CHAPTER VII

THE FITTED AGRICULTURAL PRODUCTION FUNCTION

1. INTRODUCTION

The purpose of the present Chapter is to understand the contribution of the quantities of different inputs to the total agricultural output. Such a study helps in the furtherance of the knowledge of the factors of differences in agricultural development in the districts. In addition, such knowledge, along with the knowledge of the supply position of different input factors, may provide an insight into the direction that agricultural development efforts should take in the districts of Karnataka. The form of the production function employed to understand the contribution to the total output, of the qunatities of different inputs, is stated in section two of the present study. The section also presents a brief survey of earlier findings. Section three describes specification of variables and sources of data. The production function estimates are presented in section four. The conclusion is given at the end.

2. COBB - DOUGLAS PRODUCTION FUNCTION AND EARLIER FINDINGS

Of all the forms of production functions, the Cobb-Douglas type of function has been tried throughout the world in the studies of agricultural production differences because of i) its convenience in interpreting elasticities of production, ii) its use involves simple computation. This form of production function considers the relationship of the inputs taken individually but simultaneously with that of output. The Cobb-Douglas or Power Function, in the form generally used is;

$$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} \ldots\ldots\ldots X_n^{\beta_n} u,$$

where ; Y (dependent variable) is output, α is a constant, X_1 , X_2 , X_3 .... X_n are definite inputs (independent variables) say, land, labour, tractor and others respectively. The exponents or β coefficients are the elasticities of output with respect to the inputs. 'u' is the error term. Although the function is non-linear, it can, with ease, be transformed into a linear function by converting all variables to logarithms. In logarithms, the associated Linear Function is,

$$\text{Log}Y = \text{Log}\alpha + \beta_1\text{Log}X_1 + \beta_2\text{Log}X_2 + \beta_3\text{Log}X_3 + \ldots\beta_n\text{Log}X_n + \text{Log}u.$$

The regression coefficients or the elasticities of the product show the percentage change in product if the input of a factor of production is increased by one percent. The computed elasticities again provide the basis for indicating the nature of returns to scale and computing marginal productivities. The nature of returns to scale are determined from the sum of the exponents or elasticities. In the above equation, if the sum of these is equal to 1, constant returns to scale exist, an increase in each input by, say 10 % will add 10 % to the total output. A sum < 1 indicates diminishing returns to scale, while a sum > 1 indicates increasing returns to scale.[1]

An important limitation of this function is that it allows either constant, increasing or decreasing marginal productivity and not an input-output curve embracing all the three and assumes a constant elasticity of production over the entire input-output curve.[2] Further, Cobb-Douglas Function encounters the problem of Multi-collinearity and also does not take in to account the complementarity and

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1 E. O. Heady, " Relationship of Scale Analysis to Productivity Analysis", in E. O. Heady, C. L. Johnson and L. S. Hardin (Eds.), " Resource Productivity, Returns to Scale And Farm Size", The Iowa State College Press, Iowa, U.S.A., 1956, pp 88-89.

2 E. O. Heady and J. L. Dillon, " Agricultural Production Functions", Kalyani Publishers, Ludhiana, 1961, pp 75-76.

supplementarity relationship.[3] However, Klein argues that intercorrelation or Multi-collinearity is not necessarily a problem unless it is high, relative to the overall degree of Multiple correlation among all variables simultaneously.[4] Despite the weaknesses, the Cobb-Douglas production function is empirically tested and found by several researchers in most of the countries, to be efficient in explaining production relations in agriculture. Therefore, the function has been used in the present work to understand the contribution of the quantities of different input factors to the total agricultural output.

Through the Cobb-Douglas production function estimates for thirty-eight developed and underdeveloped countries for three different periods, viz., 1955, 1960 and 1965, Y. Hayami and V. W. Ruttan[5] have attempted to identify the sources of agricultural productivity differences

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3 R. H. McAlexander, " Comparisions of Results From Farm Records And Production Function Analysis ", in E.O.Heady, Johnson and Hardin (Eds.), op. cit., pp 158.

4 L. R. Klein, " <u>An Introduction to Econometrics</u> ", Printice-Hall of India, Private Ltd., New Delhi, 1969, pp 101.

