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Vol XX
No. 3

JULY-
SEPTEMBER
1965

ISSN 0019-5014

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

DEMAND FOR NITROGENOUS FERTILISERS : AN ECONOMETRIC STUDY

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The consumption of nitrogenous fertilisers[1] has increased at an annual average rate of 80 per cent during the decade 1951-61. The increase in the consumption of nitrogenous fertilisers indicates the increasing use of nitrogen to various food and non-food crops. The objective of this paper is to identify and measure the quantitative significance of the factors, region-wise and all-India-wise, that were responsible for such a rapid rise in consumption during the period 1951-61. This study will be an aid to planning future production of nitrogenous fertilisers in India.

It is well-known that irrigation or adequate rainfall is a precondition to the economic use of nitrogenous fertilisers. This suggests that available irrigation facilities is an important factor in explaining the increasing consumption of nitrogenous fertilisers. In addition, the consumption is likely to depend on the prices paid for nitrogenous fertilisers in relation to prices received by the farmers for the product. Another important factor is the extension of knowledge among farmers about the use of fertilisers. In order to represent such a phenomenon, the expenditure on demonstration programme will be the most appropriate variable but in the absence of suitable data, a time-trend variable is used. It is often the practice in econometric analysis to use time-trend in order to represent such slowly changing factors as extension of knowledge, etc. We expect a positive coefficient for irrigated area and time-trend and a negative coefficient for relative prices.

Two models are specified in the light of the above discussion. In the first model, consumption of nitrogenous fertilisers depends on current irrigated area in the region, relative price of fertilisers and the time-variable (representing extension of knowledge among farmers). The double logarithmic form is adopted :

$$\log Y_t = \log A_1 + b_1 \log X_{1t} + b_2 \log X_{2t} + b_3 t + u_{1t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Y_t, X_{1t}, X_{2t}, and t denote consumption of nitrogenous fertilisers (in nitrogen tons), total irrigated area, deflated fertiliser price and time variable respectively. U_{1t} is a stochastic variable while A_1, b_1, b_2 and b_3 are parameters of the model. The parameters are estimated by the method of Ordinary Least Squares.

The consumption data (Y_t) available for six States and all-India (totals) is obtained from Fertiliser Distribution Enquiry Committee Report (1960) and Fertiliser Statistics in India from 1951-61. The State-wise (gross) irrigated area (X_{1t}) is obtained from *Agricultural Situation in India* from 1951-59 and thereafter extrapolation is made on the assumption of the geometric growth rate up to the year 1960-61. The data on prices of different nitrogenous fertilisers are available in

* This paper is prepared at the Institute of Economic Growth, Delhi. The author wishes to thank Dr. Raj Krishna, Dr. K. Krishnamurty, Dr. V. R. Panchamukhi and Dr. C. H. Shah for their suggestions on the earlier draft and Mr. A. S. Sethi for his statistical assistance.

1. Ammonium Sulphate (20·6% N), Ammonium Sulphate Nitrate (26%N), Calcium Ammonium Nitrate (20·5%N) and Urea (44 %N).

the Fertiliser Distribution Enquiry Committee Report and Fertiliser Statistics in India. The price per ton of nitrogen is computed by considering the percentage of nutrients contained in each product according to Indian Specification Standards and the weighted average price[2] per ton of nitrogen is obtained by using production of various fertilisers as weights. The Farm Harvest Price Index Number is constructed on the basis of average farm harvest prices in different States for various crops during the years 1951-60. The year 1953-54 is chosen as the base year in order to maintain consistency for all the States. The deflated price per ton of nitrogen is obtained by the formula

$$X_{2t} = \frac{\text{Price per ton of nitrogen}}{\text{Farm Harvest Price Index No.}} \times 100.$$

In the second model, the consumption of nitrogenous fertilisers is made a function of the irrigated area in the previous year, deflated price of nitrogenous fertilisers and a time-trend variable. This relationship may introduce a specification bias. The irrigated area may be used for cultivation in the next season instead of next year. In the absence of seasonal data, one year's lag is tried. Like model (1), a double logarithmic form is used.

$$\log Y_t = \log A_2 + b_1 \log X_{1t} + b_2 \log X_{2t} + b_3 t + U_{2t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

In expressions (1) and (2), the normal assumptions of conditional regression analysis are made $E(U_{it}/X_{it}) = 0$ and $V(U_{it}/X_{it}) = \sigma^2$, $(i=1, 2.)$

