Economic Analysis of Fertilizer Demand in the Punjab

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Introduction

It is a well known fact that increased use of purchased farm inputs, such as chemical fertilizers, pesticides, seeds and farm machinery, etc., has been associated with a substantial increase in agricultural production and higher farm productivity. Since demand for farm inputs is derived from demand for farm products, therefore, agricultural development in a country or region may be studied either through the changes in farm production and productivity, or through the changes in demand for various farm inputs. The demand for fertilizers, especially, lends itself to this type of analysis, because fertilizer is a highly divisible farm input.

This paper analyses the demand for nitrogenous fertilizers in the Punjab-Pakistan, during the period of 1959-60 to 1972-73. There has been a considerable increase in the aggregate fertilizer consumption in Pakistan accompanied by significant increases in farm production during the sixties and early seventies. During 1959-60 to 1972-73, fertilizer consumption in Pakistan increased from 19.4 thousand nutrient tons to 436.5 thousand nutrient tons [11, 12]. Nitrogen has accounted for approximately 90 percent of the total fertilizer consumed in the country. The share of the Punjab has been about 70 percent of the total nutrient consumption in Pakistan.

Fertilizer use is growing in importance and is likely to play an ever increasing role in the country's quest for agricultural development. Considerable public and private resources have been and are being invested in producing, importing, marketing and distributing chemical fertilizers. During the last couple of years the fertilizer consumption has been wavering and it has

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adversely affected our farm production. The government has been concerned about this situation and has adopted some *adhoc* measures to rectify the situation. It is important to identify and measure the impact of various factors that influence fertilizer demand. This type of analysis will be useful to the policy makers in providing methodical guidelines for increasing fertilizer consumption besides being helpful in predicting future demand for fertilizers.

Previously, fertilizer demand in Pakistan has been studied by Leonard [8], Ayub [1], and Chaudhry and Javed [2]. The present study besides estimating a slightly different demand function than the previous studies differs from those in two important aspects: (i) The geographical scope of this study is limited to the Punjab only and covers the time span of 1959-60 to 1972-73. Punjab province though a land of considerable physical, topographical and landscape variations is much more homogeneous in terms of major crops grown here; agricultural practices and farming technology than the whole of Pakistan. Therefore, it is expected that the analysis of fertilizer demand at the provincial level will provide a better understanding of the forces influencing fertilizer demand. Since the Punjab accounts for the lion's share of the total fertilizer consumption in Pakistan, factors affecting fertilizer demand here are, therefore, likely to exert considerable influence on the overall fertilizer consumption also. (ii) The analysis of aggregate time series data on the use of nitrogenous fertilizers is supplemented with the analysis of per acre use of nitrogen, over the years, in order to study the changes in the intensity of fertilizer use over time. It may be mentioned here that the previous studies, cited above, were limited to the analysis of aggregate data only.

Methodology

Demand for fertilizers, being a derived demand from farmer's supply of farm products, may be studied from the supply responses to the prices of their products. With assumptions of profit maximization and constant returns to scale, the demand for fertilizers may be derived from the production functions estimated for different crops. Nevertheless, these are restrictive conditions and may not hold true. This is especially true for developing countries where agriculture is subjected to a wide range of price fluctuations, and lack of information thereof characterizes their agriculture in addition to the vagaries of uncertain weather. A disequilibrium situation in the context of fertilizer use has characterized the Punjab agriculture. The available evidence [16, 18], suggests fertilizer use deviating from the optimal levels for the major crops of the Province. Moreover, fertilizer being an innovation, first introduced in 1952, some learning has been involved on the part of the farmers' over time by which they have become familiar with the use of fertilizer technology and its role in increasing farm production. Hence, we shall estimate the demand function for fertilizers directly from the time series data instead of deriving it from the production function under the restrictive assumptions described above.

Nitrogen, phosphorus and potassium are the principal fertilizer nutrients. The main sources of nitrogen in Pakistan have been ammonium sulphate, ammonium nitrate and urea. In the beginning ammonium sulphate was the most commonly used nitrogenous fertilizer but in recent years urea has replaced ammonium sulphate as the leading source of nitrogen supply in the country. The nitrogenous fertilizers have dominated the fertilizer scene in the country. Main reasons for this are listed below:

(*i*) Pakistani soils have been relatively deficient in nitrogen, hence, nitrogen was the first fertilizer element introduced in the country in 1952.

