Projection of the Demand for Fertilizer

— Time series data analysis —

by

Bai Y. Sung, Dale C. Dahl, and Young K. Shim

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I. Introduction

Total consumption of commercial fertilizer in Korea has been increased at a rapid rate during the last two decates. In the period from 1952 to 1961, the consumption of fertilizer was 208 thousand metric tons. In the period from 1962 to 1971, the average consumption was increased to 442 thousand metric tons on the plant nutrient basis per year on the average. During the same period the total area of arable land was not increased, but there was a little increase in the rate of land utilization by the multi-cropping farmers. Therefore, the usage of fertilizer on the unit cultivated area has been doubled during the last two decades. Also the component of fertilizer on the basis of N, P, and K have been changed along with more usage of fertilizer by the farmers. The nutrients, N, P, and K composed 94, 1, and 5 precent in 1952, 64, 31, and 5 percent in 1962 and 58, 26, and 16 percent in 1972. This means that farmers follow a more balanced fertilizer application that is encouraged by the government.

Most of the fertilizer consumption by farmers was imported up until early 1967. Recently there are six fertilizer manufacturing plants that have a potential of reaching self-sufficiency, particularly in nitrogen production at the present, However, if the consumption of fertilizer continues with the same trend as the previous two decades, there will be a shortage of fertilizer supply after several years again. For this, it is important to figure out the possible demand in the future for the preparation of another plant to increase production. Also, it would be very important to improve our knowledge about the changing of the individual nutrient component year after year.

In view of this, a study of the demand for fertilizer will help future planning by the manufacturers as well as the government. Unfortunately, there are limitations of research work on demand dealing with the aspect of fertilizer so far. This study purposes to quantify the

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**Bai Y. Sung is research assistant and Dale C. Dahl is professor of agricultural and applied economics, both at the University of Minnesota. Young K. Shim is professor of agricultural economics at Seoul National University, Korea.

potential demand for fertilizer by nutrients in Korea for policy making.

All of the data used in this study, except land prices and the seed improvement index, are derived from official reports of the Ministry of Agriculture and Fisheries and the National Agricultural Cooperative Federation.

Ⅱ. Statistical model

Two models are established using two different assumptions: (1) instantaneous quantity adjustment and (2) lagged quantity adjustment. The first model is a multi-variable model and the second is an adjustment model. The multi-variable model assumes that quantity adjusts instantaneously to changes in price, but the relationship between price and quantity shifts because of changes in other relevant variables.

Under the assumption of instantaneous quantity adjustment, four functions are estimated for total plant nutrient, nitrogen, phosphate, and potash. The equations fitted are linear and linear in logarithms: $Y_k=A_k+\Sigma_i b_{ik}X_{ik}+\Sigma_j b_j X_j+e_k \qquad k=1,2,3,4$

Where k represents total nutrients, nitrogen, phosphate and potash, i represents the specific variable corresponding to each nutrient function, and j represents the common variables to all nutrient functions. In estimating demand functions for each nutrient separately using the ordinary least squares method (OLS), the error term e_k is assumed to be independent of the error in the other nutrient demand functions. If the e's are correlated with each other, estimation of the demand parameters using generalized least squares wiil give more efficient estimates than OLS.

In the adjustment model it is assumed that quantity adjustment in relation to change in prices does not take place instantaneously. The demand function determines the desired use and the long-run equilibrium level of use. Between one period and the next, actual use changes only by some fraction of the difference between the current use and the desired use. The adjustment equation assures that the farmer moves in the direction of eliminating the disequilibrium but does not necessarily eliminate it all at once. Actually, equilibrium would be attained only if all the independent variables were to remain constant, which they never do. We assume that the change in fertilizer use is a function of the difference between "desired" and current use. In particular, it is assumed that the adjustment equation is linear in the logarithms of the desired and actual consumption, hence the implicit adjustment path is non-linear, slowing down as the difference between the two becomes small.

