

$$\partial x_{it}/\partial P_{jt} = \partial x_{jt}/\partial P_{it} \quad (i \neq j = 1, 2, \ldots, n) \tag{7}$$

Factor price homogeneity implies that the equilibrium price elasticities sum to zero.

### *Disequilibrium Model*

The cost of producing a given output in the presence of internal or external costs of input adjustment is likely to exceed the cost-minimizing level. If at least one input is in disequilibrium, capital for example, other inputs are likely also to be in disequilibrium. The input demand adjustment framework, equation (2), is employed to capture potential disequilibrium in a system of translog input cost-share equations. For a single equation, the disequilibrium model is:

$$S_{it} - S_{it-1} = \sum_{j=1}^{n} b_{ij}(S_{jt}^{*} - S_{jt-1}) \qquad (8)$$
$$(1 = 1, 2, \ldots, n)$$

where $S_{it}$ is the observed cost share for the ith input in period t, $S_{jt}^{*}$ is the optimal cost share, and $b_{ij}$ are parameters. The difference between the observed cost share in periods t and $t - 1$ is assumed to be proportional to the difference between the optimal cost shares in period t and the observed cost shares in period $t - 1$.

If equation (3) is substituted for $S_{jt}^{*}$, and $S_{it-1}$ is subtracted, then equation (8) can be rewritten:

$$S_{it} = \sum_{j=1}^{n} b_{ij}\left(d_j + \sum_{j=1}^{n} d_{ij} \ln P_j\right) + (1 - b_{ii})S_{it-1} - \sum_{j \neq i}^{n} b_{ij}S_{jt-1} \qquad (9)$$
$$(i = 1, 2, \ldots, n).$$

The observed cost share, $S_{it}$, is a function of the optimal cost shares for all inputs in the current period and last period's input cost shares. Parameters $b_{ij}$ are elements of an nxn adjustment matrix B which is assumed to be constant over the sample period. If $b_{ii} = 1$ and $b_{ij} = 0$ for all $i \neq j$, then the disequilibrium model collapses to the equilibrium model and all inputs adjust in a single time period. Therefore, the equilibrium input cost-share system is a restricted form of the disequilibrium model. Constraints on the coefficients of the adjustment process are necessary if the observed shares in the disequilibrium system are to sum to unity. Cost shares sum to unity in the presence of disequilibrium when:

$$i(S_t - S_{t-1}) = iB(S_t^{*} - S_{t-1}) = 0 \qquad (10)$$

where i is a unit vector of dimension lxn. Equation (10) indicates that the sum of the changes in cost shares across all inputs is zero. For autoregressive models, equation (10) is satisfied if and only if:

$$iB = zi \qquad (11)$$

where z is an unknown constant (Berndt and Savin).

Both short-run and long-run price elasticities can be derived for the disequilibrium model. Computed long-run price elasticities have the same form as equilibrium price elasticities in equations (5) and (6). Own-price and cross-price elasticities in the short-run, holding output constant, are:

$$(P_{it}/x_{it})(\partial x_{it}/\partial P_{it}) = \left[S_{it}^2 - S_{it} + \sum_{k=1}^{n} b_{ii}d_{ik}\right]/S_{it} \qquad (12)$$
$$(i = 1, 2, \ldots, n)$$

$$(P_{jt}/x_{it})(\partial x_{it}/\partial P_{jt}) = \left[S_{jt}S_{it} + \sum_{k=1}^{n} b_{ij}d_{jk}\right]/S_{it} \qquad (13)$$
$$(i \neq j = 1, 2, \ldots, n)$$

where short-run elasticities are interpreted as the first period response of input demand to changes in input prices.

### Estimation Methodology and Data

The share equations for the equilibrium model manifest nonzero contemporaneous covariances; therefore, single-equation estimation by ordinary least squares is inefficient. The share system is estimated using maximum likelihood procedures. Because maximum likelihood estimates are invariant to which equation is deleted

[Barten], the share equations are transformed to an estimable form by deleting the nth share equation. The equilibrium cost-share system, with symmetry and homogeneity constraints applied, is estimated as:

$$S_{it}^* = d_i + \sum_{j=1}^{n-1} d_{ij}\ln(P_{jt}/P_{nt}) + e_t \qquad (14)$$

$$i = 1, 2, \ldots, n-1$$

where $e_t$ is a random error.