(*ii*) The application of nitrogenous fertilizer gives the plant leaves a dark green outlook and the healthier looking plants convince the farmers about its usefulness. However, this is not true for other two fertilizer nutrients.

Previous researches on the subject [5, 6, 20] and economic theory suggest that demand for fertilizers is likely to be influenced by their relative prices, prices of substitutes, income of the farmers and farmers' know how about fertilizers. Adequate and secure supplies of irrigation water are also important for the economical use of fertilizers. Therefore some index of irrigation development must be included in the estimated demand function. Aggregate fertilizer consumption/demand in a region is greatly influenced by the size of market. Hence, while analysing fertilizer dmand of a region we should incorporate cultivated or cropped acreage or some variation thereof in our model. Another important variable that could be important in the context of fertilizer demand is the level of information in the agricultural sector and farmers' experience with fertilizers, etc. In the absence of adequate measures for this variable, it has been a common practice to use a time trend variable to account for the changes occurring over time.

We have specified two types of equations in the light of above discussion, to estimate the parameters of the demand function. The first equation is based on the aggregate consumption of fertilizers (nitrogen) in the Punjab. The second equation is based on the average per acre use of nitrogenous fertilizers:

$$\ln Y_t = \ln Bo + B_1 \ln X_{1t} + B_2 \ln X_{2t-1} + B_3 \ln X_{3t} + B_4 \ln X_{4t} + B_5 T + e \ldots (1)$$

where,

Y_t = consumption of nitrogenous fertilizers in the Punjab in year t (in nutrient tons)

X_{1t} = relative price per ton of nitrogen in year t

$$= \frac{\text{price per ton of nitrogen}}{\text{weighted price index of major crops}} \times 100$$

X_{2t-1} = weighted price index of major crops in year t-1

X_{3t} = number of private tube-wells in the Punjab in year t

X_{4t} = area under major crop or irrigated area or total cropped area in the province in year t

T = time trend

B_o = constant and $B_1 \ldots B_5$ are the co-efficients to be estimated

e = the error term

$$\ln y_t = \ln bo + b_1 \ln x_{1t} + b_2 \ln x_{2t-1} + b_3 \ln x_{3t} + b_{4t} T + e \quad \ldots(2)$$

where,

y_t = cosumption of nitrogen per crop acre, per major crop acre or per irrigated acre in the province (in nutrient lbs.) in year t

x_{1t} = relative price per lb of nitrogen in year t

x_{2t-1} = weighted price index of major crops in year $_{t-1}$

x_{3t} = number of private tube-wells per thousand cultivated acres

T = time trend

b_o = constant and $b_1 \ldots b_4$ are the co-efficients to be estimated

e = the error term

A brief discussion about the variables included in our demand equations is provided below.

The relative prices of nitrogenous fertilizers—nominal prices deflated by the weighted price index of six major crops[1] is used in our analysis as one of the independent variables. The relative price is preferred over nominal prices because it is the relative change in the prices of input and output that is more important. The weighted price index of major crops lagged by one year is used, as a proxy, for the farmers' income. Lagged price index is used in the hope that farmers make their expectations of future prices in the light of their experience in the immediate past, since the future prices (save for a few years) were unknown to the farmers at the time of crop planting and fertilizer use.

The acreage under principal crops[2] or irrigated acreage or total cropped acreage is used in our estimated equations. These acreages were preferred over cultivated acreage because fertilizer is applied to cropped acreage only and fallow land does not count much in this regard. Because of lack of disaggregation in the irrigated acreage into cropped and fallow acreage, irrigated acreage was used. In addition to these acreages, the number of private tube-wells in the province were used to account for the development of irrigation facilities at the farm level. Finally, the time trend is included as a proxy for the changes in the level of information in the farm sector and farmers' experience in the use of fertilizer over the years. The parameters were estimated by the method of Ordinary Least Squares.

Discussion of Results

As discussed earlier, we have estimated two types of demand functions:

(1) based on aggregate time series data of nitrogen consumption in the Punjab, and

(2) based on the use of nitrogenous fertilizers per acre or, per irrigated acre or per major crop acre.

[1]Wheat, rice, maize, cotton, oil seeds and *gur* and *shakkar* (for sugarcane). These are main crops accounting for most of the cash income of the Punjabi farmers.

