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Abstract

Previous empirical models of fertilizer demand for corn or feedgrains production, which have been analyzed mainly within a static framework, indicate that the functions are price elastic or nearly price elastic. This result implies that taxes could be an effective policy tool to reduce nutrient use in agriculture. If application rates and independent variables are nonstationary, static regressions, which would then be misspecified dynamically, could result in a spurious relationship with inconsistent parameters. [In this paper, we estimate a set of dynamic demand models for nitrogen, phosphate, and potash use in corn production, which accounts for nearly half of total U.S. fertilizer nutrient use. The results provide strong statistical evidence that nutrient demands for corn are price inelastic both in the short and the long run.]

Keywords: Fertilizer nutrient demands, dynamic process, shortrun and longrun elasticities, unit roots, nonstationarity, and cointegration and error correction models.

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Elasticities of Fertilizer Demands for Corn in the Short and the Long Run

A Cointegrated and Error-Correcting System

Mark Denbaly
Harry Vroomen

Introduction

Water quality concerns have raised the possibility of various policies targeted to reduce fertilizer use in agriculture. One potential strategy is to tax fertilizer. The effectiveness of this policy depends on the price elasticity of nutrient demands. Previous empirical models have found that the demand for fertilizer on corn (Roberts and Heady) and on feed grains (Gunjal and others) is price elastic or nearly price elastic, implying that a tax could be an effective policy tool. However, most of the earlier empirical work were carried out within a static framework. If nutrient application rates and independent variables are nonstationary, static regressions, which would then be misspecified dynamically, could result in a spurious relationship with inconsistent parameters. In this paper, we develop a dynamic model and estimate the shortrun and the longrun price elasticities of fertilizer demands for corn because it accounts for nearly half of total U.S. fertilizer use.

Economists have estimated the price elasticities of fertilizer nutrient demands. National or regional level demand functions for total fertilizer or nutrient applications on all crops were examined by Griliches (1958, 1959), Heady and Yeh, Rausser and Moriak, Gyawu and others, Carman, and Roberts. Gunjal and others stressed sector-specific demands. They found that fertilizer demands of different crop sectors responded in varying degrees to changes in fertilizer prices and government policies for the period 1952-76. Roberts and Heady emphasized the importance of modeling crop-specific demands for individual nutrients. They found that application rates for specific nutrients on corn, soybeans, and wheat reacted differently to changes in crop and fertilizer prices during the same period.

Elasticities estimated by Roberts and Heady provide information needed to measure the effects of potential fertilizer taxes and crop-specific policy provisions on fertilizer use by nutrient. However, the estimates pertain to the period 1952-76, limiting their use for current policy impact analysis. More importantly, Roberts and Heady's analysis adopted a static framework. Estimation of their model produced a high degree of positive autocorrelation and a relatively high R^2 . As Hendry and Mizon demonstrate, such results are a sign of possible dynamic

misspecification. The reasons for the dynamic nature of fertilizer demands are illustrated clearly in Gunjal and others, and Griliches (1958, 1959). Gunjal and others, for example, state that "Farmers are expected to make adjustments to changes in economic phenomena. However, because of imperfect information and habit persistence, farmers may not make the full adjustment to longrun equilibrium within one year" (p. 112).

In this paper, recently developed techniques are used to extend the typically specified static theory into a dynamic model of crop and nutrient-specific fertilizer demands. The dynamic model corrects for the errors that result from shortrun deviations of fertilizer nutrient use from its longrun equilibrium level. The Engle and Granger technique is then used to estimate a set of error-correction demand models for nitrogen, phosphate, and potash use on corn, which accounts for nearly half of total U.S. fertilizer nutrient use (Vroomen).

The Static Model

We assume that farmers are risk neutral and that they choose input levels by maximizing expected profits. This means that

$$\max_X E[Pf(X'; \epsilon) - R'X], \quad (1)$$

where E is the expectation operator conditional on information currently available to the farmers, P is output price, $f(X'; \epsilon)$ is the production function, X is a column vector of inputs, ϵ is a random component, and R is a column vector of input prices. If the farmer knows input prices when inputs are chosen and if expected output price is uncorrelated with ϵ , then the first-order conditions imply that a farmer chooses inputs to the point where the expected marginal product is equal to the expected real input price. Given that the second-order conditions are satisfied, solving these first-order conditions for the fertilizer nutrient demands yields:

$$X = g[R', E(P)]. \quad (2)$$

Since equation 2 is homogenous of degree zero, X can equivalently be written as:

$$X = h(Z), \quad (3)$$

where Z is the row vector of input prices relative to expected output price.

