An Econometric Model of Relationship between Inputs and Aggregate Agricultural Production in Gujarat State—1961-62 to 1973-74[*]

T.K. Jayaraman[**] and *V.B. Savdasia*[**]

Introduction

THE objective of this paper is to explain the past agricultural production trends by the levels of use of certain agricultural inputs and prices of these inputs in Gujarat State. Non-availability of detailed data in regard to various agricultural commodities and inputs utilised in the production of each of these commodities has forced the study to be confined to agricultural production in aggregative sense covering both cereal and non-cereal crops, including cash crops. The paper is divided into three sections. The first section describes the methodology adopted in this study. The second section presents the empirical findings, whereas the third and the final section summarises the conclusions emerging from the study.

*This paper was presented at the Conference of the Indian Society of Agricultural Economics at Surat in November 1976.

**Dr. T.K. Jayaraman is Area Development Commissioner, Kadana Irrigation Project, Ahmedabad and Shri V.B. Savdasia is Joint Director, Bureau of Economics and Statistics, Government of Gujarat.

The authors are grateful to the Gujarat Computer Centre for all facilities. The views expressed in this Paper are the personal views of the authors and do not reflect those of the Government.

©NCAER [Margin, July/Oct. 1977, Vol. 9, No. 4 & Vol. 10, No. 1]

Methodology

It is hypothesised that the agricultural production in the State is a function of capital employed, fertilisers and energy consumed and average rainfall. This is not an exact production function since it may be seen that we have excluded the labour variable. The labour variable is hypothesised to have a direct effect on the capital employed and the amount of the fertilisers and energy consumed in the production of agricultural output through impact of pressure of population on land. This particular interaction is explained later. With a view to avoiding multicollinearity, labour as a variable has been eliminated from the functional relationship.

The capital employed in turn depends on long term loans obtained lagged by one period, hectares per capita and irrigation expenditure incurred by the Government. Specification of long term finance in the acquisition of capital employed is straight forward. The delayed effect of loan on capital obtained is explained by the lagged nature of the variable since it at least takes a while to acquire machinery such as pump sets or tractor once the loan is obtained. Through the variable of hectares per capita, we are trying to assess the influence of population pressure on land on intensive cultivation. A decline in the per capita land availability leads to intensive use of land which is reflected in the augmentation to capital employed in agriculture. Similarly, if irrigation facility provided by the Government decreases, there is a consequential increase in private capital employed to compensate it in terms of digging wells and installation of oil or electric motors.

The level of fertilisers used is hypothesised to depend on their price level, land per capita reflecting the intensive use of land and short term finance facilities. Similarly, the level of energy is assumed to depend on its price, land per capita and short term finance available to the farmers.

The per capita land under cultivation is hypothesised to depend on the level of production lagged by one period, rainfall and irrigation expenditure incurred by Government. It is assumed that there is a positive relation with the past years production level and the current year quantum of land under cultivation. Given the population, a rise in production leads to extensive cultivation of land. Similarly there is a positive association between rainfall and hectares per capita under cultivation. In regard to irrigation expenditure incurred by Government it is assumed that a reduction in expenditure should lead to extensive cultivation of land; hence there is a negative relationship between the dependent and the explanatory variables.

The above hypothesised relationships are expressed in notational form in a system of equations given below:

$$Q=f\,(K,\ F,\ E,\ R) \qquad (1)$$

$$K=f\,(LT_{-1},\ \frac{A}{POP},\ IRE) \qquad (2)$$

$$F=f\,(Fp,\ \frac{A}{POP},\ ST) \qquad (3)$$

$$E=f\,(Ep,\ \frac{A}{POP},\ ST) \qquad (4)$$

$$\frac{A}{POP}=f\,(Q_{-1},\ R,\ IRE) \qquad (5)$$

where

Q = Aggregate agricultural production;
A = Total hectares under cultivation;
F = Fertilisers consumed in aggregate;
E = Energy consumed in aggregate;
K = Cumulative investment in agriculture at constant prices;
LT = Long term loan capital at constant prices;
ST = Short term loan capital at constant prices;
IRE = Irrigation expenditure incurred by Government in constant prices;
POP = Population in millions;
Fp = Fertiliser price;
Ep = Energy price;
R = Rainfall;
P = Agriculture price;
W = Wholesale price.

In addition to the above aggregative model, the following model per hectare basis was also used for the study:

$$\frac{Q}{A}=f\,(\frac{K}{A},\ \frac{F}{A},\ \frac{E}{A},\ R) \qquad (1)$$

$$\frac{K}{A}=f\,(\frac{LT}{A_{-1}},\ \frac{A}{POP},\ \frac{IRE}{A}) \qquad (2)$$

$$\frac{F}{A}=f\,(Fp,\ \frac{A}{POP},\ \frac{ST}{A}) \qquad (3)$$

$$\frac{E}{A}=f\,(Ep,\ \frac{A}{POP},\ \frac{ST}{A}) \qquad (4)$$

$$\frac{A}{POP}=f\,(\frac{Q}{A_{-1}},\ R,\ \frac{IRE}{A}) \qquad (5)$$

The above system on equations has five endogenous variables (Q, K, F, E, $\frac{A}{POP}$) and seven predetermined variables (R, LT_{-1}, ST, Fp, Ep, IRE, Q_{-1}).