A nonlinear solution algorithm is used to obtain maximum likelihood estimates for the disequilibrium share equations. The adding-up restrictions, equation (10), allow the adjustment matrix for the disequilibrium system to be simplified. Because the observed shares sum to unity, the B matrix can be transformed to $B^n$:

$$B^n = \begin{bmatrix} b_{11} - b_{1n} & b_{12} - b_{1n} & \ldots & b_{1n-1} - b_{1n} \\ b_{12} - b_{2n} & b_{22} - b_{2n} & \ldots & b_{2n-1} - b_{2n} \\ \vdots & & & \vdots \\ b_{n-11} - b_{n-1n} & \ldots & \ldots & b_{n-1n-1} - b_{n-1n} \end{bmatrix}. \qquad (15)$$

Elements of B cannot be uniquely determined unless restrictions are imposed on elements of B in addition to the adding-up conditions (Berndt and Savin). A necessary and sufficient condition for identification is that there is at least one zero restriction in each row of $B^n$ (Berndt, Fuss, and Waverman). For this analysis, we assumed that during the sample period, 1947–74, energy was readily available in the agricultural production sector and adjustments in energy demand never impeded adjustments in other factor markets.

The disequilibrium cost-share system, with symmetry and homogeneity constraints maintained in the underlying long-run equilibrium system, is estimated as:

$$S_{it} = \sum_{j=1}^{n-1} b_{ij}^*\left(d_j + \sum_{j=1}^{n-1} d_{ij}\ln(P_{jt}/P_{nt}\right)$$

$$+ (1 - b_{ii}^*)S_{it} - 1 - \sum_{j\neq 1}^{n-1} b_{ij}^* S_{jt-1} + u_t \qquad (16)$$

$$i = 1, 2, \ldots, n-1$$

where

$$b_{ij}^* = b_{ij} - b_{in} \qquad i = 1, 2, \ldots, n.$$

and $u_t$ is a random error.

Annual time-series data compiled by Brown and Christensen are used to estimate parameters of the equilibrium and disequilibrium models. The data span the years 1947 through 1974. Five inputs are used in the estimation: energy, fertilizer, land, hired labor, and capital equipment. All other inputs in production are assumed to be additively separable. This strong assumption is made to limit the number of parameters requiring estimation without distorting relationships among remaining variables. An additional input would require 5 parameters in the equilibrium model and 10 parameters in the disequilibrium model to be estimated. Changes in prices or quantities of inputs not considered in this analysis are assumed not to affect either equilibrium or disequilibrium cost functions.

The Brown and Christensen data are the most consistent information available on input use in agriculture. Hired labor data were formulated to account for differences in the productivity of different types of workers and changes in quality due to education. Separation of price and quantity components of outlays on equipment and land is based on the correspondence between asset prices and service or rental prices implied by the equality between the value of an asset and the discounted value of its services (Griliches and Jorgenson). The service price depends on the asset price, the rate of return, and the rate of replacement. Outlays on equipment and land are separated into price and quantity components by combining the rate of return with other components of the service price. Fertilizer data use information on primary nutrient content to account for quality changes. Price data on nitrogen, phosphorus, and potassium are aggregated using a Divisia index. An aggregate quantity index is derived by division. Energy data are developed by combining U.S. Department of Agriculture's Mechanical Power and Machinery index with expenditures on petroleum products and electricity.

