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Articles in the field of agricultural economics, suitable for publication in the journal, will be welcomed.

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Contents

Demand functions for fertilizer in South Africa

by

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1. INTRODUCTION

The consumption of fertilizer plant nutrients in South Africa increased almost five-fold during the period 1952-1966. This must have played a crucial part in raising South African agricultural productivity. The main aim of this paper is to investigate and isolate the factors that contributed to the increase.

The structural relationships underlying the demand for fertilizers may provide the basis for evaluating the effectiveness of policy instruments such as product price supports or subsidies on fertilizers. With a total expenditure on fertilizer of about R65 million (1968) and with a State subsidy of about R14 million (1969), light cast on the effectiveness of the subsidy would be important to policy makers. In this study it is shown that the subsidy on fertilizer may be an effective policy tool in manipulating the quantity demanded.

2. CONSTRUCTION OF A RESOURCE DEMAND FUNCTION

The model described in equation 1 can be considered as the foundation of empirical resource demand analysis. The demand for a factor is treated as a derived demand, derived from the demand of the product, the production function and the supply conditions of other factors of production.

$$X_i = f\left(\frac{P_i}{P_y}, \frac{P_j}{P_y}, X_k\right) \qquad (1)$$

X_i = consumption of ith factor
P_i = price of ith factor
P_y = price of product
P_j = prices of variable factors j = 1 ..... n
X_k = quantities of fixed factors k = 1 ..... m

While prices of variable factors are included in the demand model, the quantities of fixed factors are considered. In the models reported in this study a budget constraint was also incorporated by the inclusion of an income variable.

The use of price ratios, suggested by static theory, implies a symmetrical response of the input quantity demanded to product and factor prices. Thus, if input and output prices increase or decrease by the same proportion, the quantity demanded remains unchanged. The demand is homogeneous of degree zero i.e. if all prices change by the same proportion ~~then the demand~~ quantity remains unchanged.

Single equation regression analyses were used as it was found that farmers were not able to influence the prices of fertilizer in any way. The fertilizer market in South Africa is of an oligopolistic nature with only a few large suppliers. These firms announce their prices early in the year and rarely vary them during the season. In the short run the price paid by the farmer may be considered as predetermined.

3. DISCUSSION OF VARIABLES

In Fig. 1 the total consumption of plant nutrients, the price of fertilizer relative to crops and the total real income of farmers are depicted on an index basis. There appears to be a symmetrical response in consumption caused by a decline in the fertilizer to crop price ratio. The price of pure plant nutrients for example, decreased by approximately 17% in South Africa during the period 1952-1966.[1] In this study the decline in fertilizer price relative to the price of crops was found to be the most important factor contributing to the phenomenal increase in fertilizer use as depicted in Fig. 1.

Time series demand functions were derived for the 15 year period, 1952-1966 and for the 25 year period, 1944-1967.

The following variables were tried in alternative models:

$P_{FW(t)}$ = Price of plant nutrients deflated by the wholesale price index for year t. (Calender year, 1952 = 100).

$P_{FC(t)}$ = Price of plant nutrients deflated by the price of crops for year t. (Calendar year, 1952 = 100).

$P_{F(t)}$ = Price of plant nutrients calculated from weighted consumption data deflated by the wholesale price index for year t. (Calendar year, 1952 = 100).

$P_{LW(t)}$ = Price of land deflated by wholesale price index for year t. (Calendar year, 1952 = 100).

$I_{W(t)}$ = Cash income from farming in thousand rand deflated by the wholesale price index and lagged six months. (Split year basis, price index 1947/48-49/50 =100).

1) Indexes of fertilizer prices of the Division of Agricultural Marketing Research show an increase in fertilizer prices for the corresponding period. This is because the indexes of the Division are based on the total volume of fertilizer whereas in this study the price of fertilizer is expressed in terms of plant nutrients.