The basic model expressed as follows:

$$\log Y_t^*=\log b_0+b_1 \log X_{1t}+b_i \log X_{it}+u_t$$

where Y_t^*=the desired level of fertilizer consumption

X_1=the price of fertilizer or relative price

X_i=other shifting variables (these variables are alternatively added)

u_t=disturabnce term

The adjustment equation is:

$$\log Y_t^* - \log Y_{t-1} + r(\log Y_t^* - \log Y_{t-1})$$

The variables used are the following:

As dependent variables:

Y_1=total nutrients of commercial fertilizer consumed per year (1,000M/T)

Y_2=total nutrients of nitrogen consumed per year (1,000M/T)

Y_3=total nutrients of phosphate consumed per year (1,000M/T)

Y_4=total nutrients of potash consumed per year (1,000M/T)

As independent variables:

a) own price index:

X_1=annual average real price index of total fertilizer paid by farm (1965=100). Average real price is obtained by dividing the annual weighted average of price per kg of nutrient of ammonium sulfate, urea, triple super phosphate, and potassium chloride by wholesale price index.

X_2=average real price index of nitrogen on the farm. Annual weighted price of ammonium sulfate and urea divided by wholesale price index is the average real price of nitrogen.

X_3=average real price index of phosphate on the farm. The price of triple super phosphate is averaged annually to be the average price of phosphate.

X_4=average real price index of potash. The price of potassium chloride is annually averaged out to be the average price of potash.

b) other input prices:

X_5=real price index of farm wage. Farm wage accounts only for hired labor.

X_6=real price index of farm machinery. This price is an annually weighted average of monthly prices of hoe, shovel, forked rake, weeding hoe, plow, sprayer, thresher, agricultural motor, pumping machine and plow share.

X_7=price index of land

c) output price:

X_8=real index of price received by farm, one year behind. Annual average weighted price of all crops at the farm level is divided by the wholesale price index to be the real price received by farm.

d) technological change:

X_9=ratio of well irrigated area

X_{10}=seed improvement index of rice. The weighted aveage of proportion of cultivated area of various rice varieties is calculated to make the seed improvement index. The weight is the average yield of the corresponding variety.

X_{11}=time

e) other veriable:

X_{12}=planting acre (1,000 ha.)

For this study, we took into consideration the following points:

1) The change in land price has little affect on the use of land in production, because all arable land is fully cultivated regardless of its price. Therefore, land price data is excluded from the variables in the models.

2) The weights used in determining various imput price indexes are the proportion of purchasing costs of a specific input to total expenditure for farming and households. The weights of output price are the ratio of values of a specific output to the total value of agricultural output produced.

3) It is assumed that farmers make decisions for use of fertilizer based on the price of fertilizer relative to the price received for crops because the market information systems are less developed so that farmers can not reasonably predict the price of crops at harvest time.

4) Technological change is regarded as an important factor in shifting the demand function over time. When time is used as a proxy for technical change, there are several limitations. First, it assumes that technological progress takes place at a constant rate which is not clear. Second, other variables used in the demand function have a strong trend so that multicollinearity between time and the other variables can cause estimation problems. Finally, since time can be a factor shifting the supply function of fertilizer as well as the demand function, the identification problem arises. Therefore, the seed improvement index and irrigated area to the total paddy fields will also be used as proxies for technological change.

(a) The development of new varieties of a crop is an important factor for technological change affecting the usage of fertilizer. The seed improvement index of rice was developed to reflect the improvemdnt in the variety of the crop. This index is the average of the proportion of the cultivated acreage of the important varieties of rice weighted by the average yield of the corresponding varieties. The important thirty-six varieties of rice out of about eighty which have been cultivated during the period from 1960-71 were used to develop this index.

The computed index is shown not to be so significantly different over time that it is not meaningful to incorporate this index into the fertilizer demand function. The new high yielding variety of Tongil rice (IR-667 system) was disseminated to farmers on very limited small areas 2,750 hectares in 1971. Therefore, the use of this index as an alternative proxy of technological change was excluded in this study.

(b) The irrigation ratio as another variable of technological change was also disregarded because the estimated results using the irrigated ratio were not significantly different from that of the model using the time variable.