**TABLE 1. Parameter Estimates for the Disequilibrium and Equilibrium Models.**

| | Disequilibrium Model | | Equilibrium Model | |
|---|---|---|---|---|
| Parameter[a] | Estimate | Standard Error | Estimate | Standard Error |
| dw | 0.193 | 0.008 | 0.120 | 0.003 |
| dww | −.036 | .097 | −.001 | .009 |
| dwk | .191 | .093 | .028 | .012 |
| dwf | .096 | .031 | .051 | .005 |
| dwl | −.041 | .044 | .053 | .004 |
| dk | .326 | .014 | .312 | .003 |
| dkk | −.068 | .283 | .049 | .024 |
| dkf | −.091 | .048 | −.063 | .009 |
| dkl | −.113 | .040 | −.035 | .004 |
| df | .117 | .006 | .103 | .003 |
| dff | .050 | .015 | .032 | .006 |
| dfl | −.030 | .015 | −.017 | .004 |
| dl | .273 | .008 | .290 | .507 |
| dll | .130 | .021 | .137 | .006 |
| bww | .493 | .268 | | |
| bwk | .127 | .253 | | |
| bwf | −.024 | .257 | | |
| bwl | −.157 | .189 | | |
| bkw | −.281 | .162 | | |
| bkk | .121 | .122 | | |
| bkf | −.404 | .203 | | |
| bkl | −.394 | .103 | | |
| bfw | .505 | .282 | | |
| bfk | −.306 | .269 | | |
| bff | .798 | .297 | | |
| bfl | .082 | .205 | | |
| blw | −.890 | .570 | | |
| blk | −.221 | .543 | | |
| blf | −.284 | .545 | | |
| bll | .651 | .405 | | |

[a] w = labor, k = capital, f = fertilizer, and l = land.

## Empirical Results

Parameter estimates for the equilibrium and disequilibrium models are presented in Table 1. Parameters are estimated for U.S. agriculture and with linear homogeneity in factor prices and symmetry imposed on the optimal input cost shares. Conventional $R^2$'s (computed as one minus the ratio of the residual sum of squares to the total sum of squares in each equation) are 0.99 (0.99) for labor, capital, and land and 0.98 (0.95) for fertilizer. Figures in parentheses refer to the equilibrium model. Durbin-Watson statistics are 2.27 (0.69) labor, 1.98 (0.83) capital, 1.91 (0.62) fertilizer, and 2.34 (0.93) land. Values of logarithms of likelihood functions for the equilibrium and disequilibrium models are 371.2 and 425.9, respectively.

The equilibrium model is a subset of the more general disequilibrium model. A likelihood ratio test is constructed to determine if the two models are statistically different. Since each model's parameters are maximum likelihood estimates, the likelihood ratio test statistic is:

$$\lambda = L(\theta^*)/L(\theta) \qquad (17)$$

where $L(\theta^*)$ is the restricted (equilibrium) likelihood function and $L(\theta)$ is the unrestricted (disequilibrium) likelihood function. Therefore, $-2\ln\lambda$ is distributed asymptotically as a chi square with degrees of freedom equal to the number of independently imposed restrictions.

The null hypothesis is that there is no statistical difference between restricted equilibrium and the unrestricted disequilibrium translog models. More precisely, the null hypothesis asserts all $b_{ij}$ equal zero. The null hypothesis is rejected at the 0.5-percent level with 16 degrees of freedom.

Observed values of $S_t$ should converge to $S^*$ from any initial condition $S_0$ given a sufficiently long period of time. Through recursion, $S_t$ is written as a weighted sum of previous values and initial conditions:

$$S_t = BS_t + (I - B)BS_{t-1} + \ldots + (I - B)^{t-1}BS_1 + (I - B)^tS_0 \qquad (18)$$

**TABLE 2. Estimated Short-Run and Long-Run Price Elasticities.**[a]

| Input | Input Price<br>Labor | <br>Capital | <br>Fertilizer | <br>Land | <br>Energy |
|---|---|---|---|---|---|
| Labor: | | | | | |
| Short-Run | −0.73 | 0.77 | 0.28 | −.14 | −0.19 |
| Long-Run | −.9 | 1.17 | .53 | −.08 | −.68 |
| Capital: | | | | | |
| Short-Run | .26 | −.63 | −.05 | −.03 | .46 |
| Long-Run | .86 | −.93 | −.20 | −.27 | .54 |
| Fertilizer: | | | | | |
| Short-Run | .70 | .47 | −.01 | −.19 | −.97 |
| Long-Run | 1.18 | −.61 | −.20 | −.19 | .03 |
| Land: | | | | | |
| Short-Run | −.36 | −1.54 | −.80 | .54 | .87 |
| Long-Run | −.15 | −.73 | −.18 | .30 | .76 |
| Energy: | | | | | |
| Short-Run | .14 | .93 | .59 | −.16 | −.18 |
| Long-Run | −.94 | 1.10 | .25 | .24 | −.39 |