[2]Crops included under this category in the paper are rice, wheat, maize, jowar, sugarcane, cotton, tobacco, potatoes and other vegetables.

In the first form we have tried various combinations substituting irrigated acreage, cropped acreage or area under major crops. The results are presented in Table 1. All these formulations appear quite satisfactory in terms of high F-ratio and right sign for almost all the variables. These equations explain a little over 98 percent of the total variation in the fertilizer demand during the period under study. The first equation is slightly better than the other equations reported in Table 1. The results of demand analysis based on per acre fertilizer use are presented in Table 2.

The coefficient of multiple determination, R^2, is slightly over 0.98 in all the three equations estimated and reported in Table 2, indicating that a great deal of change in the intensity of fertilizer use per unit of irrigated land or per acre of crop land or per acre of major crop is explained by the four variables included in the model. All the co-efficients, except that of proxy for farmers' income, have right signs. The model, perhaps incorrectly, specifies that previous year's crop prices are going to reflect farmer's expectation of the future prices. We shall discuss the results in detail in the light of the estimated coefficients of equation one of Table 1 and supplement these with the results of equation two of Table 2.

We hypothesize in the light of economic theory that price elasticity of demand for fertilizers, like other normal goods, should be negative, indicating that a fall in the prices of nitrogenous fertilizers would lead to their greater use and an increase in their prices will have the opposite effect on their use.

The mean elasticity coefficient of fertilizer demand for its relative price is -0.522 and this is statistically significant. This implies that on the average, one percent increase in the relative price of fertilizer would result in one half of one percent decrease, or an increase of 10 percent in the relative price of fertilizer should result in a decrease of about 5 percent in the farmers' use of nitrogenous fertilizer, provided other things remain constant. On the other hand if fertilizer prices decrease by one percent we would predict, in the light of our anlaysis, that consumption of fertilizer will increase by about one half of one percent. The mean elasticity coefficient, of -0.49, for the per acre equation also supports the above argument, i.e. a ten percent increase in the relative prices of fertilizer is likely to result in approximately 5 percent reduction in the use of fertilizer on an acre of major crops, other things remaining the same.

The price elasticity coefficients for fertilizer demand, though statistically significant, however, are less than one (approximately one half). Nevertheless, one should not expect the price elasticity coefficients of essential farm inputs, such as fertilizers, to be greater than one and particularly when their use has become as wide-spread as in Punjab Province of Pakistan. Moreover, these elasticity coefficients are comparable to those reported for other developing countries [7, 15, 19, 20].

The use of nitrogenous fertilizers has increased during the period under study. The relative prices of fertilizers have declined from 1004.4 rupees per nutrient ton of nitrogen to Rs. 850.00, despite an increase in their nominal prices, during 1959-60 to 1972-73 from Rs. 1058.16 in 1962-63 to Rs. 1552 in 1972-73 [Table 3]. Therefore, we conclude that a decline in the relative prices of fertilizers has been one of the important factors in the increased use of nitrogenous fertilizers in the Punjab. Studies based on farm surveys [16,17]

Table 1

Estimated Coefficients of Demand Functions in the Punjab: Using Aggregate Time Series Data on the Consumption of Nitrogenous Fertilizers 1959-60 *to* 1972-73

	Constant Term	X_{1t}	$X_{2\ t-1}$	X_{3t}	X_{4t}	T	R^2	F-Ratio
1.	—9.175	—0.522* (0.273)	—0.582 (0.490)	0.155 (0.155)	2.079** (1.272)	0.152* (0.041)	0.9888	141.104
2.	5.031	—0.436** (0.306)	—0.073 (0.504)	0.244 (0.192)	0.550 (1.545)	0.159* (0.064)	0.9853	106.605
3.	—5.037	—0.523** (0.304)	—0.259 (0.460)	0.119 (0.189)	1.618 (1.604)	0.167* (0.043)	0.9867	118.912

Note: Variable definition: see text. All the variables in these equations were estimated in natural logarithms, except T–the time trend. Values in parentheses are standard errors of the estimates.

* Significant at 95 percent probability level. ** Significant at 90 percent probability level.