In addition to own-price, the prices of all substitute and complementary inputs should, theoretically, be included in such a model. However, a high degree of multicollinearity and a lack of available data do not permit individual inclusion of all the relevant variables into equation 3. In fact, past fertilizer demand studies frequently omit the prices of most substitutes and complements. For example, Carman includes the price of land as

the only potential substitute for fertilizer, while Roberts includes only the price of jointly applied nutrients. Similarly, Roberts and Heady do not include any substitutes or complements in their model and assume that the inclusion of a time trend will capture the influence of several correlated variables.

We take a somewhat different approach. We include land as a potential substitute because it was shown to affect fertilizer demand in previous studies (Rausser and Moriak, and Carman). *Land* Other substitutes and complements are captured by one summary variable, the index of prices paid by farmers for production items, interest, taxes, and wage rates. Thus, Z , the row vector of relative input prices becomes $[Z_f, Z_l, Z_o]$, where Z_f is the fertilizer nutrients own price, Z_l is the rental rate of land, and Z_o is the index of other input prices, where all Z 's are deflated by the expected corn price.

It is this type of static model (equation 2 or 3 or some variant thereof that includes other exogenous shifters) that has been estimated in most previous studies. Equations such as 3 implicitly assume that adjustments toward equilibrium are instantaneous, leaving no room for quantity demanded to diverge from longrun equilibrium levels. In reality, however, equilibrium values are not observable, and available data summarize the forces that are involved in a dynamic process of convergence toward equilibrium. In other words, the demand response to a change in any of the relative input prices is dispersed over more than just one period, giving rise to shortrun and longrun own- and cross-price elasticities.¹

Dynamics of Convergence

Earlier methods of dynamic modeling owe their origin to work by Koyck. To our knowledge, the only dynamic fertilizer demand studies were formulated using Koyck's framework (Griliches, 1958 and 1959; Gunjal and others). Recent advances in cointegration by Engle and Granger, however, provide the tools for application of error correction models, first suggested by Sargan, that explicitly incorporate the dynamics of shortrun adjustment toward longrun equilibrium.

To allow convergence to longrun equilibrium, a definition for longrun equilibrium and some sort of dynamics are needed. The usual practice, in the context of our analysis, is to assume that fertilizer demand follows a geometric lag distribution in the shortrun, that is, a partial adjustment process, which works its way in the longrun toward some steady-state growth rate. Adopting this adjustment process, along with the steady-state notion of longrun equilibrium, allows for construction of a model

¹The idea that adjustments are not instantaneous is not new. For a crystalline expression of reasons for dynamic modeling, see Scitovsky.

that corrects at time t for the previous period's deviation of the observed value from its equilibrium.

To illustrate, let the functional form of equation 3, describing the relationship in the steady state, be:

$$X = K Z_f^{v_f} Z_1^{v_1} Z_0^{v_0}. \quad (4)$$

Equation 4, which represents the stable longrun relationship (Engle and Granger), assumes that the longrun demand function is linear in the logarithms of the variables; that is.²

$$x = v_1 + zv, \quad (5)$$

where x is the logarithm of fertilizer demand; v_1 is the logarithm of the intercept, K , in equation 4; z is the row vector $[z_f, z_1, z_0]$ containing the logarithms of Z 's; and v is the column vector $[v_f, v_1, v_0]'$ made up of the longrun price elasticities. Further, let us assume an AR(1)-type process for the shortrun dynamics of x , so that it can be represented by:

$$x_t = \alpha x_{t-1} + \mu + z\theta + \xi \text{ and } |\alpha| < 1, \quad (6)$$

where μ is the intercept, θ is a column vector of shortrun price elasticities, and ξ is a serially uncorrelated error term with a constant variance and zero mean.