5 Y. Hayami and V. W. Ruttan, " Agricultural Productivity Differences Among Countries ", <u>American Economic Review</u>, Vol. LX(5), December 1970, pp 894-911.

amoung countries in three broad categories. They are i) Resource endowments : Land, Live-Stock, Internal Capital ; ii) Technological inputs : Mechanical devices, Biological and Chemical materials ; and iii) Human Capital : Education, Skill and Knowledge of population. Their results reveal that the three broad group of factors account for approximately 95 % of differences in labour productivity in agriculture between the group of less developed countries and that of developed countries.

Hopper David[6], Rajkrishna,[7] C.H.H.Rao,[8] V.Channareddy,[9] G.R.Saini[10] and G. Sahota,[11] among others, have employed

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6 H. W. David, " Allocation Efficiency in Traditional Indian Agriculture", Journal of Farm Economics, Vol.47(3), Aug. 1965, pp 611-624.

7 Raj Krishna, " Some Production Functions for Punjab", Indian Journal of Agricultural Economics, Vol. 19(384), July-Dec. 1964, pp 87-97.

8 C.H.H.Rao, " Agricultural Production Functions,Costs, Returns to Scale ", Asia Publishing House, Bombay, 1965, pp 1-26.

9 V.Channareddy, " Production Efficiency in South Indian Agriculture ", Journal of Farm Economics, Vol.49(4), Nov. 1967, pp 816-820.

10 G.R.Saini, " Resource Efficiency in Agriculture", Indian Journal of Agricultural Economics,Vol.24(2),April-June 1969, pp 1-18.

11 G.S.Sahota, "Efficiency of Resource Allocation in Indian Agriculture", American Journal of Agricultural Economics, Vol. 50(3), August 1968, pp 584-605.

Cobb-Douglas type production functions to identify the functional relationship between farm output and inputs, like cultivated land, human labour, bullock labour, seeds, chemical fertilizer, farm manure, irrigation, tractors, implements and education, etcetera, and to calculate therefrom production elasticities of inputs, returns to scale in the farm business and marginal productivities of different inputs. All their studies have been conducted by drawing heavily from the Farm Management Data relating to the 1950's. The findings of the above studies broadly reveal that in India i) the agricultural production, by and large, was subject to constant returns to scale, ii) the production elasticity of agricultural labour was positive, and iii) the farm resources, in general, were efficiently used, during the 1950's.

Robert Herdt[12] estimated the aggregate agricultural production function for sixteen states of India at two points of time, viz., 1960-61 and 1964-65, and compared his results with Hayami[13] meta - production function estimates.

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12 R. W. Herdt, "Resource Productivity in Indian Agriculture", American Journal of Agricultural Economics, Vol.53(3), Aug. 1971, pp 517-521.

13 Y. Hayami, "Sources of Agricultural Productivity Gap Among Selected Countries", American Journal of Agricultural Economics, Vol. 51(4), Aug. 1969, pp 564-575.

with the studies of Griliches[14] for U.S.A. and with the district level analysis for India conducted by D. P. Choudhari.[15] Three sets of regressions were run by him separately for 1960-61 and 1964-65. The first pair of equations included land, labour, irrigation, fertilizer and power pumps. In the succeeding equations, first power pumps and then labour were omitted. The value of gross output of 26 crops was considered as a dependent variable in all the equations. The included variables explained from 79 % to 97 % variations in output. It is interesting to note that none of the production elasticities estimated from the 1961 data was significant, while all the 1965 equations had at least two significant coefficients. However, it was observed that the productivity of land was about the same in both the years, but the productivity of labour and fertilizer were substantially higher and the production of irrigated land considerably lower in the year of better weather, viz., 1965. Further,

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14 Zvi Griliches, i),"Estimates of the Aggregate Agricultural production function from cross-sectional data", Journal of Farm Economics, Vol.45(2), May 1963, pp 417-18. ii) Research Expenditures, Education and Aggregate Agricultural Production Function, American Economic Review, Vol.LV(6), December 1964, pp 1961-73.