Table 2

Estimated Coefficients of Demand Functions for Nitrogenous Fertilizers in the Punjab: Using per Acre Use of Nitrogen, 1959-60 to 1972-73

	Constant Term	X_{1t}	$X_{2\,t-1}$	X_{3t}	T	R^2	F-Ratio
1.	1.350	—0.499** (0.298)	—0.013 (0.444)	0.271** (0.169)	0.147* (0.042)	0.9832	131.392
2.	3.593	—0.490** (0.269)	—0.350 (0.973)	0.185 (0.153)	0.166* (0.038)	0.9846	144.161
3.	2.551	—0.501** (0.283)	—0.211 (0.422)	0.156 (0.160)	0.172* (0.039)	0.9836	135.008

Note: Variable definitions: see text. All the variables in these equations were estimated in natural logarithms, except T–the time trend. Values in parantheses are standard errors of the estimates.

* Significant at 95 percent probability level.

** Significant at 90 percent probability level.

Table 3

Fertilizer Consumption, Prices of Nitrogenous Fertilizer, Weighted Price Index and Number of Private Tube-wells in the Punjab

Year	Fertilizer Consumption		Prices of Nitrogenous Fertilizer		Weighted Price Index of Major Crops	Number of Private Tube-wells in the Punjab
	Pakistan	Punjab	Money Prices	Relative Prices		
	('000' nutrient tons of Nitrogen)		(Rs. per Nitrogen ton)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1959-60	19.4	13.65	1004.40	1004.40	100.00	4084
1960-61	31.0	21.93	1004.40	908.00	110.61	6767
1961-62	37.0	26.17	1004.40	956.00	105.04	9619
1962-63	40.0	28.31	1058.16	983.00	95.31	15285
1963-64	68.0	47.91	1058.16	983.00	107.67	21776
1964-65	85.0	60.81	896.89	717.00	125.13	28746
1965-66	69.0	51.40	925.08	880.00	108.25	36217
1966-67	112.3	85.40	1066.73	757.00	140.95	44888
1967-68	177.7	121.90	1066.73	761.00	140.20	54930
1968-69	197.0	133.80	1156.25	856.00	135.12	63891
1969-70	237.5	184.80	1197.61	936.00	127.93	72825
1970-71	257.1	167.50	1452.96	1238.00	117.38	81814
1971-72	336.4	224.00	1449.20	968.00	149.78	90456
1972-73	386.4	262.30	1552.12	850.00	182.65	99025

Sources of Data:

Column 2: Year Books of Agricultural Statistics 1971-72, 1972-73 [11, 12].

Column 3: For the years 1962-63 to 1964-65 Food and Agriculture Section of the Planning Division [13]. For the years 1964-65 to 1972-73 Year Books of Agricultural Statistics 1971-72, 1972-73 [11, 12]. For the years 1959-60 to 1961-62 the fertilizer consumption in the Punjab was estimated from that of Pakistan, on the basis of 70.73 percent. This percentage was arrived at by averaging the percentages of total consumption of nitrogen in the Punjab, over the years of 1962-63 to 1972-73.

Column 4: Data on the prices of various brands of nitrogenous fertilizers were obtained from the Punjab Agricultural and Development Supplies Corporation [14]. From these data, average price per nutrient ton was worked-out. Prices for 1959-60 to 1962-63 were assumed as a simple average of the prices prevailing during 1962-63 to 1964-65.

Column 5: Column 4÷6.

Column 6: It is a weighted average price index of rice, wheat, maize, cotton, *gur* and *shakkar*, and oil seeds, calculated by the following method:

$$\frac{\Sigma w_i \; p_i}{\Sigma w_i}$$

where,

w_i = total production of the respective crops in the Punjab

p_i = wholesale price index of the respective crops [1959-60=100].

Price indices of major crops were obtained from 25 Years of Pakistan in Statistics, [9], and those of 1971-72 to 1972-73 were calculated from the Central Statistical Offices, Monthly Bulletin, Vol. 21, 7. July, 1973 [10].

Column 7: "Private Tube-well Numbers in Pakistan: A synthesis" [3].

also support our results i.e. an increase in fertilizer prices is likely to adversely affect the use of fertilizers. The events of the recent years, when fertilizer consumption dropped substantially as a result of fertilizer price hikes, also support our conclusion. In the light of our analysis it is argued that there has been a more rapid rise in the price index of major crop than that of fertilizer price during the period under consideration, which has encouraged greater fertilizer use.

