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FERTILIZER DEMAND FUNCTIONS UNDER VARYING LEVELS OF PRICES AND OPERATING CAPITAL IN KENYA

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BACKGROUND

In Kenya, just like in many other developing countries, time series data on resource use and product supply are lacking, and therefore the strategy has been to resort to linear programming (LP) techniques to estimate resource demand functions and/or product supply functions. Unfortunately, the apriori knowledge available for characterizing resource demand functions by this technique is very limited. Moore et al (1) and Ogunfowora et al (2) derived demand functions for irrigation water and fertilizer respectively by drawing heavily on the techniques used in deriving supply functions. We shall adopt the same strategy. Parametric linear programming and regression analysis techniques will be used.

The conventional method of parametric linear programming used to derive normative resource demand and product supply functions is modified in this study. The conventional method is thoroughly treated by Heady et al (3).

In this study fertilizer price, product price and capital level are set at a particular level and an optimum farm plan is obtained. These variables are again set at different levels and optimum farm plans are obtained. Associated with each plan is a quantity of fertilizer demanded. These parametric programming results are treated as though they were independent observations.

The solution quantities of capital, fertilizer and the prices of fertilizer and products are then used in a regression analysis to estimate continuous fertilizer demand functions for the farm-firm. Given that the objectives is to quantify farm-level fertilizer demand elasticities, then since the estimated functions are continuous regression equations, they can be used to derive point elasticities. However, the data generated by this method do not meet the assumptions of normality and independence used in regression analysis; statistical inference and probability statements, therefore, cannot be made (4).

Consequently, the statistical tests presented in this study should be interpreted as a measure of goodness of fit. This approach is also normative, indicating farmers' potential responses under the assumption of farm income maximization, perfect knowledge about prices, technological changes, institutions and environmental factors. To the extent that these assumptions fail, farmers' actual decisions may sometimes differ markedly from those indicated as optimum. Anderson et al(5) and Sheahy et al (6) indicate that normative approach may lead to an upward biased estimate of commodity supply and demand elasticities, and it is not yet clear to what extent normative quantities should be adjusted to closely approximate the actual supply and demand responses. Aware of this possibility, an attempt was made to stimulate as closely as possible actual farm conditions. Furthermore, fertilizer and product prices are largely fixed by the Government and this reduces price risk substantially. But there are still technological and yield risks to contend with. Thus, the fertilizer quantities generated by this approach might deviate markedly from the quantities purchased in the market.

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The fertilizer demand responses estimated in this study are for a representative farm in each agro-ecological zone and hence we do not encounter the problem of aggregation bias which we would have to contend with if we were estimating fertilizer demand function for a region.

OBJECTIVE OF THE STUDY

The objective of this study is to estimate demand elasticities for fertilizer prices, product prices and capital, and to assess their policy implications.

HYPOTHESIS OF THE STUDY

The Kenya government, realizing the potential role fertilizer can play in increasing agricultural production, uses price policy to influence its use. However, the impact and magnitude of the various variables on fertilizer use have not been estimated. In this study then, an attempt was made to test the hypothesis that substantial use of fertilizer could come about in response to (i) an increase in the price of farm products, (ii) a fall in the price of fertilizer relative to the prices of products and (iii) an increase in the level of available operating capital. The test of this hypothesis would also provide evidence for or against the assumption that the combination of these variables as a package would lead to substantial increases in fertilizer use.

SOURCES OF DATA

The data used were obtained from various sources, viz: Central Bureau of Statistics (CBS), Ministry of Agriculture District Farm Guidelines, Fertilizer Program, fertilizer distributors, publications and a farm survey conducted by the author in 1976/77 period.

FERTILIZER DEMAND MODEL

The functional relationship in fertilizer demand can be stated as follows:

$$D_F = f(P_I, P_F, K, T, U) \qquad (1)$$

where

D_F = quantity of fertilizer in kilograms
P_I = price index of farm products
P_F = price of fertilizer in Kenya shillings
K = the level of operating capital in Kenya shillings
T = the level of technology
U = error term

The specification of the above model could have included prices of other inputs that are either substitutes for or complements to fertilizer. However, the inclusion of the variables in the model was dictated by the data that could be generated by using the parametric linear programming technique.