As there is simultaneity bias involved for estimating the equations, regression analysis was carried out using the method of two-stage least squares[2]. While running regressions an error term was added to each of the equations. Further, time trend was also included as a variable in each of the equations. This is in accordance with our assumption that the combined influence of the variables left out in the true equations is a smooth function of time[3].

Apart from running the regression equations in linear form, regressions were also carried out in double logarithmic forms. The purpose was to obtain the most appropriate set of functional relationships, fitted out of the four different models:

(1) Linear aggregate model

$$Q = a_{11} + a_{12}K + a_{13}F + a_{14}E + a_{15}R + a_{16}T + e_1$$

$$K = a_{21} + a_{22}LT_{-1} + a_{23}\frac{A}{POP} + a_{24}IRE + a_{25}T + e_2$$

$$F = a_{31} + a_{32}Fp + a_{33}\frac{A}{POP} + a_{34}ST + a_{35}T + e_3$$

$$E = a_{41} + a_{42}Ep + a_{43}\frac{A}{POP} + a_{44}ST + a_{45}T + e_4$$

$$\frac{A}{POP} = a_{51} + a_{52}Q_{-1} + a_{53}R + a_{54}IRE + a_{55}T + e_5$$

(2) Linear per hectare model

$$\frac{Q}{A} = b_{11} + b_{12}\frac{K}{A} + b_{13}\frac{F}{A} + b_{14}\frac{E}{A} + b_{15}R + b_{16}T + e_6$$

$$\frac{K}{A} = b_{21} + b_{22}\frac{LT}{A-1} + b_{23}\frac{A}{POP} + b_{24}\frac{IRE}{A} + b_{25}T + e_7$$

$$\frac{F}{A} = b_{31} + b_{32}Fp + b_{33}\frac{A}{POP} + b_{34}\frac{ST}{A} + b_{35}T + e_3$$

$$\frac{E}{A} = b_{41} + b_{42}Ep + + b_{43}\frac{A}{POP} + b_{44}\frac{ST}{A} + b_{45}T + e_9$$

$$\frac{A}{POP} = b_{51} + b_{52}\frac{Q}{A-1} + b_{53}R + b_{54}\frac{IRE}{A} + b_{55}T + e_{10}$$

(3) Log linear aggregate model

$$\log Q = c_{11} + c_{12}\log K + c_{13}\log F + c_{14}\log E + c_{15}\log R + c_{16}T + e_{11}$$

$$\log K = c_{21} + c_{22}\log LT_{-1} + c_{23}\log\frac{A}{POP} + c_{24}\log IRE + c_{25}T + e_{12}$$

$$\log F = c_{31} + c_{32}\log F_P + e_{33}\log\frac{A}{POP} + c_{34}\log ST + c_{35}T + e_{13}$$

$$\log E = c_{41} + c_{42}\log Ep + c_{43}\log\frac{A}{POP} + c_{44}\log ST + c_{45}T + e_{14}$$

$$\log\frac{A}{POP} = c_{51} + c_{52}\log Q_{-1} + c_{53}\log R + c_{54}IRE + c_{55}T + e_{15}$$

(4) Log linear per hectare model

$$\log\frac{Q}{A} = d_{11} + d_{12}\log\frac{K}{A} + d_{13}\log\frac{F}{A} + d_{14}\log\frac{E}{A} + d_{15}\log R + d_{16}T + e_{16}$$

$$\log\frac{K}{A} = d_{21} + d_{22}\log\frac{LT}{A-1} + d_{23}\log\frac{A}{POP} + d_{24}\log\frac{IRE}{A} + d_{25}T + e_{17}$$

$$\log\frac{F}{A} = d_{31} + d_{32}\log Fp + d_{33}\log\frac{A}{POP} + d_{34}\log\frac{ST}{A} + d_{35}T + e_{18}$$

$$\log\frac{E}{A} = d_{41} + d_{42}\log Ep + d_{43}\log\frac{A}{POP} + d_{44}\log\frac{ST}{A} + d_{45}T + e_{19}$$

$$\log\frac{A}{POP} = d_{51} + d_{52}\log\frac{Q}{A-1} + d_{53}\log R + d_{54}\log\frac{IRE}{A} + d_{55}T + e_{20}$$

where a_{ij}, b_{ij}, c_{ij} and d_{ij} are parametric coefficients and e's denote error term.

The data used in the study cover the period between 1961-62 to 1973-74 and are in the form of index numbers. They have been prepared on the basis of the official statistics of the State Government. An Appendix to this paper lists the data sources and describes the methodology involved in preparing the index numbers of the relevant variables.

Results of the Regression Analysis

Results of the regression analysis for each of the four models are presented in Tables 1 to 4.