[a] Elasticities calculated for the mean share of each input.

where $S_t$ is the observed input share, $S_t$ is the optimal share, and $S_0$ is the initial condition. In equilibrium, $S_t$ equals $S^*$. Therefore, equation (18) can be rewritten as:

$$S_t = [I + (I - B) + (I - B)^2 + \dots + (I - B)^{t-1}]BS^* + (I - B)^t S_0 \qquad (19)$$

Stability requires $(I\text{-}B)^t$ to converge to a zero matrix as t approaches infinity. If $(I - B)^t$ converges to zero, then the matrix $[I + (I - B) + (I - B)^2 + \dots]$ approaches $B^{-1}$ and $S_t$ approaches $S^*$.

A sufficient condition for $(I - B)^t$ to converge to a zero matrix is that the characteristic roots of $(I - B)$ lie within the unit circle. The adjustment path is monotonic if the characteristic roots are real numbers and oscillates if at least one of the roots is complex. Because the number of nonzero characteristic roots equals the rank of $(I - B)$, the disequilibrium system has four nonzero roots. Only three of the roots lie within the unit circle (0.067, 0.249, and 0.693). The fourth root exceeds one (1.055) indicating the system is divergent and may be unstable when used for forecasting.

The disequilibrium model's short-run and long-run price elasticities are reported in Table 2. All own-price elasticities except those associated with land have the theoretically correct negative sign. In addition, the share system, except land, is consistent with the LeChatelier Principle (Samuelson). That is, long-run own-price elasticities are greater than short-run elasticities because there is greater flexibility to adjust inputs in the long-run. The inappropriate sign on the own-price elasticity for land may be attributed to data problems associated with government set-aside programs. Furthermore, simultaneity of the supply and demand for land may have led to an identification problem. Own-price elasticities for the equilibrium share system computed at the means are labor (−0.8), capital (−0.5), fertilizer (−0.6), land (−0.1), and energy (0).

The cross-price elasticities have, in general, the expected signs and are of reasonable magnitudes. For example, capital is a strong substitute for labor particularly in the long-run, a complement with land, and a substitute for energy. Results indicate an increase in the rental price of capital causes an increase in fertilizer use in the short-run, but a decrease in the long-run. Increases in the rental price of capital have the most dramatic effects on the use of other inputs in the short-run and long-run. The cross-price elasticities between land and fertilizer which indicate a complementary relationship appear incorrect. Experience suggests that land and fertilizer are probably substitutes.

## Summary

In this analysis, a fully integrated model of input demand is formulated and estimated using cost-share equations. The disequilibrium nature of the model follows the generalized accelerator approach of Lucas and Nadiri and Rosen. The null hypothesis of no statistical difference between the disequilibrium and equilibrium models is rejected. Within this context, the disequilibrium version of the translog share system is judged structurally superior to its equilibrium counterpart for the data used in the experiment. This, of course, is not the same as rejecting equilibrium. The alternative hypothesis that a different model with equilibrium assumptions may produce statistically superior fit cannot be rejected. Estimated parameters from the disequilibrium model are used to compute long-run and short-run input price elasticities. With the exception of land, the own-price input elasticities are negative and consistent with the Le-Chatelier Principle.

All economic analyses use assumptions to make complex problems more manageable. However, static equilibrium assumptions used to simplify input demand systems for aggregate agriculture may sacrifice too much reality in the name of computational ease. There are many reasons why agricultural inputs do not adjust to long-run equilibrium within a year. Therefore, these assumptions make the equilibrium modeling framework inconsistent with the economic environment and distort analytical results, such as the computation of demand price elasticities. Agricultural policy based on equilibrium systems will likely lead to ill-timed measures which may intensify rather than relieve problems. This analysis shows that the dichotomy between long-run and short-run, important for most conceptual economic models, can be easily integrated into an input cost-share approach.

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