5) The dependent variables Y_2, Y_3, and Y_4 (consumption of nitrogen, phosphate and potash) are not determined separately but simultaneously. The increase in use of these nutrients will not be explained by completly different variables but will include some common variables. Hence, the assumption that the error terms of the demand functions are independent does not hold and OLS estimation of the demand function will result in biased estimates. Therefore, the simultaneous estimation of the parameters using generalized least squares should result in more efficient estimation than OLS. Because of the small number of observations it is not possible to use generalized least squares. Therefore, ordinary least squares are used throughout the study.

It is hypothesized that (1) the slope of the demand curve of an input with respect to its own price is negative, (2) the signs of other input are either positive or or negative depending on whether they are substitutes or complements for commercial fertilizer, (3) output price has a positive effect on the use of fertilizer, and (4) technology plays an important role in explaining the increased use of fertilizer.

Ⅲ. Results of the analysis

The regression coefficients and related statistics for total fertilizer demand equations are shown in the following table 1. The equation (Ⅰ) includes such variables as price of fertilizer, wage, machine price, output price, land, and time in linear. The equation (Ⅱ) represents a linear in logarithms of the same variables as in equation (Ⅰ). Both equations are the multi-variable models under the assumption of instantaneous quantity adjustment.

The coefficients of the fertilizer price is negative as expected but are not statistically different from zero. The coefficients of output price are negative and are not statistically significant. The significant coefficients of the fertilizer price and output price can be

Table 1. Regression coefficients and related statistics for total fertilizer demand function, Korea, 1960-1972

	Equations		
	I (Linear)	II (Linear in logarithm)	III (Linear in logarithm)
Intercept	184.1074	3.5354	1.9591
(a_1)	(599.7224)	(9.4543)	(1.5935)
Price of fertiilzer	−0.8367	−0.1655	−0.1688
(x_1)	(1.7207)	(0.3603)	(0.1882)
Wage	1.4349	−0.3337	
(x_3)	(1.5450)	(0.4355)	
Price of machinery	−1.3651	0.3316	
(x_6)	(4.0715)	(0.8819)	
Price of output	0.3966	0.1218	
(x_8)	(1.8736)	(0.3614)	
Land	0.0105	0.2312	
(x_{12})	(0.1061)	(0.8910)	
Time	21.7188+	0.0592*	
(x_{11})	(11.9274)	(0.0285)	
Lagged D.V.			0.8090**
(Y_{1t-1})			(0.1370)
Coefficient of adjustment (r)			0.191
Long-run elasticity (b_1)			0.884
R^2	0.969	0.968	0.945
F	60.86**	62.99**	105.85**
D	2.14	2.34	1.84

Figure in ( ) is corresponding standard error

R^2 : coefficient of determination adjusted by degree of feeedom

F : F-statistic

D : Durbin-Watson statistic

Significance level **= 1 percent

*= 5 percent

+=10 percent.

explained by the following. First, most of the farms produce their output for subsistence. These subsistence farmers may evaluate their output more than market prices and may not relate to market prices. This means that the fertilizer price and the output price may not be an important factor in the farmer's decision to buy fertilizer. Secondly, the information service is too primitive to provide the expectation of output and price information to farmers in advance. Thirdly, the government administrates the supply price and quantity of fertilizer based on fertilizer production costs and the distribution costs of fertilizer. Finally, the underlying fertilizer response schedule may be so steep that price changes have little effect on the use of fertilizer.

The demand elasticity with respect to the farm wage rate is about 0.33. This implies that fertilizer is a substitute for farm labor. Over a certain range, fertilizer can be substituted for human care for crops. A more important factor in Korean history would be the effect of substitution of commercial fertilizer for the labor allocation to the production of self-supplied fertilizer such as compost and animal and green manures.

The economic relationship between fertilizer and farm machinery can not be specified with the statistical model.

The coefficients of land in linear equation is very small and is not statistically different from zero. The land coefficient in linear equation says that if the planting area increases by one hectare the fertilizer consumption increases by 10 kilograms. The cross-elasticity between fertilizer use and planting area is about 0.23.

The consumption of fertilizer appears to have a positive trend over time but it is not statistically significant. The coefficient of the time variable in linear equation is 21.7, which means that total fertilizer consumption has been increased by 21.7 thousand tons every year, if the other variables remained constant. The time variable as a proxy for technological change is the most important variable affecting the increase in the use of fertilizer.

