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The Demand for Nitrogen Fertilizers in the West

by

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ABSTRACT

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Demand equations for nitrogen in the 11 Western states are estimated with two alternative models. The results are acceptable from both an economic and statistical viewpoint. The demand for nitrogen is price inelastic in most states, especially in the short-run. Nitrogen demand has demonstrated strong growth through time.

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Introduction

Applications of commercial fertilizers in the 11 Western states have increased dramatically since 1955. In 1976 total fertilizer sales in these states was reported at 2,152,000 tons, up 305 percent from the 530,000 tons sold in 1955. The largest increase was for nitrogen which increased 326 percent from 340,300 tons to 1,450,300 tons. Nitrogen now accounts for over two-thirds of commercial fertilizer sales in the West.

Apparent fertilizer shortages in 1973 and 1974 accompanied by sharply increased prices raised serious questions concerning the adequacy of future fertilizer supplies and the nature of fertilizer demand. Fertilizer was the subject of a number of hearings and special reports.[1/] A combination of factors contributed to the sharp increase in both foreign and domestic demand with the most important being the worldwide surge in commodity prices and the accompanying increase in crop acreage. At the same time the costs of producing and transporting nitrogen fertilizers increased sharply due to increased prices for natural gas, oil and other energy forms. Increases in the productive capacity of fertilizer plants moderated price increases but it is highly unlikely that prices will decrease to levels observed from 1970 to 1972.

Western farmers, public officials and others continue to be concerned about the future availability and demands for nitrogen fertilizers and other inputs. There has been little detailed information available on which to base assessments of likely future occurrences. This paper attempts to partially alleviate this situation by presenting the results of a state-by-state study of the aggregate demand for nitrogen fertilizer.

The Demand for Nitrogen

The demand for production inputs is a derived demand based on the demand for the final product. Economic theory suggests that the quantity of nitrogen fertilizer used will be a function of expected output prices, the price of nitrogen fertilizer, prices of related inputs, the productivity of nitrogen and related inputs, and knowledge of fertilizer practices.

Previous Work

Models of both national and regional demand for fertilizer have been estimated in a number of empirical studies. A partial list includes reports by Griliches [1958, 1959], Heady and Yeh [1959], Brake, King and Riggan [1960], and Rausser and Moriak [1970]. The models specified in these studies exhibit many similarities and some differences. The dependent variable has most often been specified as total fertilizer use for a region or for the United States. Griliches [1958] deflated total plant nutrient use by an index of cropland acreage while Rausser and Moriak [1970] employed total nutrient use per acre as their quantity variable. Only Heady and Yeh [1959] examined the demand for the individual major nutrients (N, P, K). The variables affecting quantity demanded have included fertilizer prices, crop prices, total cash receipts from crops, total crop acreage, acres of specified crops, cash rent, wage rates, wholesale price index, and time. Each of the models was estimated by single equation methods on the assumption that prices of fertilizer, other inputs, and output prices can be regarded as predetermined at the time the purchase decision is made. Each study concentrated on estimating functions specified as linear in logarithms.

Model

Nitrogen use in the Western states is hypothesized to be a function of the price of nitrogen, lagged crop income, crop acreage, and time. To test this hypothesis, two alternative functional relationships were specified. The two relationships differ only in their treatment of shifts in demand through time.

The first set of demand equations (model 1) includes time as an independent variable. The equation estimated for each state is:

$$\ln Q = a_0 + a_1 \ln P + a_2 \ln Y_{t-1} + a_3 \ln T + \mu \qquad (1)$$

where Q is pounds of nitrogen sold divided by total crop acreage, P is a nitrogen price index (1967 = 100), Y_{t-1} is gross crop income divided by total crop acreage lagged one year, T is time with 1955 = 1, ..., 1976 = 22, and μ is the error term. The advantage of this specification is that it provides an explicit estimate of shifts in demand through time occurring as a result of such things as technology, increased irrigation, and improved knowledge. It has a potential problem of autoregressive disturbances.

The second set of demand equations (model 2) utilizes Griliches' [1958, 1959] simple distributed lag model to measure adjustments through time.[2/] The equation estimated is of the form:

$$\ln Q = ba_0 + ba_1 \ln P + ba_2 \ln Y_{t-1} + (1 - b) \ln Q_{t-1} + \mu \qquad (2)$$

where the variables are as defined above and b is the adjustment coefficient. The adjustment coefficient indicates the proportion of the difference between desired use for the present year (year t) and actual use of the previous year (year t-1) to which farmers adjust. Griliches [1958, p. 603] points out that the lagged value of the dependent variable plays the same role as a trend variable. His model recognizes the fact that changes in the dependent variable are not independent from what has happened before and, thus, it provides an economic interpretation of why there should be serial correlation in the variables.