The identification problem is usually encountered in demand estimation. However, this problem is not encountered in this estimation of demand for fertilizer because of the way the data was generated.

A constant level of technology was assumed for this study. If technology is eliminated from the model, then the estimating model reduces to the following functional form:

$$D_F = b_0 + b_1P_I + b_2P_F + b_3K + U \qquad (2)$$

With no apriori knowledge of the functional form of fertilizer demand function, various functional forms - linear, quadratic, exponential - were fitted to the data. Next, the square root transformation of the independent variables was applied. It has proved very successful in fertilizer studies(7). The function with square root transformation of the product price index was selected to represent the demand for fertilizer as it conformed with accepted theory and logic, while the size of the coefficient of multiple determination, R^2, and statistically significant F values for the regression mean squares gave additional support for this function.

From economic theory, we would expect b_1 and b_3 to be positive while b_2 should be negative, implying that the demand for fertilizer should increase ceteris paribus as the product price index and operating capital level increases while the demand for fertilizer should decrease as the price of fertilizer increases.

The ecological zones covered in this study included the Tea zone, the Coffee zone and the High Altitude Grass zone (HAG). Four crops in the Tea zone, four in the Coffee zone and three in the HAG zone were assumed to be the main fertilizer users. To generate data for estimating the demand functions, several levels of product price were used, the magnitude of each being raised by equal proportions. However, the magnitudes varied among different products. They were based on past price movements as well as future price expectations for the different products. Tables 1, 2 and 3 show the expected range and magnitudes of price increases for individual products for the Tea, Coffee and HAG zones respectively.

Table 1 :EXPECTED RANGE AND MAGNITUDE OF PRICE INCREASE FOR THE TEA ZONE

Products	Price Range (Shs per kg)								Increase
	1*	2	3	4	5	6	7	8	%
Hybrid Maize	0.91	1.09	1.31	1.57	1.88	2.26	2.71	3.25	20
Beans	2.54	2.79	3.07	3.38	3.72	4.09	4.50	4.95	10
E. Potatoes	0.87	0.91	0.96	1.01	1.06	1.11	1.17	1.23	5
Tea	0.72	1.08	1.62	2.43	3.65	5.48	5.48	12.33	50

*Prevailing prices in the survey area during 1974-75 period.

Table 2 : EXPECTED RANGE AND MAGNITUDE OF PRICE INCREASE FOR THE COFFEE ZONE

Products	Price Range (Shs per Kg)								Increase
	1*	2	3	4	5	6	7	8	%
Hybrid Maize	0.76	0.91	1.09	1.31	1.57	1.88	2.26	2.71	20
Beans	2.49	2.73	3.00	3.30	3.63	3.99	4.39	4.83	10
E. Potatoes	0.83	0.93	0.98	1.03	1.08	1.13	1.19	1.25	5
Coffee	0.97	1.46	2.19	3.28	4.92	7.38	11.07	16.61	50

*Prevailing prices in the survey area during 1974-75 period

Table 3 : EXPECTED RANGE AND MAGNITUDE OF PRICE INCREASE FOR HAG ZONE

Products	Price Range (Shs per Kg)								Increase
	1*	2	3	4	5	6	7	8	%
Hybrid Maize	0.89	1.07	1.28	1.54	1.85	2.22	2.66	3.19	20
Beans	1.63	1.79	1.97	2.17	2.39	2.63	2.89	3.18	10
E. Potatoes	0.60	0.63	0.66	0.69	0.72	0.76	0.81	0.85	5

*Prevailing prices in the survey area during 1974-75 period

Given the above increases in product prices, it was assumed that farmers' incomes in the area would increase. Thus, we raised the level of operating capital by 20 per cent. Table 4 shows the levels of operating capital by zone.

Table 4 : LEVEL OF OPERATING CAPITAL BY ZONE (SHS)

Zone	Initial Level	Current Level	Percentage (Increase)
Tea	1,266*	1,520	20
Coffee	832	998	20
HAG	1,054	1,267	20

* Prevailing operating capital level during the survey.