15 D.P.Choudhari, "Education Innovation And Agricultural Development", I.L.O., Publication, Croom Helm, London, 1979, Chapter 3.

his study, along with Choudhari's, indicated a much smaller effect of education on agricultural production in India than that in the U.S.A. Therefore, he concluded that " until India's agriculture is transformed to a much greater degree, productivity differences will depend upon land, labour, irrigation and fertilizer".[16]

K. William Easter, Martin E. Abel and George Norton[17] have provided, on the basis of data for the two periods, viz., average of 1959 to 1962 and average of 1967 to 1969, agricultural production function estimates for the two regions of India, viz., wheat (73 districts) and Rice (69 districts). They have considered the aggregate output as dependent variable and crop area, irrigated area, fertilizer, tractors, labour, total rainfall, alluvial soil, work animals, surface roads and irrigation index as independent variables. Four sets of Cobb-Douglas production functions, for each region and for each period , were estimated. In both the regions, the included variables provided the better fits of the estimates in terms of

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16 Ibid.

17 K. William Easter, Martin E. Abel and George Norton, "Regional Differences in Agricultural Productivity in Selected Areas of India", American Journal of Agricultural Economics, Vol. 59(2), May 1977, pp 257-265.

Multiple Coefficients of Determination(R^2), viz., 0.90 to 0.94 in wheat and 0.80 to 0.90 in Rice regions. On the basis of their findings, they have concluded that "Factors other than traditional inputs unadjusted for quality differences are important in explaining agricultural productivity differences within and between the wheat and rice regions of India".

Rajkrishna,[18] Ashok Parikh,[19] C. H. H. Rao,[20] T. P. Abraham and S. K. Raheja,[21] Y. K. Alagh,[22] among others, have fitted the Cobb-Douglas production function to the time-series data to investigate the relative contribution of different inputs to the growth of agricultural

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18 Rajkrishna, "The Growth of Aggregate Output in Punjab", Indian Economic Journal, Vol. 12(1), July-September 1964, pp 53-59.

19 Ashok Parikh, "State-wise growth rate in agricultural output — An Econometric Analysis", Arth-Vijnana, Vol. 8(1), March 1966, pp 1-50.

20 C.H.H.Rao,"Growth of Agriculture in Punjab During Decade 1952-62", Indian Journal of Agricultural Economics, Vol. 20(3), July-Sept. 1965, pp 20-32.

21 T. P. Abraham and S. K. Raheja, "Analysis of Growth of Production of Rice and Wheat Crops in India", Indian Journal of Agricultural Economics, Vol. 22(3), July-September 1967, pp 1 - 15.

22 Y. K. Alagh, " Regional Disparities in rates of growth and Productivity in Indian Agriculture : Causes and Remedies", Anvesak, Vol.X(1), June, 1980, pp 1-40.

production over a period of time. One common conclusion that stems from their studies is that, in the recent past, cropped area, irrigation and fertilizer have made a major contribution to the total agricultural output in India.

Sudhin K. Mukhopadyaya[23] have studied the sources of variations in agricultural productivity among the 72 predominantly wheat-growing districts of India, on the basis of time-series and cross-section data for the period 1959-60 to 1968-69. With the help of the Econometric Analysis, he finds that only a small percentage of variation (i.e., 41 %) in output is explained by measuable inputs, namely, land, irrigation, fertilizer, tractors and literate labour. He attributes the remaining about 60 % variation mostly to, what he calls regional effects and temporal effects, the former accounting for 95 % of the remainder 60 % . The implication of his study is that it is difficult to remove the observed regional disparities in the growth of farm output by allocation of inputs.[24] But this seems to be an issue which is not easy to be resolved. However, the inclusion of more of critical measurable

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23 S. K. Mukhopadyaya, "Sources of Variation in Agricultural Productivity", The MacMillan Company of India, Ltd., Dew Delhi, 1976.

24 Ibid., pp 34.

economic variables in the model would have given different results, showing a relatively higher contribution of measurable inputs to the growth of output.