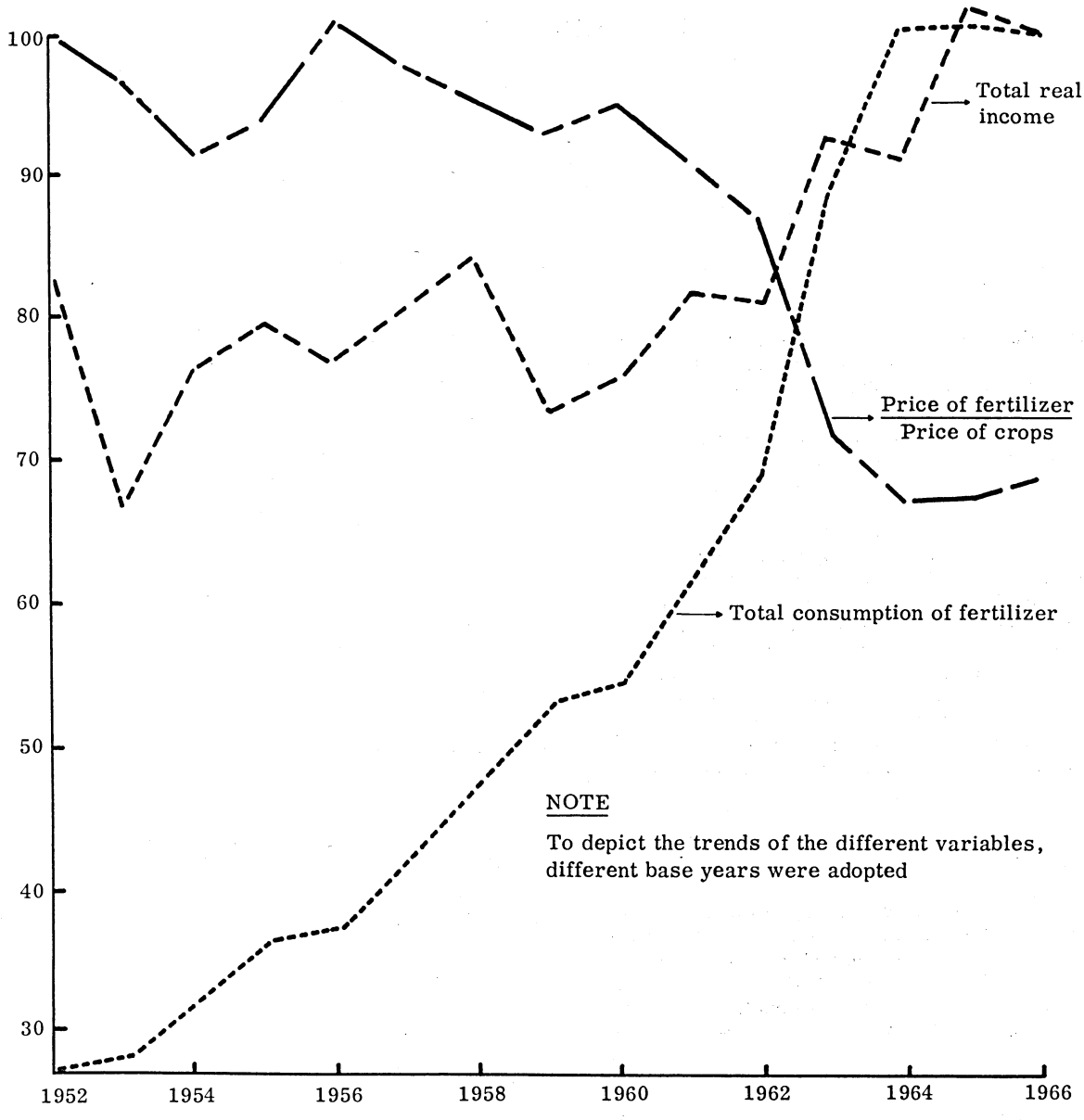

FIG. 1 - Trends in fertilizer consumption, the price of fertilizer relative to crops and real farm income, 1952-1966

$I_{I(t)}$ Cash income in rand from farming deflated by prices of farm inputs, including labour and lagged six months. The period 1947/48-49/50 was used as a base for input prices.

$C_{C(t)}$ Capital assets in million rand at constant prices on a calendar year basis. (1947/48-49/50 100).

The variables can be further explained as follows:

Nutrient consumption (F)

The dependent variable is the simple sum of tons of pure N, P and K, assuming that farmers attach the same importance to the different components. In an attempt to improve the model, the purchases of individual plant nutrients were also weighted by their respective price coefficients. The assumption is made that farmers are only interested in the weight of plant nutrients applied and not in the total weight of the fertilizers.