Table I gives the estimated parameters, b_1, b_2 and b_3 associated with irrigated area, relative prices and time-trend. The standard errors of the estimated coefficients and corrected coefficient of multiple determination are also given. For Kerala, results of model (2) are given. For Punjab, the results for model (1) and (2) are given. Referring to Table I, it is found that the trend coefficient (b_3) is significant in case of Bihar, Mysore (1) and Orissa. This means that the effect of time-variable representing technical knowledge (improvement in seeds, managerial and organisational changes and fertiliser consciousness among farmers) is considerably high in explaining the variations in consumption of nitrogen. For Kerala, Mysore (1), Punjab and all-India, the elasticity coefficient with irrigated area is positive and significant. The positive sign is expected on the basis of economic theory. At all-India level one percentage increase in irrigated area leads to approximately 6 per cent increase in consumption of fertilisers. The price-elasticity coefficient should be negative on *a priori* considerations. But, negative price-elasticity is obtained only in three cases. In all

2. The distribution of nitrogenous fertilisers has been undertaken by the Central Fertiliser Pool through co-operatives. In all States, the fertilisers are distributed at the same price. Few States bear the cost of subsidy and as a result the prices charged from the farmers are lower than those charged in other States. However, State-wise prices of various fertilisers in different States do not vary significantly. Statewise production of various fertilisers as weights will not yield significantly different results since Ammonium Sulphate was consumed to a great extent until the year 1960-61. Recently, Sindri Fertilisers has undertaken the production of Ammonium Sulphate, Nitrate and Urea while Nangal produced Calcium Ammonium Nitrate since 1961-62.

TABLE I—REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND MULTIPLE COEFFICIENT OF DETERMINATION (CORRECTED)

States	Regression Coefficient			Correlation coefficient between log X_{1t} and t	Multiple coefficient of determination $\bar{R}^2$	No. of observations
	b_1	b_2	b_3			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bihar (1) ..	—·1511 (·2643)	·3415 (·1625)	6·3061* (2·1904)	·5023	·8075	9
Kerala (2) ..	5·6614* (·6583)	—·4154 (·4737)	·0304 (4·3255)	·9650	·9000	9
Madras (1) ..	·9712 (3·1289)	—·7600 (1·9226)	5·5360 (5·1155)	·6944	·9552	
Madras (2) ..	1·3124 (·9041)	—·9421 (·5982)	·0346 (·0188)	·8732	·8767	9
Mysore (1) ..	2·3772* (0·2465)	·6844 (1·0605)	8·5826* (2·5974)	·8798	·9650	9
Mysore (2) ..	·4000 (·6958)	—1·5072 (·6070)	8·2101 (3·9240)	·9063	·9363	9
Orissa (1) ..	1·2620 (·6754)	3·8222 (1·8978)	8·3221* (2·0172)	·7033	·8550	9
Punjab (1) ..	9·7232* (1·9089)	1·8156 (1·5529)	·5633 (8·9662)	·9850	·8080	9
Punjab (2) ..	11·1764* (5·5000)	2·9589 (1·3400)	—2·5036 (7·3700)	·9650	·8530	9
All-India (1) ..	6·2646* (1·3807)	—·2639 (·8345)	·0035 (·0081)	·0206	·7650	10

* Significant at 5 per cent level.

Note: (1) The bracketed figures are standard errors in cols. 2, 3 and 4.
(2) The numbers in brackets in column 1 refer to the models.
(3) The results for both the models are not given for each State and all-India. This was decided on the goodness of fit criterion for both the models of Table II. For Bihar (2), Kerala (1) and Orissa (2) $\bar{R}^2$ is very low. For all-India, the results of model (2) are unsatisfactory.

three cases, the price-elasticity is not significant. For Punjab (2) and Bihar (1), the price-elasticities are positive and twice their standard errors. The price may have no role to play in explaining the consumption of fertilisers since the relative price of fertilisers is showing a steady trend or remaining constant. It may be also true that there is uncertainty with regard to the use of new input like fertilisers, to begin with. This may be removed gradually. In such a process, price may have no relationship because new and better equilibrium may be attained through time.