In the 1975 period, the government announced that the fertilizer price subsidy would be reduced from 40 to 25 per cent. With this in mind, fertilizer prices were reduced by 40 and 25% respectively. Table 5 shows fertilizer types and their initial prices and subsidized prices.

The fertilizer price subsidy of 25% was tantamount to raising fertilizer prices from the 40% subsidy level. Two fertilizer price levels represented the two subsidy rates for each fertilizer type, i.e. P_{F1} for 40% subsidy rate and P_{F2} for the 25% subsidy rate. Two levels of operating capital availability were specified. K_1 and K_2 represented, respectively, the initial operating capital and operating capital levels after a 20% increase.

Table 5: FERTILIZER TYPES, THEIR INITIAL PRICES AND SUBSIDIZED PRICES (SHS/KGS)

Fertilizer Type	Initial Price	Price at 40 Percent Subsidy	Price at 25 Percent Subsidy
P_2O_5	1.92*	1.15	1.44
NP	2.19	1.31	1.64
NPK	2.38	1.43	1.79

SOURCE: Survey data

* Prevailing fertilizer prices during the survey.

These various levels of operating capital and fertilizer price were combined with the seven levels of product price and programming solutions obtained for each combination. Each optimum solution provided the data needed for estimating the demand functions for fertilizer.

FERTILIZER DEMAND ESTIMATES FOR THE TEA ZONE

From the discrete observations, the following equation and statistics were obtained for the fertilizer demand function in the Tea zone.

$$D_F = 67.61 + 26.92P_I^{1/2} - 344.38P_F + 0.56K \quad (3)$$
$$(0.98) \qquad (-5.18) \qquad (5.93)$$

$$R^2 = 0.73 \text{ and } F_{(3,24)} = 21.37^{**}$$

In this and other equations to be presented later, the figures in parentheses are the t-values. The significance of the B-coefficients and F-values at 5% and 1% levels is indicated by one or two asterisks, respectively.

The explanatory variables displayed the expected signs. The coefficient of multiple determination, R^2=0.73, is high, implying that the explanatory variables accounted for a substantial amount of variability in the quantity of fertilizer demanded by the farm-firm in the Tea zone. The F-test of the regression mean square was significant at the 1 per cent level, implying that the regression model fitted the data adequately. If the observations had been independent then the B-coefficients of fertilizer price and capital are significant at the 1 per cent level while that of product price is not significant even at the 10% level. The lack of independence in observations should also be borne in mind in interpreting the results of Coffee and HAG zones equations.

FERTILIZER DEMAND ESTIMATES FOR THE COFFEE ZONE

The following equation and statistics were obtained for the fertilizer demand function in the Coffee zone:

$$D_F = -264.15 + 17.79P_I^{1/2} - 55.70P_F + 0.48K$$
$$(5.16) \qquad (-.80) \qquad (5.64)$$

The three explanatory variables had the expected signs. They explained 92% of the variation in fertilizer demand for the farm-firm in the Coffee zone. The F-test of the regression mean square was significant at the 1% level implying that the regression model fitted the data adequately. The coefficients of fertilizer price, product price and capital are significant at the 1% level.

FERTILIZER DEMAND ESTIMATES FOR THE HIGH ALTITUDE GRASS ZONE

The equation and statistics obtained for the fertilizer demand function in the High Altitude Grass zone a re presented below:

$$D_F = 51.69 + 3.05P_I^{1/2} - 24.44P_F + 0.13K \quad (5)$$
$$(2.51) \qquad (-11.21) \qquad (41.74)$$

$$R^2 = 0.98 \text{ and } F_{(3,24)} = 652.02$$

The explanatory variables had the expected signs. They explain almost all - 98% - of the variation in the fertilizer demand for the farm-firm in the HAG zone. The F-test of the regression mean square was significant at the 1% level, indicating the regression fitted the data. The B-coefficient of fertilizer price and capital are significant at the 1% level, while that of product price is significant at the 5% level.