The results of estimating the total demand for fertilizer using the adjutment model are presented in equation (Ⅱ) that is linear in logarithm in Table 1. The estimated coefficient of adjustment is 0.2 indicating that approximately 20 percent quantity adjustment to the price change is completed within one year. This regression implies a substantially higher price elasticity in the long-run than in the short-run. The short-run price elasticity of fertilizer demand is −0.17 but is not statistically significant, whereas the long-run elasticity is −0.88. Obviously, the fertilizer price is not the only variable affecting the demand for fertilizer, and the omission of some other relevant variables would tend to bias the estimates of these coefficients. Therefore, we might say that this estimate of long-run elasticity is somewhat too high and that the estimate of the adjustment coefficient is somewhat too low. Inclusion of other variables in the adjustment equation results in meaningless coefficients.

The coefficients of determination in all equations are more than 0.94, but all of the coefficients in the multi-variable model are not statistically significant except that of time variable. This result comes from the fairly high correlation between independent variables and from the small number of observations. But the individual nutrient demand functions shows statistically significant coefficients. The F-statistics are so high that we can say that the regression relationship is very significant. The significance test based on the t and F distribution are no longer valid when the error terms are autocorrelated. Unfortunately, the computed Durbin-Watson statistics (D) with 13 observations can not be compared with the theoretical Durbin-Watson Statistics table. But by extrapolation we may say that there is neither positive nor negative serial correlation at the 5 percent significance level.

Ⅳ. Demand peojection for fertilizer

In the time series analysis, demand functions of total and individual nutrients are estimated using prices of total and individual nutrients, wage rate, machine price, cropping acres and technological change as explanatory variables from 1960 to 1970 on an annual basis. After all exogeneous variables introduced are estimated by trends, linear and linear in logarithm equations are estimated under both assumptions of instantaneous quantity adjustment and the quantity adjustment takes place over time.

The estimated results of demand for fertilizer are utilized in the projection. The projection of demand was based on the aggregate demand functions estimated from time series data, the economic and technological variables are utilized. The economic variables (E) include the prices or quantities of inputs and output such as prices of fertilizer, wages, prices of farm machines, price received by farmers, family labor used, composts, and total land cultivated. The technological variables (T) include the developmen of new varieties, irrigation, and the time period.

For the projection the following function form was applied under the assumption that the other variables remain constant over time.

$$Q_{Fi}^{FD} = F(E,T)$$

Where i represents total and individual nutrients at the national level, and the comma between variables means and/or.

As a result, the actual quantities of fertilizers consumed in 1971 and the conditional projections of demand for fertilizers based on the aggregated demand functions are presented in table 2. The quantites demanded of total fertilizer are 709, 882 and 1,053 thousand metric tons in 1975, 1980 and 1985 respectively. The sums of quantities projected of individual nutrients are 717, 880 and 1,044 thousand metric tons in 1975, 1980 and 1985 respectively. These sums result in increases by 17, 46 and 75 percent compared with the actual consumption of fertilizer in 1971.

Among total fertilizer projected, nitrogen will be increased by 56, 55 and 55 percent, phosphate 25, 24, 23 percent, potash, 19, 21, 22 percent in 1975, 1980 and 1985 respectively.

Since this aggregate demand functions were made after a small number of years of observation, the non-statistical error might be great and multi-collinearity between independent variables due to the trend of these variables over time could distort the econometric analysis by providing unstable estimates.

The assumption wihch were made here for the projection may be changed over time. Also technological change in both the input industry and agriculture tends to have a gradual influence on the demand for fertilizer and the government policies for the price and quantity supplied will be affected in determining the demand for fertilizer. In view of this, the projected quantity of fertilizer could greatly change according to the changing of assumptions and variables which we made in this study.