Given the shortrun dynamic model 6, the steady-state solution can be obtained when longrun equilibrium is defined as a dynamic steady state in which all equilibrium values grow at a constant rate. To see this, rearrange equation 6 by subtracting x_{t-1} from both sides and adding and subtracting $z_{t-1}\theta$ on the right side to obtain:

$$g_x = \mu + g_z\theta + (\alpha-1) [x_{t-1} - (1-\alpha)^{-1}z_{t-1}\theta] + \xi, \quad (7)$$

where g_x is the rate of consumption growth and g_z is the row vector of growth rates of the variables in z . The term inside the brackets in equation 7 provides the error correction mechanism. If the demand, x , rises above its longrun equilibrium level at time $t-1$, the term in the brackets becomes positive. However, because $(\alpha-1)$ is negative, its effect at time t is to reduce the growth rate of the observed x toward its steady-state path. For this reason, equation 7 is referred to as an error correction model.

Longrun elasticities can be derived from the estimated parameters of equation 7. Note that in steady state, x and z must satisfy the linear logarithmic relationship of equation 5. This is

²The necessary and sufficient condition for the demand function to be log-linear is the existence of a Cobb-Douglas production function with constant returns to scale.

reflected in the term inside the brackets in equation 7. Comparing equation 5 with this term reveals the restriction that:

$$v = (1-\alpha)^{-1}\theta, \quad (8)$$

which makes the relationship between the parameters of the model and the longrun elasticities explicit. Similarly, v_1 can be derived from equation 7. Suppressing the error term, setting the term inside the bracket to v_1 , and substituting g_2v for g_x yields:

$$v_1 = (1-\alpha)^{-1}[\mu + g_2(\theta - v)]. \quad (9)$$

Empirical Analysis

How can equation 7 be estimated? In some instances, prior economic knowledge provides values for the longrun elasticities, v . In these instances, the error correction term can be calculated, and equation 7 can then be easily estimated as in Davidson and others. In our case, however, no concrete information exists a priori. Fortunately, work by Engle and Granger in cointegration and error correction models provides an estimation procedure. Equation 5, referred to as a cointegrating equation, represents a stable longrun relationship if the variables are cointegrated; that is, if the nonstationary variables in the equation are integrated of the same order and the residual error is a stationary white noise process.³ As Engle and Granger, and Stock, demonstrate, least squares estimators of regressing x on z are super consistent and efficient if equation 5 is cointegrated, in which case the residuals from this equation can be used in place of the error correction term in equation 7 to proceed with the estimation. Engle and Granger show that least squares estimators of equation 7 are then consistent and efficient.

Data Description

Annual data for 1964-89 are used to estimate fertilizer nutrient demand functions for corn. This period was determined by the availability of fertilizer application rate data specific to U.S. corn production. Nutrient application rates for 1964-88 were taken from Vroomen, while data for 1989 were obtained from the Department of Agriculture's (USDA) Agricultural Resources: Inputs Situation and Outlook Report. Fertilizer price data are for May (1977-85) and April (1964-76; 1986-89) and were obtained from USDA's Agricultural Prices. The price of nitrogen is a weighted national average of the prices of anhydrous ammonia, urea, ammonium nitrate, ammonium sulfate, and nitrogen solutions. The

³A variable is integrated of order d , $I(d)$, if its d th difference is a stationary, invertible, nondeterministic autoregressive moving average process. A variable integrated of degree zero is therefore stationary in its level; that is, a white noise process.

phosphate and potash prices are, respectively, the prices of concentrated superphosphate and potassium chloride.

Tegene and Kuchler report cropland rents for the Lake States, Corn Belt, and Northern Plains, the principal corn-producing regions. These rents were weighted by planted corn acres to construct a rental rate for land in corn production. The index of prices paid by farmers for production items, interest, taxes, and wage rates was taken from annual issues of Agricultural Prices. Finally, the futures price at planting is used as a proxy for the expected corn price. The March price of a December contract on the Chicago Board of Trade (Statistical Annual) was averaged over March to reduce short-term price fluctuations.