The elasticities of the fertilizer demand with respect to its own price, product price and capital level for the three zones were calculated at their mean values of observations as follows:

$$\bar{P}_F = (dQ/dP_F) \cdot (\bar{P}_F/Q) \quad (6)$$

$$\bar{P}_F = (dQ/dP_I).(\bar{P}_I/Q) \quad (7)$$

$$\bar{K}_F = (dQ/dK).(\bar{K}/Q) \quad (8)$$

where Q = quantity of fertilizer demanded. Table 6 shows the mean values used in the calculation of elasticities by zone.

Table 6: MEAN VALUES USED IN THE CALCULATION OF ELASTICITIES

Zone	Q(Kgs)	P_I	P_F (shs)	K(shs)
Tea	335.79	2.79	1.61	1,393
Coffee	125.64	2.28	1.61	915
HAG	172.09	2.18	1.30	1,161.50

SOURCE: Calculated

The elasticity of the fertilizer demand was -1.65, -0.71 and -0.24 with respect to its own price in the Tea, Coffee and HAG zones respectively; while it was 2.32, 3.49 and 0.87 with respect to operating capital in the Tea, Coffee and HAG zones respectively. The elasticity of the fertilizer demand was 0.27, 0.32 and 0.04 with respect to the product price index in the Tea, Coffee and Hag zones respectively.

The magnitude of the elasticities show that the demand for fertilizer would be most responsive in the operating capital level, followed by fertilizer price and product price in that order in all the three zones. These elasticities imply for instance in the Tea zone that a 1 per cent increase in fertilizer price ceteris paribus is predicted to reduce fertilizer consumption by 1.65 per cent. Similarly, a 1 per cent increase in operating capital is predicted to increase fertilizer consumption by 2.32 per cent and 1 per cent increase in product price is predicted to increase fertilizer consumption by 0.27 per cent. The plausible explanation of a low elasticity of product price index is that with a limitation on capital, the use of fertilizer cannot be extended beyond a certain point (capital limitation) regardless of how far prices of products are increased.

The results of our analysis are depicted in graphs of Figures 1, 2 and 3 for the Tea, Coffee and HAG zones respectively, in which the quantity of fertilizer is graphed against output price index. In these figures, fertilizer price and capital variables are assumed to be shift parameters. Using the Tea zone figure as an example, these figures can be interpreted as follows: Given the initial demand function for fertilizer as K_1P_{F1}, the fertilizer demand curve shifts to the left, K_1P_{F2} as the price of the fertilizer increases. The increase of capital level to K_2 shifts the demand curve to K_2P_{F1}. The demand curve K_2P_{F2} reflects an increase in both capital level and fertilizer price. The magnitudes of the shifts reflect relative influence of fertilizer price and capital level on fertilizer demand response, while the slopes of the curves reflect the influence of product price index on fertilizer demand response.

After the estimation of the elasticities for product price index, fertilizer price and capital for the three zones, an attempt was made to see how the product price index elasticity for fertilizer demand would change if there was a policy decision to increase product prices. If we assume that product price increases lead to an increase of the mean product price by 50% in all the zones, then we proceed to calculate the new product price index elasticity for each zone. The new product price indices are 4.19, 3.42 and 3.27 for the Tea, Coffee and HAG zones, respectively. The mean fertilizer quantity remains the same for all the zones. The new product price index elasticities for fertilizer demand are 0.34, 0.48 and 0.06 for the Tea, Coffee and HAG zones. The original elasticities were 0.27, 0.32 and 0.04 respectively. This indicates that even with substantial increase in product price index, the product price index elasticity for fertilizer demand does not change substantially.

The results presented in this study compare favourably with results obtained in other studies which have attempted to estimate farm level fertilizer demand for small farmers in developing countries.

Ogunfowora et al (8), using the same technique in Northern Nigeria as the one employed in this study, estimated that the elasticity of fertilizer demand was -0.79 with respect to its own price, 1.63 with respect to capital, and 0.32 with respect to product price index. Timmer (9) has reported that the few studies that have used time-series data to estimate price elasticity of demand in developing countries have obtained a short term price elasticity of about 0.5 to -0.1, and the long term elasticity is in the range of -1.5 and to about -3.0. Thus, the values obtained in our study can be interpreted as reasonable estimates of elasticities of farmer response to changes in fertilizer price, product price and capital level in the study area.