With regard to the linear aggregate model, each of the five equations turns out to be a good fit since the adjusted R^2 for degrees of freedom is of a fairly high order. However, in the first equation fitting the aggregate production only rainfall seems to be the significant variable, the level of significance chosen being at 5% and it has the theoretically expected sign. In the second equation which has the investment as the dependent variable, per capita hectares has the theoretically expected sign and is significant at 5% level. This confirms that a decline in per capita hectares leads to intensive cultivation over time leading to capital intensiveness. In the third equation seeking to explain the variations in the level of fertilisers, none of the explanatory variables is significant. The equation having energy as the dependent variable has both the per capita hectares and short term loan variables with the expected signs and significant. This assures that a decline in per capita hectares leads to intensive cultivation through utilisation of energy and that higher short term loans lead to greater use of energy. In the equation attempting to explain the variations in per capita hectares, rainfall alone is significant confirming the relationship of positive association.

In the second linear per hectare model, we have again obtained good fits signified by R^2 adjusted for degrees of freedom. The first equation seeking to explain the variations in yield per hectare has two variables significant at 5% level. One is rainfall with the expected sign; the other is the energy variable with a disturbing negative sign. The equation with investment per hectare as dependent variable has only per capita land being significant with the appropriate sign. Again the third equation explaining variations in the use of fertilisers per hectare has no significant explanatory variables. However, the equation attempting to explain the variations in energy consumption per hectare has one variable being significant at 5% level, namely per capita land with the expected sign. The last equation with per capita land as the dependent variable has only rainfall as an explanatory variable significant and with the appropriate sign.

In the third model of log linear aggregate relationships, we have again good fits for all equations. In the first equation having aggregate production as the dependent variable, three explanatory variables are significant. Both rainfall and fertilisers have the expected positive signs whereas the energy variable has the disturbing negative sign as in the previous model.

The second equation with investment as the dependent variable has per capita land term loan lagged by one period significant and these two variables have the expected signs. Short term loan alone as an explanatory variable is significant in the next equation which attempts to explain the variations in level of fertiliser use. In the equation attempting to explain the variations in energy as the dependent variable, per capita land and short term loan are the two explanatory variables significant and they have the expected signs. But the energy price with a disturbing negative sign is also significant. In the last equation with per capita land as the dependent variable two explanatory variables are significant and have the appropriate signs. They are Government irrigation expenditure and the production lagged by one period.

In the final log linear yield per hectare model, rainfall with positive sign and energy consumption with inappropriate sign are significant in the first equation. In the second equation explaining the variations in investment per hectare three explanatory variables are significant and they have the appropriate signs. They are per capita land, long term loans lagged by one period, and Government irrigation expenditure. In the third equation having the fertiliser consumption per hectare as the dependent variable, none of the explanatory variables is significant. In the fourth equation attempting to explain the variations in energy consumption per hectare, per capita land is significant with the appropriate sign. However, the energy variable having the inappropriate positive sign is also significant. In the last equation with per capita land as the dependent variable only Government irrigation expenditure is significant having the appropriate sign.

Summary and Conclusions

An econometric analysis of relationship between inputs and agricultural production over a thirteen-year period, 1961-62 to 1973-74, shows that there is generally no clear picture of significant association between inputs and aggregate production. This is perhaps due to the aggregative nature of the study. Were detailed data available in regard to each of the major crops included in the aggregate production index, studies of specific crops might have been possible and they might have perhaps established relationships in clear terms.

Perhaps these very same limitations might have been responsible for the two strange results; one with regard to the theoretically inappropriate sign of energy variable in the first equation in Models 2, 3 and 4 and the other with regard to the negative sign of energy price in the fourth equation in Models 3 and 4. It is difficult to explain these unexpected results except to state that data deficiencies behind the construction of index numbers would have caused these results.

However, broadly speaking the study in general has established the following conclusions:

—Rainfall and consumption of fertilisers have been significantly responsible for agricultural production in the State during the last thirteen-year period.

—Though the significance of investment has not been established, long term financial loans do certainly influence capital formation in agriculture.

—Capital intensiveness is significantly influenced by the per capita land availability for cultivation.

—The significance of impact of price on the level of fertilisers consumption has not been established.

—Short term financing has a significant positive influence on the level of consumption of fertilisers.

—There is a significant direct relationship between rainfall and per capita land put to use.

It is difficult to select any one of the four models as the most appropriate model. All the four models have well fitted equations, though they do have the strange result relating to energy variable in the last three models.

References

1. Misra, V.N.: "Some Economic Factors and Population Pressure Crop Output Growth in Gujarat—An Inter-district Analysis", *Artha Vijnana*, Vol. XVI, No. 4, December 1974, pp. 419-440.
2. Johnston, J.: *Econometric Methods*, Second Edition, New York: McGraw-Hill Book Company, 1972, Chapter 9.
3. Rao, P. and Miller, R.L.: *Applied Econometric*, Belmont, California: Wadsworth Publishing Company, 1971, pp. 32-34.