3. REGRESSION VARIABLES AND SOURCES OF DATA

The twelve variables considered in the production function of the present study are as follows :

Y = Net District Domestic Product of Agricultural Sector at 1960-61 Prices(in Rs.);

X_1 = Gross - Cropped Area in Hectares;

X_2 = Total Number of Agricultural Workers (Cultivators + Agricultural Labourers);

X_3 = Number of Literate Agricultural Workers;

X_4 = Rainfall (Annual Average) in mm;

X_5 = Gross Irrigated Area in Hectares;

X_6 = Number of Agricultural Implements (Ploughs All Types);

X_7 = Livestock (Number of Cattle);

X_8 = Chemical Fertilizer (Nutrients of NPK) in metric tons;

X_9 = Number of Pumpsets (Oil + Electric);

X_{10} = Area under HYV Crops in Hectares;

X_{11} = Number of Tractors.

The variable, Net District Domestic Product of Agricultural Sector(Y), is the dependent variable and all other variables are independent variables in the present study.

The data are obstained from several published and unpublished sources. By and large, the sources of data are obtained from Bureau of Economics and Statistics, Population Census Reports, State Department of Agriculture and Livestock Census Reports. However, for 1960-61, the data on agricultural workers are not taken directly from the 1961 Census, as they are not comparable with those of the 1971 Census. Therefore the adjusted worker data of 1961 are used for the year 1960-61. For the year 1975-76, the agricultural workers are estimated through the extrapolation method on the basis of the 1971 population Census figures and the 1981 Census provisional figures. By applying the district-wise rural literacy rates of 1961 and of 1971 to the total adjusted agricultural workers figures of 1961 and to the total agricultural workers figures of 1971 Census, respectively, the literate agricultural worker figures for these years are obtained. The 1971 rural literacy rate was applied to the estimated agricultural worker figures of 1975-76, to obtain the literate agricultural workforce for the year

1975-76. However, the variables, total agricultural workers(X_2) and literate agricultural workers(X_3), are used alternatively to know the contribution of educated workers to agricultural output. The data on all the variables have been given already in Appendix Tables 6.1, 6.2, and 6.3 for the years 1960-61, 1970-71 and 1975-76 respectively.

4. PRODUCTION FUNCTION ESTIMATES

The hypothesis is that factors, namely, gross cropped area, agricultural workers, education of farm workers, annual rainfall, irrigated area, agricultural implements, livestock, fertilizer, pumpsets, area under HYV crops and tractors contribute positively to the agricultural output and therefore account for inter-district variations in agricultural development.

To understand the relative contribution of each of the above factors to agricultural output in Karnataka, the Cobb-Douglas type of Production Fuctions are fitted to the inter-district cross-sectional data for the years 1960-61, 1970-71 and 1975-76 separately. The Least Squares Method has been employed to estimate the parameters. Of the several equations (150) tried, only four sets for each period are selected as the best in terms of $\bar{R}^2$ and the 't' values of coefficients. The estimates of Cobb-Douglas production functions of agricultural income on selected variables for the years 1960-61, 1970-71 and 1975-76 are presented in Table 7.1.

Equations (1) to (4) are for the period 1960-61. Equation (1) contains five independent variables. Production coefficients of literate workers, annual rainfall and gross irrigated area are found to be significant at 5 % level with the expected signs. But production coefficients of land(GCA) and implements have negative signs. Since these coefficients are not significant at 5 % level, it is difficult to comment on their contribution. The inclusion of livestock in equation(2) results in a marginal fall in $\bar{R}^2$. But such inclusion makes the production coefficient of area irrigated non-significant at 5 % level, though it has a positive sign. The coefficient of literate worker goes down and that of rainfall goes up. The coefficient of livestock, though positive, is not found to be significant at 5 % level. In equation(3), the variable, agricultural implements, is dropped, since there is a high inter-correlation between agricultural implements and livestock. By this arrangement, no effect is found on $\bar{R}^2$. Though the coefficients of gross irrigated area and livestock found to be positive, are not significant at 5 % level. However, the size of the coefficient of literate worker further reduced. In equation(4) the variable, number of pumpsets, is included and the variable, literate workers, is replaced by agricultural workers. As a result $\bar{R}^2$ is reduced substantially. However, production coefficients of annual rainfall and gross irrigated area have not only increased but are also found to be significant with the expected signs. The coefficient of land turns out to be positive but is found to be non-significant at 5 % level. Whereas, a negative but insignificant coefficient for agricultural workers is observed. Livestock and pumpsets, though having the expected signs before them, are not found to be significant at 5 % level. Thus, the selected variables explain 50 % to 63 % of variations in agricultural production in Karnataka for the year 1960-61. The results indicate that the factors, namely, literate workers, rainfall and irrigated area, have made significant contribution to agricultural production differences for the period under examination.