Unit Root and Cointegration Tests

To identify the order of integration of the time series, Dickey and Fuller unit root tests are applied. The procedure requires the following regression:

$$\Delta y_t = \alpha + \beta t + (\rho - 1) y_{t-1} + \sum_{i=1}^m \rho_i \Delta y_{t-i} + e_t, \quad (10)$$

where y is the variable under consideration, Δy_{t-i} is the first difference of the observation at time $t-i$, and m is the number of lags that ensures the error term, e_t , is white noise. The null hypothesis for a unit root requires that $\rho = 1$, indicating that the variable y is nonstationary; that is, its variance will explode in time.⁴ The statistic used, τ_τ , is the usual t statistic calculated under the null hypothesis. However, it is not distributed as the standard studentized t (Fuller calculates the point distribution). If τ_τ favors the existence of a unit root, one might also test whether the mean is a function of time and/or a drift exists. Dickey and Fuller provide the appropriate statistics (ϕ_3 , ϕ_2 , ϕ_1 , $\tau_{\alpha\mu}$, τ_μ , and τ) and their point distributions. The statistic ϕ_3 tests the null that a unit root exists jointly with no deterministic linear time trend, that is, $\beta = 0$, while ϕ_2 tests the null that a unit root exists jointly without a linear time trend and no drift. If ϕ_3 supports its null hypothesis but ϕ_2 does not, then the presence of a drift is suspected. In this case, the test statistic $\tau_{\alpha\mu}$ for the difference model can be used to confirm the existence of the drift. On the other hand, if both ϕ_3 and ϕ_2 sustain their null hypotheses, then the statistics ϕ_1 , τ_μ , and $\tau_{\alpha\mu}$ for model 10 without the deterministic time trend and the statistic τ for model 10 without the drift and time trend are used to confirm

⁴Strictly speaking, if the alternative hypothesis cannot be rejected, certain additional conditions are needed for z_t to be stationary. For a simple exposition, see Dickey and others (appendix A).

that y is a nonstationary process without a drift and a time trend.

If a unit root is detected, it is possible that a second unit root exists, as equation 10 has m characteristic roots. In this case, application of the Dickey-Fuller test to the first difference of a variable will test for the possible existence of a second unit root. Upon finding a second unit root, the procedure is continued until the order of integration, that is, the appropriate number of differences to achieve stationarity, is identified. In practice, the exact order of the autoregression, m , is not known. Engle and Yoo suggest using the Akaike information criterion, which determines the order of autoregression by estimating equation 10 over a selected grid of values of m . The optimum lag is one that attains the minimum of the criterion. Application of this procedure indicated that the rates of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) applied to corn, as well as all real input prices, are generated by AR(1) processes.⁵ Further tests for an additional lag indicated that AR(1) was sufficient to represent these processes.⁶ This means that for all variables there could be only one unit root, and the maximum order of integration is one.

Results were similar for all three nutrient application rates (table 1). Further, various tests were consistent across these rates. The null hypotheses of τ_τ , ϕ_3 , and ϕ_2 could not be accepted at the 1-percent significance level, signifying that the variables are level stationary. Therefore, the levels of these variables depict stationary processes around a time trend, which explains why time has been significant in static models using a linear trend as a proxy for technological advancement.

The outcome was also similar for all real input prices. Based on τ_τ , the null hypothesis of a unit root could not be rejected at the 10-percent significance level for all variables but PPr, which was nonstationary at the 5-percent level. Consistent with τ_τ and one another, ϕ_3 and ϕ_2 favored the existence of a unit root even at the 10-percent level, indicating that all prices contain a unit root and have no deterministic time trend or a drift. Subsequent tests confirmed these results. Under the assumption of an AR(1) process without a time trend, the null hypothesis of ϕ_1 , that a unit root exists without a drift, also could not be rejected at the 10-percent level. $\tau_{a\mu}$ and τ_μ verified these results. The $\tau_{a\mu}$ (a 2-sided test) sustained its null of no drift for all variables at the 10-percent level with critical values of

⁵These findings are also consistent with the behaviors of autocorrelation and partial autocorrelation functions.

⁶The test is based on Fuller's proof (1976, ch. 8) that while limit distributions of OLS estimators of α , β , and ρ are not normal, although consistent, distribution of such estimators for ρ_i 's converge in the limit to a multivariate normal. Consequently, an ordinary t-test can be used to test for possible existence of an additional lag.

Table 1--Unit root tests for the levels¹

Test	N	P ₂ O ₅	K ₂ O	NPr	PPr	KPr	LPr	OPr
τ_τ^2	-4.61	-4.61	-5.59	-2.84	-3.52	-2.60	-2.95	-2.64
ϕ_3^3	18.30	16.77	25.21	4.41	6.26	3.70	4.57	3.51
ϕ_2^3	15.62	11.91	20.50	2.96	4.21	2.54	3.25	2.49
ϕ_1^3	--	--	--	3.12	2.36	1.35	2.19	1.31
$\tau_{\alpha\mu}$	--	--	--	2.46	2.17	1.63	2.02	1.53
τ_μ^2	--	--	--	-2.49	-2.15	-1.59	-1.97	-1.49
τ^2	--	--	--	-.43	.09	.19	.51	.50

-- = Not applicable.