The quantity of nitrogen sold per acre is expected to vary inversely with the price of nitrogen and to vary directly with expected gross crop income. Since expectations cannot be observed, but are based on recent experience, gross crop income per acre lagged one year is used to capture this effect. The coefficient for time should be positive due to increasing levels of nitrogen use through time as a result of new crop varieties, increased irrigation, improved knowledge, and technology. Total nitrogen sales are the product of per acre sales and total crop acreage.

Data

Annual nitrogen sales by state are from annual issues of Agricultural Statistics with recent data coming from annual issues of Commercial Fertilizers, Consumption in the United States. The nitrogen price index is for available N based on the price of ammonia sulphate. Price data are from Agricultural Prices, Annual Summary. Crop acreage and total cash receipts from crops are from annual issues of Agricultural Statistics.[3/] All of the cited publications are published by the U.S. Department of Agriculture.

Results

Two sets of demand equations based on models (1) and (2) were estimated using ordinary least squares. The results are shown in Tables 1 and 2.

The results of estimating model (1) are generally in line with expectations (Table 1). The signs on the coefficients for the price index (P) and lagged per acre crop income (Y_{t-1}) are as expected with the exception of Colorado, Nevada and New Mexico. The t-statistics for these variables in these three states are small, indicating that the estimated coefficients are not significantly different than zero. Note that the estimated price and lagged crop income coefficients are statistically significant at the five percent level only in California, Oregon and Utah. The coefficients on the time variable (T) are positive and statistically significant reflecting the growth in demand for nitrogen through time. The size of the coefficient on

TABLE 1

Regression Coefficients and Related Statistics for Nitrogen Fertilizer Demand Model (1), Eleven Western States, 1955-1976[a/]

State	Variables				R^2	d[b/]
	Constant	lnP	$\ln Y_{t-1}$	lnT		
	---coefficients---					
Arizona	3.946 (5.353)[c/]	-.142 (-.895)	.062 (.253)	.525 (8.493)	.938	.866
California	1.968 (8.506)	-.245 (-3.058)	.556 (6.199)	.243 (5.407)	.983	2.120
Colorado	-.970 (-1.199)	.298 (.829)	-.109 (-.311)	1.178 (8.852)	.966	1.179
Idaho	.812 (1.629)	-.137 (-.634)	.226 (1.118)	.939 (10.093)	.981	2.472
Montana	1.901 (.760)	-1.181 (-1.619)	.752 (1.714)	1.102 (6.907)	.886	.667
Nevada	.408 (.573)	.043 (.181)	-.175 (-.811)	.962 (8.684)	.963	1.211
New Mexico	2.336 (3.082)	.280 (1.416)	-.512 (-1.779)	.931 (11.157)	.935	1.891
Oregon	2.850 (6.594)	-.740 (-3.745)	.789 (4.302)	.359 (4.845)	.959	1.807
Utah	.694 (1.255)	-.552 (-2.234)	1.106 (3.906)	.382 (4.113)	.948	2.318
Washington	2.849 (7.368)	-.198 (-1.214)	.114 (.778)	.637 (10.540)	.966	2.494
Wyoming	.341 (.220)	-.464 (-.892)	.479 (1.143)	1.128 (8.114)	.939	.817

a/ The dependent variable (Q) is total nitrogen sales divided by total crop acreage.

b/ "d" is the Durbin-Watson statistic. The critical values at the five percent level of significance are: $d_L = 1.05$, $d_u = 1.66$.

c/ Figures in parentheses are t-statistics.