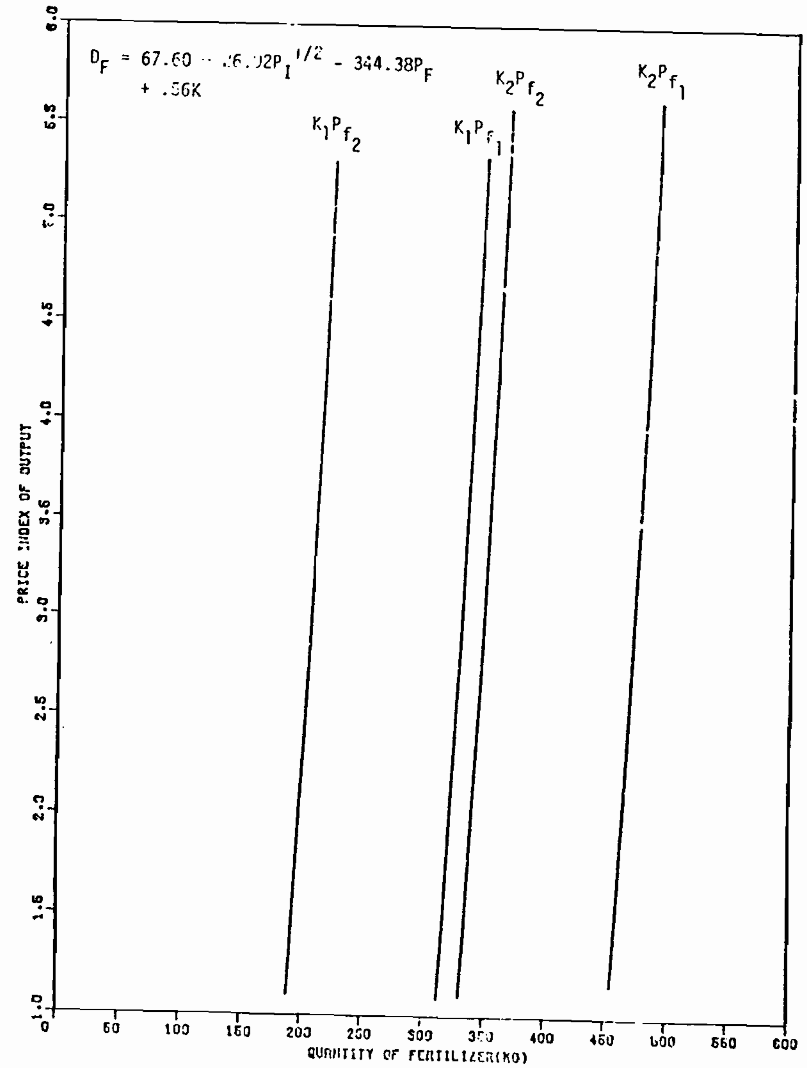

FIGURE 1
FERTILIZER DEMAND FUNCTIONS FOR VARIOUS LEVELS OF OUTPUT AND FERTILIZER PRICE LEVELS AND CAPITAL AVAILABILITY FOR THE TEA ZONE