The mean elasticity coefficient of fertilizer demand with respect to acreage under major crops is 2.079 and is statistically significant. This shows that one percent increase in the acreage of major crops will, on the average, result in approximately two percent increase in the aggregate fertilizer consumption in the province. It may be pointed out here that coefficients of total cropped area and total irrigated area in equations 2 and 3 of Table 1, though positive, nevertheless, are statistically not significant. It appears that changes in the acreage under major crops included in this study i.e. rice, wheat, jowar, cotton, sugarcane, tobacco, potatoes and other vagetables are more important in explaining the variations in fertilizer demand than those of changes in the total crop acreage, or changes in the irrigated area of the province. It may be mentioned that acreage under the above mentioned crops increased by about 30 percent while the total cropped acreage increased by only 17 percent, during the time period under study. Moreover, these are the principal crops which account for a major share in fertilizer consumption of the province.

With the introduction of high yielding varieties of wheat, rice and corn etc., the acreage under these crops have increased considerably and this increase has been mainly at the cost of those crops which do not matter in fertilizer consumption, such as grams, barley and oil seeds, etc., or fallow land. This is especially true for the canal irrigated areas and the development of tube-well irrigation has further strengthened this trend. This sort of collinearity between the acreage under major crops and the development of tube-well irrigation facilities may partly explain the lack of precision of the otherwise positive mean elasticity coefficient for the private tube-wells in our equations.

The coefficient of the proxy for farm income lagged by one year has a negative sign in all the estimated equations including those on per acre basis. This is contrary to our expectations. However, the coefficients are not statistically significant. It may be recalled that price index of major crops lagged by one year was used as a proxy for the farmers' income, in the hope that farmers base their expectations of future incomes on the basis of their previous year's income. The function supposed, perhaps incorrectly, that the price index of last year will serve as an index of farmers' income in the current year.

The coefficient of time trend is positive and statistically significant in all the estimated equations indicating that aggregate as well as per acer use of nitrogenous fertilizers has been increasing over time. This has been mainly as a result of the accumulating information about fertilizers and their profitability in the farming sector because of the promotional efforts and market development activities of both private and public sector agencies. Moreover, farmers' own experience in handling fertilizers at the farm level has increased over the years. Nevertheless, one could also argue that supplies of nitrogenous fertilizers, which are determined by various institutional factors such as import policy, availability of fertilizer in the international market and from donors under various aid programmes, and crop targets; have been increasing. Moreover,

the domestic production though subject to various socio-political and institutional constraints, has also increased over the years. Therefore, farmers have been responding to increased supplies as a result of various promotional efforts and market development activities.

Summary of Results and Concluding Remarks

From our analysis of time series data on fertilizer use, it is observed that the relative prices of nitrogenous fertilizers have been quite important in influencing their demand. A relative decline in the prices of fertilizers has been one of the important factors in encouraging fertilizer use. Another important factor in this regard has been the increased acreage under major crops of the province, especially under high yielding varieties of food grains. It also appears that over the period, the use of nitrogenous fertilizers has been increasing. This may have resulted from various factors such as increase in the level of information about fertilizers in the farm sector, farmer's experience and awareness about the profitability of the use of fertilizers.

Demand for fertilizers has increased interchangably at high and low rates but has not experienced a sustained decline for a long period of time. The demand for fertilizers' in the short run may experience a decline as a result of increased fertilizer prices, etc., but is likely to stage an upsurge as a result of shortages in farm supplies which will result in higher farm prices. What is important in this regard is that the rate of increase in the fertilizer prices must not exceed the rate of increase in farm prices if we want to avert shortages in the supplies of farm produce. In a system where prices of the various farm inputs as well as those of the major farm produce are regulated by the government, the policy makers while fixing prices of the farm inputs as well as of the farm outputs must strike a balance between these prices, otherwise the shortages and higher prices and huge imports are likely to raise their ugly heads. Pakistan's own experience of recent years provides ample proof of that.

At present there are considerable number of farmers who are not using fertilizers for one reason or the other. Once this source of increase in fertilizer demand is exhausted the prices are likely to be even more important in influencing fertilizer use and its level of intensity. Sooner or later we will reach a stage where finer points and finer tunings will become limiting and at the same time more important. Then a fine balance between the prices of various varieties of fertilizer and farm products would become even more important.

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