¹All variables are in natural logarithms for the 1964-89 period.

²The asymptotic critical values at the 1-, 5-, and 10-percent levels of significance are respectively 4.38, -3.6, and -3.24 for τ_τ ; -3.75, -3.0, and -2.63 τ_μ ; and -2.66, -1.95, and -1.6 for τ (Fuller, p. 373).

³The asymptotic critical values at 1- and 10-percent significance levels are respectively 10.61 and 5.91 for ϕ_3 ; 8.21 and 4.67 for ϕ_2 ; and 7.88 and 4.12 for ϕ_1 (Dickey and Fuller).

± 2.61 . τ_μ favored the existence of a unit root even at the 10-percent level. Finally, model 10 under the assumptions of an AR(1) process without the time trend and with no drift was estimated. The τ test indicated that with probability of at least 90 percent, prices contain a unit root. The price levels are, therefore, nonstationary processes without a linear trend and no drift. That is, they are trendless random walks and therefore I(1). Thus, their first differences are stationary, I(0).⁷

Since the nonstationary variables are integrated of the same order, residual errors of the cointegrating equations were then examined to see if they are stationary in their levels; if they are, the variables are cointegrated. As Roberts and Heady found, nutrient application rates across a particular crop are correlated. Because nutrients are often applied jointly in the form of mixed fertilizers, a nonoptimal quantity of nitrogen applied per acre is likely to be associated with a nonoptimal

⁷To ensure that the processes are not I(2), the tests were also applied to the first differences. In all cases, the null hypothesis of a second unit root could not be accepted at the 1-percent significance level.

rate of other nutrients applied. Consequently, to improve the efficiency of the estimators, seemingly unrelated regression was used to estimate the cointegrating equations.

Using the same Dickey-Fuller tests described above, the possible existence of a unit root in the estimated residuals was examined. Neither of the residuals contained a drift or a time trend. The calculated statistics for τ were -3.89, -4.87, and -4.22 for the N, P₂O₅, and K₂O equations, respectively, confirming with 99-percent probability that the residual errors of the cointegrating equations are I(0).⁸ Given that the variables are cointegrated, the estimators are consistent and efficient.⁹ Consequently, the estimated residuals can be treated as the distance that the system is away from the equilibrium defined by equation 5.

Error Correction Models

The previous section presented evidence that fertilizer nutrient application rates on corn are cointegrated with their own price, land rental rates, and an index of other input prices. This implies that there exists an error correction model that represents the dynamics involved (Engle and Granger). As demonstrated above, the dynamic model would relate the rate of growth of the nutrient application rates to past deviations from equilibrium as well as to the rates of growth of the other variables. Substituting the estimated residuals of the cointegrating equations for the deviations of application rates from their equilibrium levels, a system of three error correction equations was estimated using SUR (table 2).

Durbin-Watson statistics are indicative of no autocorrelation and R-squares are high for a percentage change equation. All coefficients, with the exception of the constant in the P₂O₅ equation, are significant at the 5-percent level or less. The error-correcting terms and the own-price elasticities have the expected negative signs. Land and fertilizer are substitutes, consistent with other studies, while other inputs, as a group, were found to be complements.

⁸As Hall warns, because residuals are estimated, Fuller (1976) and Dickey and Fuller critical values should be used with care. The true critical values depend on the number of variables in the cointegrating equation as well as the sample size. These critical values exist only for τ_{μ} and τ for up to 5 variables and a minimum of 50 observations (Engle and Yoo). In our case, the limited availability of application rate data restricted our expanding of the sample to take advantage of Engle and Yoo's table.

⁹Technically speaking, for a set of cointegrated variables, the residual error of regressing any of the variables on the rest of the variables must be I(0). Across fertilizer nutrients, statistical evidence of a unit root was not found at the 5-percent level in any of the nine residual errors.

Laura,

The staff report you are looking at is an earlier version of the work. The much-improved version was published in the AJAE, 75 (Feb 1993): 203-209. There you will find that the elasticity is you referred to is -0.25 in the short run and -0.37 in the long run.