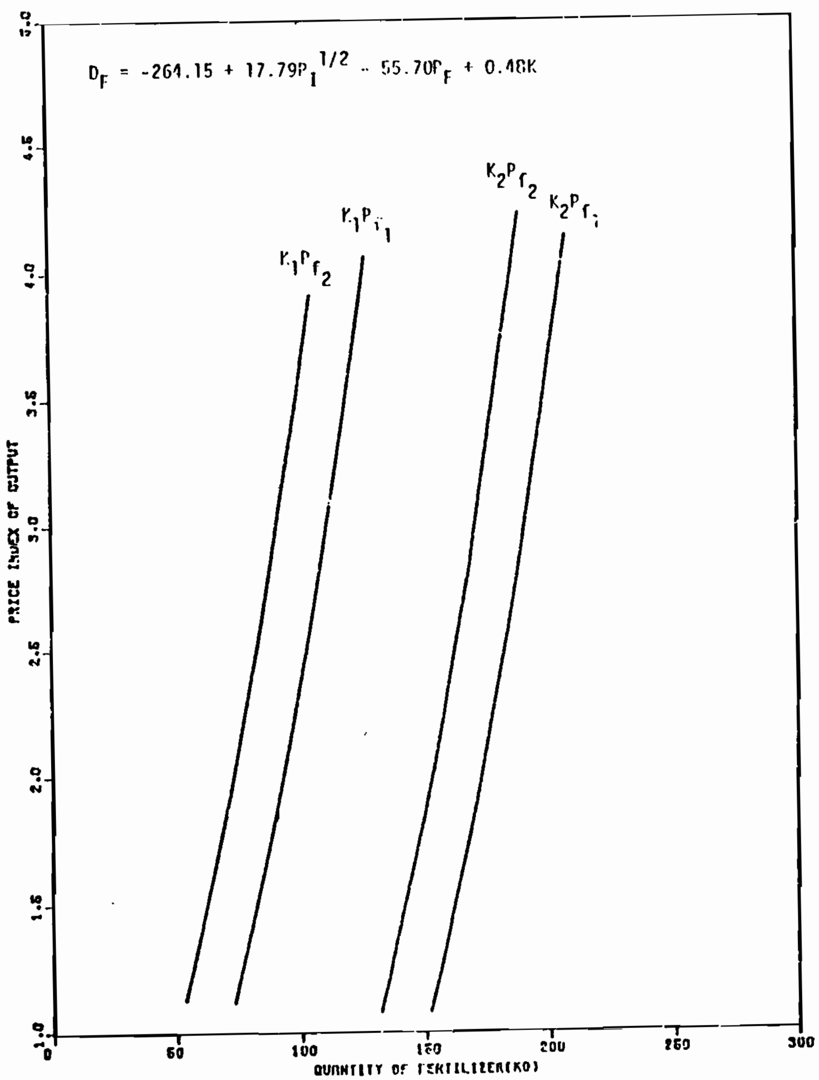

FIGURE 2
FERTILIZER DEMAND FUNCTIONS FOR VARIOUS LEVELS OF OUTPUT AND FERTILIZER PRICE LEVELS AND CAPITAL AVAILABILITY FOR THE COFFEE ZONE