Real or relative price of fertilizer (P_F)

Price indexes of fertilizer were computed by dividing the expenditure on fertilizer by the consumption of nutrients. In determining the cost of fertilizer to the farmer, the subsidy on fertilizer was also considered. The fertilizer price is thus calculated as:

$$\text{Price} = \frac{\text{Total expenditure on fertilizer minus subsidy}}{\text{Consumption of plant nutrients}}$$

This price index was deflated by the crop or wholesale price index of the same year. Farmers know the prevailing fertilizer prices, but can only guess at crop prices for the rest of the year. This indicates that farmers buy fertilizers on the basis of

TABLE 1 - Statistics of estimates of demand functions for fertilizer, (t values in parentheses), South Africa.* (Key to variables presented in section 3)

Equation	d	df	R^2	Constant	$P_{FC(t)}$	$P_{F(t-1)}$	$P_{FW(t-1)}$	$I_{W(t)}$	$P_{LW(t-1)}$	$C_{C(t)}$	$I_{I(t)}$	$F_{(t-1)}$
2(L)	2,19	9	0,958	-13,40			-0,933 (t=1,8)	0,822 (t=1,5)	1,140 (t=4,3)	1,708 (t=2,6)		
3(O)	2,57	9	0,964	-89 494			-2 756 (t=2,4)	0,474 (t=2,1)	854 (t=2,6)	78 (t=1,7)		
4(L)	1,87	10	0,907	- 4,34		-1,207 (t=2,7)			1,388 (t=6,0)	1,928 (t=2,6)		
5(O)	1,50	21	0,980	153 363	-1 483 (t=3,7)							0,792 (t=9,0)
6(L)	1,38	20	0,991	3,85		-0,811 (t=5,5)					0,297 (t=1,8)	0,648 (t=9,4)
7(L)	1,63	21	0,989	6,08	-0,708 (t=5,0)							0,746 (t=16,1)

L = Napierian logarithms
O = Original values

* Total tonnage of pure plant nutrients is taken as the independent variable in equations 2,3,5,6 and 7. Fertilizer consumption data in equations 2 and 3 were calculated by the Division of Agricultural Marketing Research for the period 1952-1966, while the consumption data on which equations 5,6 and 7 are based, were calculated by Prof. Orchard, Head of the Soil Science Department at the University of Natal for the period 1944-1967. Consumption of plant nutrients is weighted in equation 4 for the period 1952-1966

current fertilizer prices but past crop prices. However, because the greater part of fertilizer is sold during the latter part of the calendar year in South Africa the price of fertilizer was deflated by crop prices of the same year. Because of price stabilising measures under the Marketing Act, prices of summer and winter cereals do not vary much from year to year.

Cash income of farmers (I)

This includes cash income and value of farm consumption minus wages, salaries, interest and rent. Fertilizer companies in South Africa are aware of the fact that more fertilizer is sold when a good crop is expected or harvested.

The expected sign of this coefficient is positive because a priori reasoning indicates that an increased demand for fertilizers is associated with a higher level of income and because higher incomes improve the liquidity position of farmers. When capital is limited, farmers will be unable to fertilize at optimum rates. Under these conditions the marginal cost of resources will be equated with one another but each will be less than the corresponding marginal revenue. An increase in income will thus encourage farmers to move towards the optimum level of fertilization. Fertilizer studies conducted in South Africa also indicate that this factor is applied below optimum levels.

Capital assets (fixed)

In addition to income, this variable is a measure of purchasing power. Capital assets are an indication of the borrowing capacity of the farmer. The level of capital assets may also influence the productivity of fertilizer. Capital assets include machinery, implements and vehicles, livestock, fixed improvements and land.

Prices of related inputs

The relationship between the consumption of fertilizer and the price of land can be expected to be positive as this is an indication of a substitution of fertilizer for land.

4. THE RESULTS

In Table 1 regression coefficients of fertilizer demand are presented with t values in parentheses.

When an instantaneous adjustment to price changes is assumed the fertilizer price elasticity is estimated as approximately one in equations 2 to 4. This means that if the "real" price of fertilizer declines by 1%, then the consumption of fertilizer will increase by about 1%.

Making allowance for a lag in adjustment*, 99% of the variation in fertilizer purchases are explained by the price of fertilizer relative to crops in models 5 and 7. In model 7 the short run price elasticity is estimated as -0,71 and the long run elasticity as -2,79, showing an inelastic short run demand but an elastic long run demand. The adjustment coefficient is estimated as 0,25 (1-0,75), indicating that almost 80% of the indicated adjustment is completed within five years of the displacement.

The liquidity position of farmers as expressed by the income variable also affected fertilizer consumption. The income elasticity was positive but less than one in equations 2, 3 and 6. An increase in cash income of farmers by 1% is estimated to increase fertilizer consumption by about 0,7%. This indicates the direction, and to some extent the possible change in fertilizer consumption as a result of a good crop or a drought.