Similar analyses for the period 1970-71 are contained in equations (5) through (8). The behaviour of the coefficients in this set of equations with respect to alternative specifications is interesting to study. Equation (5) includes five independent variables and the production coefficients of all the variables, viz., gross cropped area, agricultural workers, number of implements and fertilizer, are found to be significant. Except in the case of agricultural workers, the coefficients of all factors bear positive signs before them. It seems, a measurement problem existing with the labour variable may explain the negative and significant production coefficient for agricultural workers. The labour variable in the model represents the stock of labour available in each district and not the amount of labour actually used. It is reasonable to assume that the difference between labour available and labour actually used is negatively related to output per hectare, viz., high productivity districts make fuller use of available labour than low productivity districts. Therefore, the error on account of measurement of literates would lead to a downward bias in the estimated labour coefficients.[25] Inclusion of livestock in equation (6) resulted in the reduction in size of coefficients of all factors except fertilizer. There is little improvement in the size of coefficient of fertilizer. However, the coefficient of livestock turns out to be non-significant at 5 % level, though, it has a positive sign. When the variable agricultural workers is replaced by the variable literate workers and a new variable area under HYV crops is included in equation (7), the $\bar{R}^2$ is found to have significantly

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25 See, for similar arguments, K. William Easter, Martin E. Abel and George Norton, op. cit., pp 259-60.

improved. Inclusion of these variables has resulted in substantial improvement in the coefficients of rainfall, agricultural implements and fertilizer. But there is a slight reduction in the coefficient of land. The sign of livestock coefficient becomes negative. Again, as the coefficient of livestock is not found to be significant at 5 % level, it is difficult to attached any reasonable meaning to it. The coefficient of HYV area, though it has the expected sign, is not found to be significant. The negative coefficient of literate worker, again, may be due to the error on account of the measurement of literates. However, its positive effect on production cannot be ruled out. That it gets reflected in the improvement of the size of coefficients of other factors is confirmed when the size of coefficients of rainfall, agricultural implements and fertilizer is observed. Further, it is generally said that the HYV crop cultivation, inter-alia, depends on irrigation facilities. Therefore, this variable is included in equation (8) and the variable livestock is dropped, since the livestock is highly correlated with agricultural implements. In equation (8), the sign of the irrigation coefficient is found negative, which is rather in conflict with the general experience that irrigation gives a positive increase in output. It seems that the high correlation between rainfall and irrigation must have given this results.

However, it is difficult to say with confidence that its effect on production as its coefficient is non-significant at 5 % level. The positive effect of irrigation on production may be found in the behaviourial changes in the coefficients of its complementory factors, namely, fertilizer, HYV area and agricultural implements. Such a change in the specification contained in equation (8) has resulted in improvement in the size of coefficients of fertilizer, implements and HYV area . In addition, the $\bar{R}^2$ is further improved with the inclusion of the irrigation variable. Thus, the hypothesis, that the positive effect of irrigation on production, is difficult to reject. However, the size of coefficient of HYV area is non-significant at 5 % level. This only suggests that the HYV programme has not yet made its headway in Karnataka during the year 1970-71.

To know the contribution of modern machinery to the agricultural output in Karnataka, the production functions were also tried with the inclusion of tractors and pumpsets. The inclusion of these factors, however, did not give satisfactory results. The sizes of coefficients of these factors were found to be negative and non-significant at 5 % level. Further, the inclusion of tractors and pumpsets in the equations resulted in the worsening of $\bar{R}^2$. This only suggests that the modern agricultural machinery has a negligible effect on agricultural production in the state. However, from the selected production functions, it can be observed that the selected variables explain 58 % to 67 % of variation in the agricultural production in the state for the period 1970-71. Gross cropped area, rainfall, agricultural implements and fertilizer, on the whole, are the factors found to be significantly contributing to the agricultural production differences in Karnataka in 1970-71.