Mark

Table 2--Estimated elasticities of error-correction models

Variables	Nitrogen		Phosphate		Potash	
	SR	LR	SR	LR	SR	LR
Constant	0.02 (2.18)	--	0.01 (1.19)	--	0.03 (2.56)	--
Own price	-.23 (-4.56)	-.48	-.02 (-3.37)	-.30	-.16 (-2.08)	-0.27
Land price	.90 (4.87)	1.83	.61 (3.29)	.92	.89 (4.51)	1.49
Other input price	-.56 (-3.19)	-1.13	-.43 (-2.37)	-.65	-.65 (-3.30)	-1.08
Error correction term	-.49 (-4.76)	--	-.66 (-5.08)	--	-.60 (-7.21)	--
R-squares ²	0.72		0.66		0.73	
Durbin-Watson	1.72		2.12		1.89	
F statistic	8248		4684		6934	

SR = short run; and, LR = long run.

-- = Not applicable.

¹Numbers in parentheses are t statistics.

²Reported R-squares are from the first stage regressions (OLS) and do not take into account the additional restrictions imposed by SUR estimation.

Fertilizer nutrient application rates for corn are very inelastic, both in the short run and the long run. This is in direct contrast to the results of Roberts and Heady who found the rates of N, P₂O₅, and K₂O applied to corn to be price elastic. Unlike the elasticities estimated by Roberts and Heady, the dynamic model suggests that a fertilizer tax would be of only limited effectiveness in reducing the rates of fertilizer applied to corn. For example, even a 20-percent fertilizer tax would reduce the rate of N, P₂O₅, and K₂O applications by only 4.6, 4.0, and 3.2 percent, respectively, in the short run. Even in the long run, such a tax would result in only 9.6, 6.0, and 4.7 percent reductions, respectively.

Thus, while a tax on fertilizer use may be relatively easy to implement, other strategies such as "best-management" practices may be necessary to achieve significant environmental benefits.

Land values are higher in the presence of price supports for program crops because the program benefits tend to be capitalized into land values (Offutt and Shoemaker, 1988 and 1990;

Shoemaker). Offutt and Shoemaker (1988) and Shoemaker report that U.S. acreage reduction programs have supported land values by an estimated 7 percent above what they would have been in the free market. Applying this estimate to the cross-price elasticities for land in table 2 suggests that, in the absence of acreage reduction programs, the rate of N applied to corn would have been 6.3 percent lower in the short run and 12.8 percent lower in the long run. Similarly, application rates of P_2O_5 and K_2O would have been lower under this scenario, although by a lesser extent.

Conclusions

Concerns over water quality have raised the possibility of various policies, such as a tax on fertilizer, to reduce the use of water-contaminating nutrients in agriculture. An important piece of information needed to assess the effectiveness of potential tax policies is the price elasticities of fertilizer nutrient demands. Most earlier elasticity estimates have been based on static models that often resulted in low Durbin-Watson statistics and relatively high R^2 's, indicating that the models may be dynamically misspecified. This article builds on previous fertilizer demand studies by developing a dynamic model of nutrient application rates for corn, which accounts for nearly half of total U.S. fertilizer nutrient use. Using cointegration techniques, we estimate an error-correcting model for the rates of nitrogen, phosphate, and potash applied to corn for the period 1964-89.

NoxC) Results indicate that fertilizer nutrient application rates for corn are very inelastic, both in the short and the long run. This is in direct contrast to the results of Roberts and Heady who found the demand for nitrogen, phosphate, and potash applied to corn to be price elastic. Estimated elasticities indicate that a tax on fertilizer would be of only limited effectiveness in reducing nutrient application rates, at least for corn. Thus, while a tax on fertilizer may be relatively easy to implement, other strategies such as "best-management" practices may be necessary to achieve significant environmental benefits.