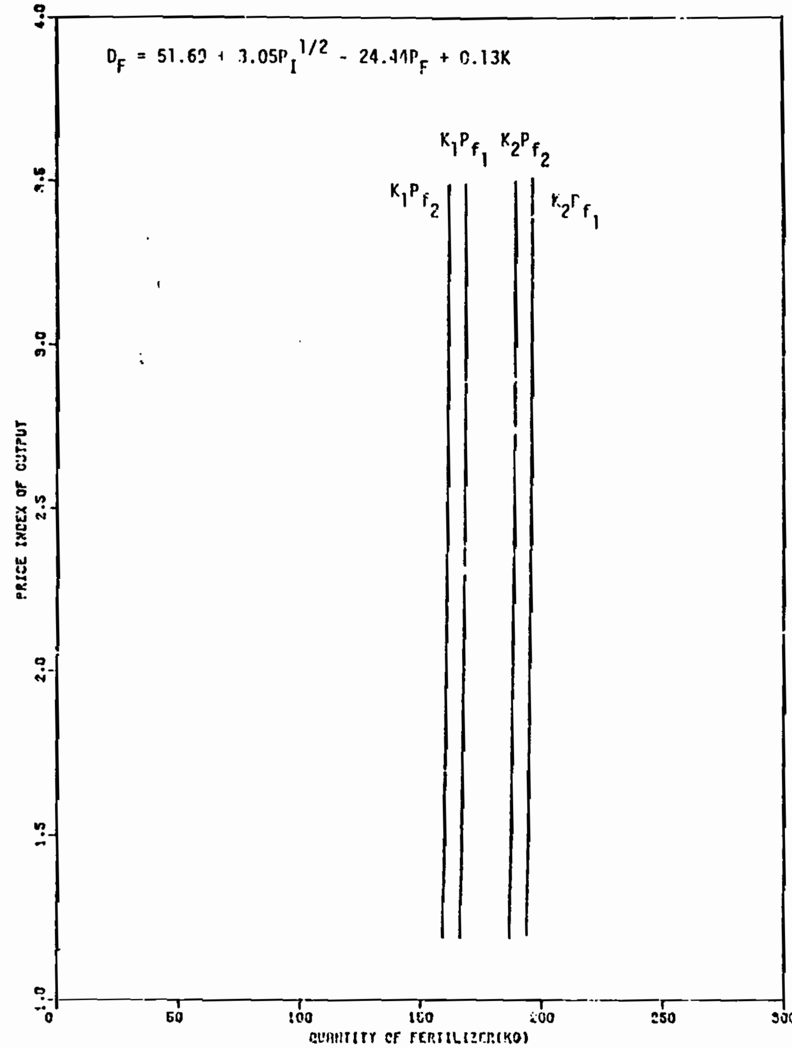

FIGURE 3
FERTILIZER DEMAND FUNCTIONS FOR VARIOUS LEVELS OF OUTPUT AND FERTILIZER PRICE LEVELS AND CAPITAL AVAILABILITY FOR THE HIGH ALTITUDE GRASS ZONE

POLICY AND RESEARCH IMPLICATIONS

The results obtained in this study have important implications to both policy makers and researchers. The estimated price elasticity with respect to a change in fertilizer price is much higher than the price elasticity with respect to change in the product price index in all three of the zones. This, then, would tend to indicate that the zero homogeneity condition for fertilizer demand functions might not hold in developing countries. That is, the effect of raising product price by 1 per cent is not symmetric with effect of lowering the fertilizer price by 1 per cent. Many research workers as well as policy makers who have to choose the appropriate policy instrument - fertilizer subsidies or product price support - tend to rely on the symmetry assumption. Our results, just like those reported from developing countries by Timmer, Ogunfowora et al and Raj Krishna, tend to refute this assumption (10, 11, 12). But Heady and Tweeten's estimates for the United States seem to confirm it (13).

Krishna (14) however, suggests that product price support might work better than input subsidies for a variety of reasons. Peasants tend to be more familiar with product prices and will probably be more sensitive to their variation. The critical factor for peasants is not insurance against high input prices, but guarantees that product prices will not collapse, leaving the cultivator helplessly in debt. Some input prices are difficult to subsidize - especially land and labour, which frequently form a large proportion of total costs - and only product price supports can be fully effective in stimulating the output of particular crops.

The results have also indicated that increase in capital has a high potential for increasing demand for fertilizer. This has important policy bearing in Kenya, where both product price support and fertilizer price subsidies are employed. Thus, even if fertilizer price subsidy and product price support can induce a substantial use of fertilizer, and hence increased output, their impact can be reduced tremendously if capital is limiting. That capital is limiting in the three zones has been established in this study. Further, it was shown that capital elasticities were higher than fertilizer price as and product price index elasticities in all the zones. This would imply that any policy designed to increase fertilizer demand in the study area must provide for adequate fertilizer credit. Thus, just like one might argue that two policy instruments are more effective than one, one can also argue that three instruments employed simultaneously will result in greatest response. The response by farmers to these policy instruments takes time, and consequently the results obtained in this study might not approximate farmers' behaviour in the short run but it is hoped that they will predict their behaviour in the long run.

The issue of the relevance of results obtained in a study like this can be raised by policy makers and justifiably so. But Timmer (15) has summarized the situation well, when he observed that no policy maker would dare use these numbers if better ones were available. But this is the disturbing reality; little is known about factors affecting fertilizer use which is relevant at a policy level. Further, fertilizer policy making, like many agricultural policies, might be placed in the realm of judgement, experience and politics in addition to the realm of analysis.

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