STATISTICAL PROBLEMS

Two main problems, that are inherent in time-series analysis are: Multicollinearity and Autocorrelation. Let us analyse the problem of multicollinearity

Two explanatory variables, namely, irrigated area and time are highly correlated in most of the cases. There is no remedy to the problem of multicollinearity unless some extraneous information is incorporated in the study or one or more variables are dropped out. Owing to the presence of multicollinearity, our estimated parameters have an unsatisfactorily low degree of precision and therefore, it has been decided to compute the regression coefficients for both the models (1) and (2) after excluding the time-variable. In Table II, the elasticity coefficients associated with irrigated area and price-elasticities are presented.

TABLE II—REGRESSION COEFFICIENTS, STANDARD ERRORS AND CORRECTED MULTIPLE COEFFICIENT OF DETERMINATION

States	Model No.	Regression b_1	Coefficients b_2	Corrected multiple coefficients of determination $\bar{R}^2$	No. of observations
(1)	(2)	(3)	(4)	(5)	(6)
Bihar	(1)	3·0593	2·3771*	·445	9
		(1·3104)	(·7933)		
	(2)	1·1770	2·5394	·216	9
		(1·5488)	(1·2810)		
Kerala	(1)	4·5344	·2589	·410	9
		(2·2358)	(1·4900)		
	(2)	6·1964*	—·4264	·880	9
		(·6037)	(·7344)		
Madras	(1)	2·9181*	—·8048	·692	9
		(·7600)	(.9710)		
	(2)	2·6896*	—1·1325	·811	9
		(·6667)	(·7726)		
Mysore	(1)	3·8392*	·6388	·888	9
		(·4256)	(1·8400)		
	(2)	1·5624*	—2·1985*	·907	
		(·3662)	(.6470)		
Orissa	(1)	3·1302	·6781	·232	9
		(1·3926)	(2·8400)		
	(2)	2·9365	2·7014	·168	9
		(1·6011)	(2·3051)		
Punjab	(1)	10·9500*	1·7524	·841	9
		(1·7427)	(1·4076)		
	(2)	9·8933*	3·0678*	·876	9
		(1·3050)	(1·2294)		
All-India	(1)	6·5458*	—·2410	·801	10
		(1·1340)	(·7750)		

* Significant at 5 per cent level.

Note: The figures in brackets in columns 3 and 4 are standard errors.

The results of Table II indicate that the elasticity coefficients associated with irrigated area for models (1) and (2) are positive. Statistically significant results are obtained for Mysore, Madras and Punjab in case of model (1), and for Kerala, Mysore, Madras and Punjab in case of model (2). At the all-India level, the elasticity coefficient is statistically significant and indicates a 6 per cent rise in consumption for 1 per cent increase in irrigated area. A negative sign is expected for price-elasticity but negative signs are obtained in only five cases. For Mysore (2), the price-elasticity is significant while for Bihar (1) and Punjab (2), positive and significant price-elasticities are obtained. This result is not accepted on the economic grounds. In other cases, price-elasticities are positive but insignificant.

The other important problem in economic time-series is the problem of autocorrelation. Durbin-Watson[3] ratio statistic[4] is computed and the hypothesis of no autocorrelation against positive autocorrelation is tested. Where the test remains inconclusive, Theil-Nagar[5] statistic is applied. In case of Madras (1) a positive autocorrelation hypothesis is not rejected. A first order autoregressive scheme is tried but results are not encouraging.

PROJECTIONS

The single-equation time-series analysis does not consider the simultaneous relationship between the explanatory variables. This means that our estimated parameters are subject to simultaneous-equations bias.[6] However, an attempt to estimate the consumption of nitrogenous fertilisers for future is made.

In any projection, certain basic assumptions are to be made. All of them need not be mentioned though certain general and specific assumptions require explicit mention. The main objective of the present agricultural policy is to increase the output by popularising the use of fertilisers, increasing the irrigation facilities and propagating land reforms and organisational changes. We assume that this policy will continue during the projection period. A prior information on the explanatory variables such as irrigated area is required. In order to obtain the State-wise irrigated area for the year 1965-66, we have added the additional benefits of major, medium and minor irrigation schemes likely to be accrued to the irrigated area of the year 1960-61. The Ministry of Irrigation provided the State-wise estimates of the irrigated area for the year 1970-71. In Appendix I, the irrigated area for each State is given. The prices prevailing in the year 1958-59 are assumed to continue during the projection period. In Table III, projections of nitrogen consumption for three States and all-India are presented for the year 1965-66 and 1970-71 on the basis of coefficients obtained in Table II. For Bihar and Orissa, economic variables like irrigated area and price do not play an important role in explaining the variation in consumption, according to our analysis.