References

- Carman, H.F. "The Demand for Nitrogen, Phosphorous, and Potash Fertilizer Nutrients in the Western United States," Western Journal of Agricultural Economics, 4 (1979): 23-31.
- Chicago Board of Trade. Statistical Annual. Selected issues, 1964-89.
- Davidson, J., D. Hendry, F. Srba, and S. Yeo. "Economic Modelling of Aggregate Time Series Relationship Between Consumer's Expenditure and Income in the United Kingdom," Economic Journal, 88 (1978): 661-92.
- Dickey, D.A., and W.A. Fuller. "Likelihood Ration Statistics for Autoregressive Time Series with Unit Roots," Econometrica, 49 (1981): 1057-72.
- Dickey, D.A., W.R. Bell, and R.B. Miller. "Unit Roots in Time Series Models: Tests and Implications," American Statistician, Feb. (1986): 12-26.
- Engle, R.F., and C.W.J. Granger. "Cointegration and Error Correction: Representation, Estimation, and Testing," Econometrica, 55 (1987): 251-76.
- Engle, R.F., and B.S. Yoo. "Forecasting and Testing in Co-integrated Systems," Journal of Econometrics, 35 (1987): 143-59.
- Fuller, W.A. Introduction to Statistical Time Series. New York: John Wiley & Sons, 1976.
- Griliches, Z. "An Economic Interpretation of a Technical Change," Journal of Farm Economics, 40 (1958): 591-606.
- _____. "Distributed Lags, Disaggregation, and Regional Demand Functions for Fertilizer," Journal of Farm Economics, 41 (1959): 90-102.
- Gunjal, K.R., R.K. Roberts, and E.O. Heady. "Fertilizer Demand Functions for Five Crops in the United States," Southern Journal of Agricultural Economics, 12, 2 (1980): 111-16.
- Gyawu, E.A., L.D. Jones, D.L. Debertin, and A. Pagoulatos. An Econometric Analysis of the U.S. Fertilizer Industry. Agricultural Economics Research Report 39, Univ. of Kentucky Agricultural Experiment Station, 1984.
- Heady, E.O., and M.H. Yeh. "National and Regional Demand Functions for Fertilizer," Journal of Farm Economics, 41 (1959): 332-48.
- Hendry, D.F., and G.E. Mizon. "Serial Correlation as a Convenient Simplification, not a Nuisance: A Comment on a Study of the Demand for Money by the Bank of England," Economic Journal, 88 (1978): 549-63.

- Koyck, L.M. Distributed Lags and Investment Analysis.
Amsterdam, Holland: North Holland Publishing Co., 1954.
- Offutt, S., and R. Shoemaker. "Agricultural Land, Technology and Farm Policy," Journal of Agricultural Economics, 41 (1990): 1-8.
- Offutt, S., and R. Shoemaker. Farm Programs Slow Technology-Induced Decline in Land's Importance. TB-1745. U.S. Dept. Agri., Econ. Res. Serv., May 1980.
- Rausser, G.C., and T.F. Moriak. "The Demand for Fertilizer, 1949-64: An Analysis of Coefficients from Periodic Cross Sections," Agricultural Economics Research, 22 (1970): 45-56.
- Roberts, R.K. "Plant Nutrient Demand Functions for Tennessee With Prices of Jointly Applied Nutrients," Southern Journal of Agricultural Economics, 1 (1986): 107-12.
- Roberts, R.K., and E.O. Heady. "Fertilizer Demand Functions for Specific Nutrients Applied to Three Major U.S. Crops," Western Journal of Agricultural Economics, 7 (1982): 265-77.
- Sargan, J.D. "Wages and Prices in the United Kingdom: A Study in Econometrics Methodology," Econometric Analysis for National Economic Planning. Harts, Mills, and Whitaker, eds. London: Butterworth, 1964, pp. 22-54.
- Scitovsky, T. Welfare and Competition: The Economics of Fully Employed Economy. Chicago: R.D. Irwin, 1951, pp. 48-49.
- Shoemaker, R. How Technological Progress and Government Programs Influence Agricultural Land Values. AIB-582. U.S. Dept. Agri., Econ. Res. Serv., Jan. 1990.
- Stock, J.H. "Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors," Econometrica, 55 (1987): 1035-45.
- Tegene, A., and F. Kuchler. The Contribution of Speculative Bubbles to Farmland Prices. TB-782. U.S. Dept. Agri., Econ. Res. Serv., July 1990.
- U.S. Department of Agriculture, Economic Research Service. Agricultural Resources: Inputs Situation and Outlook Report. AR-17. Feb. 1990.
- _____, National Agricultural Statistics Service. Agricultural Prices. Various annual summaries, 1964-88.
- Vroomen, H. Fertilizer Use and Price Statistics, 1960-88. SB-780. U.S. Dept. Agri., Econ. Res. Serv., June 1989.

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