The equations (9) through (12) are for the period 1975-76. In fact, equations (9) and (10) are similar to equations (5) and (6) respectively. Gross cropped area, agricultural workers, rainfall, implements and fertilizer are the five independent variables considered in equation (9). Of the five independent variables, the coefficients of gross cropped area, rainfall and agricultural implements are significant with positive signs before them. The coefficient of fertilizer is not found to be significant at 5% level, though it bears a positive sign. The coefficient of agricultural worker is negative but found to be non-significant at 5 % level. The selected variables explain 65 % of the variations in agricultural production for the period 1975-76. But the same set of independent variables explained 58 % of variation in 1970-71. The inclusion of livestock in equation (10) does not seem to bring about a substantial change either in the size of the coefficients of selected variables or in the $\bar{R}^2$. The coefficient of livestock, though it has a positive sign, is not found to be significant at 5 % level. In equation (11), the variable livestock is dropped and the variable HYV area is included. The coefficient of HYV area is found to be non-significant at 5 % level though it has a positive sign. Again, the inclusion of variable HYV area has not resulted in any remarkable change in the results. $\bar{R}^2$ remained more or less the same. However, inclusion of the variable HYV area necessitated the inclusion of the variable irrigation in the model. Therefore, irrigated area is included in equation (12). Such a change in the specification resulted improvement, not only in the size of coefficients of gross cropped area, rainfall, implements and fertilizer but also in the $\bar{R}^2$. The coefficients of agricultural workers and irrigation were found to be negative and non-significant at 5 % level. It appeares that the high correlation between rainfall and irrigation must have given the negative sign for irrigation. Since these coefficients are not found to be significant, it is difficilt to conclude about their effect on production. However, the positive effect of irrigation on production cannot be ruled out. Irrigation is expected to increase the contribution of its complementary factors such as fertilizer and HYV crops to the total agricultural output. This may be confirmed by observing the coefficients of input factors in equation (12) as compared to those in equation (11). Here, it is to be noted that irrigation and HYV area have not made a significant contribution to agricultural growth in Karnataka.[26]

Even for the year 1975-76, the inclusion of tractors and pumpsets in the specification did not provide us with better results. The production coefficients were found to be non-significant at 5 % level and $\bar{R}^2$ was lower than what has been obtained in the above four equations fitted to the 1975-76 data. It is, thus, inferred that modern machinery has an insignificant contribution to agricultural production in the year 1975-76. However, from the results of equations (9) to (12), presented in Table 7.1, it can be noticed that the selected variables provide 62 % to 65 % explanation to the agricultural production differences in Karnataka for the year 1975-76. Though the gross cropped area, rainfall, implements, fertilizer and HYV area have made positive contribution to the agricultural production in 1975-76, it is the first three factors which have made a significant contribution to it.

26 G.Swamy and S.M.Sunder Raj, "Agricultural Development in Karnataka - 1955-56 to 1974-75" (mimeograph), Institute for Social and Economic Change, Bangalore, pp 123-124.

5. CONCLUSION

i) The Cobb-Douglas type production functions fitted to the cross-section data for the year 1960-61 reveal that education of farm workers, rainfall and irrigation are the factors which have positive and significant contribution to agricultural production in Karnataka. Since the coefficients of other factors, viz., gross cropped area, livestock, pumpsets are not found to be significant at 5 % level, it is difficult to conclude about their contribution to agricultural production. The selected variables explain 49 % to 63 % of variation for the period 1960-61.

ii) Gross cropped area, rainfall, agricultural implements and fertilizer are the factors which account for the significant contribution to the inter-district variations in agricultural production in the state for the period 1970-71. The selected variables leave 35 % to 38 % variation unexplained.

iii) Though the gross cropped area, rainfall, implements, fertilizer and HYV area have a positive contribution to agricultural production, it is the first three factors which have significant contribution to it for the period 1975-76. The $\bar{R}^2$ of the selected equations varies from 62 % to 65 % for the period.

iv) From the results of 1970-71 and 1975-76, it can be inferred that the contribution of HYV seeds and fertilizer to agricultural production is insignificant in Karnataka. However, their coefficients are positive and their apparent positive contribution to output is consistent with several other studies on Indian agriculture.