The cross price elasticity of fertilizer purchases with respect to the lagged price of land is positive in equations 2, 3 and 4 indicating that fertilizers are good substitutes for land. A 1% increase in the lagged price of land is predicted to lead to an increase in fertilizer consumption which is marginally greater than 1%. However, a farmer purchases fertilizer to use on a given acreage, and not directly to substitute for land by reducing acreage.

The fact that the land price variable was highly significant may also be attributed to correlations between land price and time, and land price and general technological progress. It is highly probable that there exists a strong correlation between land price and the awareness amongst farmers of the beneficial effect of fertilizers. The effect may also be in the opposite direction; the price of land may be a function of fertilizer inputs since land productivity increased as a result of factors such as better varieties and the greater use of fertilizer. Because of increased yields per unit, farmers are prepared to pay higher prices for land.

A 1% increase in capital assets is expected to increase fertilizer consumption by as much as 1,7% (equations 2, 3 and 4). The coefficient of capital assets is significant and positive, and indicates that fertilizers and durables are complementary.

In all the models, except 4, the N, P and K contents of all fertilizers were simply added together to arrive at the total plant nutrient tonnage. In 4 the nutrients of N, P and K were weighted before being aggregated. The weights were derived from a multiple regression of prices for different mixes of fertilizer for South Africa. A random sample of 19 fertilizer mixes from different companies was used for this purpose.

The partial regression coefficients in the following equation, in original data, were used as weights for equation 4:

$$Y = 6,54 + 1,196\,N + 2,612\,P + 0,828\,K \quad \ldots\ldots \quad 8$$
$$(t=9,34) \quad (t=6,10) \quad (t=5,83)$$

$$R^2 = 0,876$$
$$df = 15$$

Y is the total value of the fertilizer mixture and N, P, K indicate the percentage content of these nutrients in the mixture.

* For method persued see Griliches, G. (1958). The demand for fertilizer. Jour. Farm Econ., 40:591-606.