Table 2. Projection of fertilizer use in 1975, 1980 and 1985 based on the aggregate demand functions and the optimum rate of fertilization

	1971	Aggregate demand estimated		
	Actual Data	1975	1980	1985
	M/T	……(1,000M/T)……		
Totual	605,137	709	882	1,053
N	347,318	401(56)	486(55)	576(55)
P	165,030	177(25)	212(24)	242(23)
K	92,789	137(19)	182(21)	226(22)
Σ		717(100)	880(100)	1,044(100)

V. Conclusion

In the time series analysis demand functions of total and individual nutrients are estimated using prices of total and individual nutrients, wage rates, machine prices, cropping acres, and technological changes as explanatory variables from 1960 to 1972 on an annual basis. All prices were constant in 1965. Linear and linear in logarithm equations are estimated under both assumptions of instantaneous quantity adjustment and on the belief that quantity adjustment takes place over time.

(1) Prices of fertilizer do not significantly affect the use of total fertilizer and nitrogen but have a significantly negative effect on the use of phosphate and potash. Prices of output measured as the price index received per farm were insignificantly related to the use of total fertilizer and potash nutrients were negatively related to the use of nitrogen and positively related to the use of phosphate. These results imply that nitrogen occupies a large proportion of the total fertilizer used and might have been over-utilized relative to its requirements. An

increase in farmers' awareness about the effects of phosphate and potash on their crop due to increasing efforts of extension and field demonstrations contributes significantly to their use. Poor market information system and the subsistance farming are partly related to the insignificant price responses.

(2) The substitutability of fertilizer for labor is observed in nitrogen but not phosphate and potash. The fact that self-supplied manure contains mostly nitrogen nutrients may explain that the increase in farm wages induces substitution of commercial nitrogen for labor. None of the significant effects of farm machinery prices are found in any of the nutrient models.

(3) An insignificant positive relationship between uses of total fertilizer and individual nutrient are observed. The positive relationships are expected but a small variance in the planting acres results in this insignificance.

(4) Because of a constant trend in the seed improvement index and because of the same results for irrigation acre in regard to time, a time variable is used as a technological change with limitations of multicollinearity between other explanatory variables due to their trend variables over time and with assumptions of constant rates of technological change. Large increasing trends in the use of fertilizer are observed, especially in phosphate and potash. Awareness of farmers about the effectiveness of these nutrients as well as the government's encouragement of balanced fertilization contribute greatly to these trend increases. The quantity adjustment is about 20 percent in one year to a change in real price of fertilizer.

(5) The projection of demand for total fertilizer results in increases by 17, 46 and 75 percents in 1975, 1980 and 1985 respectively compared to actual consumption in 1971. As the proportion of nitrogen constant over time, that of phosphate is decreased, and that of potash is increased.

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적 요

시계열분석에 의한 비료수요 계측

성배영, 데일 씨 · 달, 심영근

우리나라의 금비 소비량은 근래 급속히 증가되는 경향에 있다. 지난 1952년부터 1961년까지의 10년간 년평균 소비량은 208천톤이였는데 그후 10년간인 1962년부터 1971년까지의 년평균 소비량은 442천톤으로 배가 되었다. 이와 같은 추세에서 소비가 앞으로도 계속된다면 1975년, 1980년과 1985년에는 각각 얼마의 수요총량이 되며 소비되는 삼요소의 비율에 있어서의 구성비는 각각 어떻게 변화되는 가를 계측하여 정부 시책수립과 생산업자에 자료를 제공하는데에 목적을 두었다.

계측에 있어서의 자료는 1960년부터 1970년까지의 정부통계를 이용하여 시계열분석을 했고 여기에 쓰여진 변수는 경제적인 것과 기술적인 것에 중점을 두었다. 이 분석에서 얻어진 결과는 총량으로 추계했을 때 얻어진 비료의 수요 추정량은 1975년에는 705천톤, 1980년에는 882천톤 그리고 1985년에는 1,053천톤이 되었다. 이와 대조적으로 3요소의 성분별로 소요량을 추계하여 합산했을

때는 1975년의 717천톤을 제외하고는 위의 수량보다 약간 적어져서, 1980년에는 880천톤 그리고 1985년에서는 1,044천톤으로 추정되었다.

물론 이 분석에서 쓰여진 변수와 주어진 가정에 있어서의 변화 여하에 따라 비료의 수요 추정량에는 변화가 있게 되지만 이 분석에는 얻어진 추계에서 볼 때 1970년대의 수요 총량은 1960년대에 비해 다시 배증된 소비량이 될 것이라고 말할 수 있을 것 같다.