TABLE 2

Regression Coefficients and Related Statistics for Nitrogen Fertilizer Demand Model (2), Eleven Western States, 1955-1976[a/]

State	Variables				R^2	b	a_1
	Constant	lnP	$\ln Y_{t-1}$	$\ln Q_{t-1}$			
	---coefficients---						
Arizona	.866 (2.069)[b/]	-.181 (-1.463)	.111 (.585)	.878 (10.950)	.960	.122	-1.48
California	.469 (1.570)	-.096 (-.812)	.137 (.708)	.833 (4.584)	.979	.167	-.57
Colorado	.190 (.309)	.044 (.159)	-.032 (-.114)	.944 (10.863)	.976	.056	*[c/]
Idaho	1.184 (1.097)	-.595 (-1.246)	.607 (1.240)	.706 (3.252)	.919	.294	-2.02
Montana	1.309 (.752)	-.256 (-.468)	.052 (.153)	.904 (10.760)	.945	.096	-2.67
Nevada	.457 (.607)	.002 (.009)	.044 (.214)	.775 (8.092)	.958	.225	*
New Mexico	.318 (.385)	-.081 (-.356)	.130 (.425)	.876 (8.923)	.904	.124	-.65
Oregon	1.441 (1.867)	-.565 (-1.775)	.581 (1.785)	.623 (3.222)	.939	.377	-1.50
Utah	.706 (1.144)	-.659 (-2.444)	1.042 (2.870)	.535 (3.287)	.936	.465	-1.42
Washington	1.108 (1.510)	-.242 (-.881)	.144 (.560)	.848 (5.711)	.912	.152	-1.59
Wyoming	-.177 (-.175)	.325 (.878)	-.391 (-1.238)	.988 (13.315)	.974	.012	*

a/ The dependent variable (Q) is total nitrogen sales divided by total crop acreage.

b/ Figures in parentheses are t-statistics.

c/ A long-run elasticity was not calculated because the coefficient was positive and not significantly different than zero.

time tends to vary inversely with the 1976 level of per acre nitrogen sales. The R^2 values are comparatively high, indicating that the variables included account for most of the variation in per acre sales of nitrogen. The Durbin-Watson statistic indicates a problem of positive autocorrelation in the equations for Arizona, Montana, and Wyoming.

The results of estimating model (2) are consistent with those for model (1) (Table 2). The signs on the coefficients for price and lagged income are identical except for the lagged income coefficient for Nevada, New Mexico and Wyoming and the price coefficient for New Mexico and Wyoming. Only the coefficients for Utah are significantly different than zero. The coefficients on the lagged dependent variable (Q_{t-1}) are positive and all are statistically significant. The R^2 values for model (2) are all greater than .90 and the R^2 values for Arizona, Colorado, Montana and Wyoming are greater than for model (1).

Since the equations were estimated as linear in logarithms, the coefficients can be interpreted as elasticities. In Table 1 the estimated elasticities for nitrogen price are quite inelastic except for Montana. This indicates little response to nitrogen price changes. The short-run price elasticities in Table 2, the coefficient ba_1 for lnP, are quite inelastic. The long-run estimated price elasticities, the values for a_1, are more elastic with six of the 11 being elastic in the long-run.

Griliches [1959, pp. 99-100] stated two hypotheses which tend to apply to the results shown in Table 1 and 2. His first hypothesis states "that the more experience people have had with fertilizer the faster they will adjust to price changes. That is, areas with a long history of fertilizer use, widespread fertilizer use and high levels of fertilization will have higher adjustment coefficients (b)." His second hypothesis is "that the demand for fertilizer is more price elastic, in the long-run, in regions with low levels of fertilizer use." Griliches bases the second hypothesis on the idea of a ceiling level of use, and observes that regions with low use are farther away from their ceilings and can respond more to price changes.

Conclusions

The demand for nitrogen in the 11 Western states appears to be price inelastic in the short-run but with more elastic demand in the long-run. There has been a strong positive growth in the demand for nitrogen through time. This growth can be expected to continue but at a decreasing rate as the levels of nitrogen use increase.

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Footnotes

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1/ For examples see U.S. Senate [1974], Bell, et al. [1974], and Reidinger [1976].

2/ Griliches [1959, p. 91] begins with the equation:

$$\ln Q_t^* = a_0 + a_1 \ln P_t + a_2 \ln Y_{t-1} + \mu_t$$

where Q_t^* is the "desired" or "equilibrium" level of use. He then specifies an adjustment equation:

$$\ln Q_t - \ln Q_{t-1} = b(\ln Q_t^* - \ln Q_{t-1}) \qquad 0 < b < 1$$

where Q_t is actual use and b is the adjustment coefficient. Substituting the equation for desired use into the adjustment equation and solving for $\ln Q_t$ yields equation (2).

3/ Note that the crop acreage data do not include acreage of tree and vine crops. The impact of this omission is minor since tree and vine crop acreage varies slowly. For a comparison when tree and vine crop acreage is included see Carman and Heaton [pp. 37-39].

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