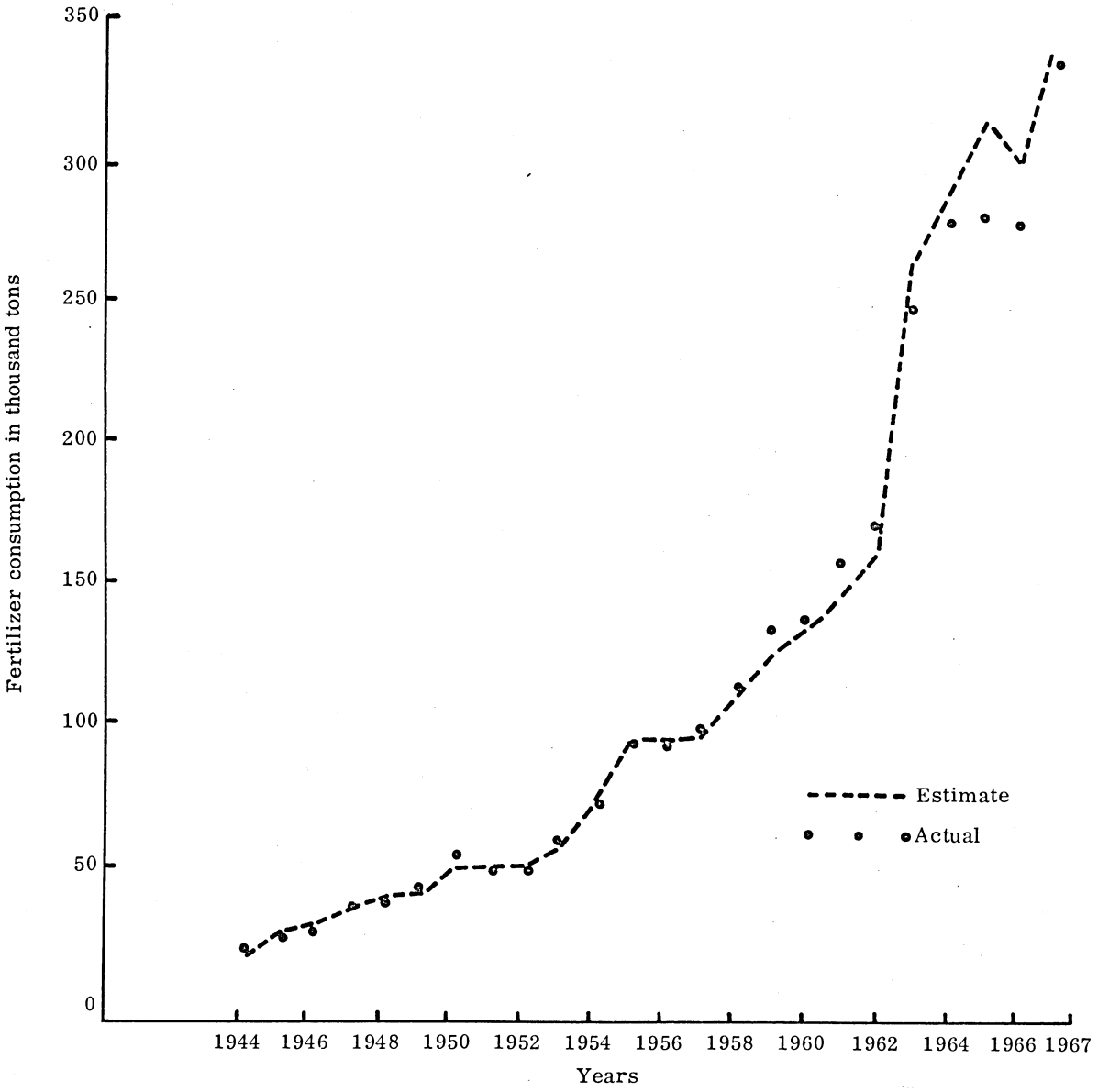

FIG. 2 - Actual and estimated consumption of fertilizer, South Africa, 1944-1967 (Model 7)

If 4 is compared with the other equations in Table 1 then no real difference can be detected between weighted and unweighted estimates of price and cross price elasticities.

The actual amounts of fertilizer purchased and the estimated quantities based on equation 7 are portrayed in Fig. 2 for the period 1944-1967. The model predicts consumption accurately except that it overestimates during the years 1964-1966, and this may partly be attributed to drought conditions that prevailed. For example gross value of maize production declined from an average of R188 million for the period 1961-1963 to R148 million for the period 1962-1965. In equation 7 only the price effect was considered and the reduction in spending power was neglected.

5. CONCLUSIONS

From 1952 to 1966 the consumption of fertilizer plant nutrients in South Africa increased by about 380%, while the absolute price of plant nutrients decreased by approximately 17%. In this paper the causes of this phenomenal increase in fertilizer use, were identified and measured statistically.

The results indicate that the "real" price of fertilizer has a significant effect on its consumption. Assuming instantaneous adjustment, a 10% fall in the "real" price of fertilizer will lead to an increase in consumption of approximately 10%. A fall in the "real" price of fertilizers could arise because of (a) an increase in the nutrient content of fertilizers without affecting the total price; (b) an increased Government subsidy to farmers; (c) an increase in product prices; and (d) a fall in the absolute price of fertilizer.

The effect of Government policies concerning fertilizer subsidies and product price supports can thus to some extent be numerically calculated.

The present fertilizer subsidy of about R14 million can be expected to increase fertilizer usages

by about 20% or approximately 70 000 tons of pure plant nutrients. At present concentration levels of plant nutrients in fertilizer, this implies an increase of about 400 000 tons of fertilizer. A 10% increase in the nutrient content of fertilizers or a 10% reduction in fertilizer price or a 10% increase in crop prices is expected to stimulate fertilizer usage by about 36 000 tons of pure plant nutrients. Allowing for a lag in consumption as a response to fertilizer price changes, the short run elasticity of fertilizer price was estimated at -0,75 and the long run elasticity at -2,50. These estimates were made from the distributed lag model 7. It was also estimated that approximately 80% of the indicated adjustment should be completed within five years. If all fertilizer suppliers reduce the price of their product, then it is expected that their total revenue will decrease in the short run but increase in the long run. Whether profits would increase in the long run with a reduction of fertilizer price depends on the cost conditions of supplying the greater quantity.

The following other factors were found to have an important effect on the amount of fertilizer purchased: Cash income of farmers, price of land and capital assets. The cross price elasticities of the explanatory variables were approximately as follows: Farm income +0,7, land price (lagged) +1,2 and capital assets +1,7. Thus, if cash income from farming increases by 10% in a favourable crop year, it can be expected that the total fertilizer consumption in agriculture will increase by a smaller proportion.

A strong complementary relationship existed between purchases of fertilizer and capital assets. These assets are also a proxy of the liquidity position of farmers and can be expected to have a positive influence on demand. Capital assets on farms are also highly correlated over time with improvements such as the selection of better seed and land improvements. These complementary factors resulted in an upward shift of the fertilizer demand schedule.