The elasticity coefficient with irrigated area for Punjab is very high and hence the consumption of nitrogenous fertilisers for the year 1965-66 are 80 per cent higher than the Planning Commission's estimate. For Kerala, Mysore and all-India, our estimates are 16 per cent, 13 per cent and 37 per cent lower than the

3. J. Durbin and G. S. Watson, "Testing for Serial Correlation in Least Squares Regression II," *Biometrica*, 1951, pp. 159-182.

4. Table value for 15 observations is used.

5. H. Theil and A. L. Nagar, "Testing the Independence of Regression Disturbances," *Journal of the American Statistical Association*, 1961, pp. 793-806.

6. It is assumed that demand function remains stable while supply function is shifting. This could be justified on the ground that fertiliser production is concentrated in the public sector which is responsive more to financial allocation than to price incentives.

TABLE III—PROJECTIONS FOR NITROGENOUS FERTILISERS (IN NITROGEN TONS)

States	1962-63	1965-66	1970-71
Kerala (2)	9,781	32,961* (39,350)	—
Mysore (1)	26,154	53,630 (61,800)	1,86,360
Punjab (1)	31,309	98,017 (57,680)	1,04,400
All-India (1)	4,26,364	6,76,710 (10,80,000)	31,35,400

* Refers to the year 1966-67.
Note : The bracketed figures in column 3 are Planning Commission's estimate.

Planning Commission's estimates, for the year 1965-66. For all-India, our estimates of 6.7 lakh nitrogen tons is in conformity with the slow growth in consumption of nitrogenous fertilisers during the last three years. The all-India estimate for the year 1970-71 appears to be very high. This may be due to high elasticity coefficient with respect to irrigated area in the estimating equation. It may be mentioned that this estimate should be used with caution.

LIMITATIONS

(1) The trend coefficient (b_3) represents a significant upward trend in the consumption function associated with time. It is well-known that time-variable is a catchall variable in regression analysis. The inclusion is made to take account of the extension of knowledge about the use of fertilisers among farmers. This may have come from the fertiliser experiments, farmers' own use and the intensive agricultural district programme. Probably, the inclusion of expenditures on demonstration programme may have explicitly explained the extension of knowledge on fertilisers. Such data, however, are not available for each State and all-India over a decade.

(2) The statistics of State-wise assured rainfall area are not available and therefore, our estimates (b_1) may have bias towards overestimation.

(3) Like many econometric studies, the sample size or the number of observations is hardly nine or ten for each State and all-India. At the same time, there is much to be desired in the quality of the available data.

SUMMARY

An attempt is made to identify and measure the quantitative significance of various economic factors in explaining the increasing consumption of nitrogenous fertilisers over a decade 1951-61. The study reveals that for Bihar and Orissa, the economic variables like irrigated area and relative prices do not explain the variation in consumption over the decade 1951-61. For Mysore and Madras, both irrigated area and prices appear to play an important role in explaining the variations in

consumption over the decade. For Punjab and Kerala, only irrigated area seems to explain the fluctuations in consumption. The projections are higher for Punjab and lower for Kerala and Mysore as compared to the Planning Commission's estimate for the year 1965-66.

APPENDIX I

STATE-WISE IRRIGATED AREA

(in '000 acres)

States	1960-61*	1965-66**	1970-71†
Andhra Pradesh	8,907	12,891	13,000
Assam	1,586	2,035	3,000
Bihar	5,411	8,475	9,000
Bombay	5,049	9,021	11,000
Jammu & Kashmir	841	933	1,000
Kerala	1,375	1,686	3,500
Himachal Pradesh	2,470	4,031	5,500
Madras	7,880	8,699	9,000
Mysore	2,554	3,612	5,000
Orissa	2,894	4,111	6,000
Punjab	9,601	11,931	12,000
Rajasthan	4,346	5,970	8,000
Uttar Pradesh	13,322	17,309	23,000
West Bengal	3,646	5,434	6,000
All-India	71,417	96,957 (83,200)	120,000

* Estimated on the basis of past data.

** Obtained by adding likely benefits of major, medium and minor irrigation schemes to State-wise estimates.

† Rough estimates provided by the Ministry of Irrigation.

Note : Figure in bracket is the total irrigated area given in the Third Plan Mid-term Appraisal.