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CROPWISE DISTRICTWISE PRODUCTION FUNCTIONS

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INTRODUCTION

Macro studies have been largely carried out for the Indian economy with a view to formulating or evaluating policy from the emerging quantitative relationships. These policy criteria have been sometimes used by the Planning Commission for an aggregate decision-making. Micro level studies such as detailed village studies, surveys and resurveys have been carried out in different parts of the country and sometimes resurveys have been the basis for studying economic and social change.[1] Macro studies observe the behaviour at an aggregate national level or at the aggregate State level while micro studies most often chose the village as the unit of observation. Very few studies in agrarian economic structure are made at a district or block level.

A very few of them are econometric in nature. The importance of these studies for the planning strategy is of no less value than is aggregate State or national study. With the rules of decentralization and administrative break-up of a State and with the formation of *Zilla Parishads* (District Committees) and the role of village panchayats, a study of a district can both help at a micro level and macro level decision-making. Aggregation sometimes results in the cancelling out of the effects of important factors and consequently sometimes such principal factors like rainfall on agricultural production do not show up in the national or State studies at times. Similarly, some of the sociological factors which are critical for a particular district will fail to show up in the national or State studies. Aggregation thus sometimes suppresses what otherwise may be true for a particular part of the country and this aspect is clearly brought out in the present study. This study measures the relationship between input and output in agriculture and reveals some of the interesting relationships for each crop in each district of Madras State. The choice of Madras State was forced by the availability of continuous data over a period of time for some of the important crops.

DATA

We have collected data from the Season and Crop Reports of Madras State which were available over the period 1953-54 to 1962-63 at the time of this study. The Season and Crop Reports are the main primary source of data at the district or State level and as this is the primary agency supplying information to the State Governments, the data produced there are the most reliable among the existing statistical sources. According to the observed pattern of percentage of area under principal crops we find that five crops seem to be occupying about 70 per cent

1. Planning Commission, Government of India: First Five-Year Plan, 1953; Second Five-Year Plan, 1956; and Third Five-Year Plan, 1961.

A. S. Manne and A. Rudra, "Studies in the Structure of the Indian Economy," *Sankya*, February-March, 1965.

M. R. Haswell : Economics of Development in Village India, 1967.

D. P. Apte and G. R. Mulla, "Comparative Costs of Lifting Water from Wells—A Case Study of Banana Cultivation," *Artha Vijnana*, Vol. 5, No. 4, December, 1963.

Farm Management Surveys of Bombay, Uttar Pradesh and Madras States, Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.

of the area at the State level. In each of the districts, the percentage of area under the principal crops varies as some districts specialise in producing paddy perhaps because of the soil and climatic conditions prevailing in the district. Chingleput, South Arcot, North Arcot, Thanjavur, Ramanathapuram and Kanyakumari had more than 40 per cent of the area under paddy in 1962-63. It is generally true that paddy and groundnut seem to be the most important crops of the State throughout 1953-54 to 1962-63.

For districtwise production functions, data are collected over the period 1953-54 to 1962-63 for the crop output, area, percentage of irrigated area to total cropped area under that crop, chemical fertilizers, rainfall and percentage departure of actual rainfall from normal. Our time-series is extremely short and as there are only ten observations for each of the districts, all the results are subject to this limitation. A long time-series for a districtwise cropwise analysis is desirable but it is not available on a comparable basis. Crops under study are paddy, *cholam*, *cumbu*, *ragi* and groundnut, the latter four are dry season crops. Groundnut is one of the important commercial crops of Madras and though cotton is the leading crop for Salem district, most of the districts have less than 5 per cent area under cotton. For Salem, data on cotton are not available continuously. Gross cropped area under a crop are available in terms of acreage and they have been used to obtain the percentage of irrigated area under a crop to the total cropped area. Irrigated area under crops are easily accessible for all the five crops over the period 1953-54 to 1962-63 from the Season and Crop Reports. Data on chemical fertilizers at a district level for each relevant crop are not available at all. For the earlier years, the total amount of chemical fertilizers used at a district level is not possible to obtain because chemical fertilizers may not have been used in large enough quantity and even if they have been, data are not compiled by any of the agencies at the district or block level. For Thanjavur district[2] where the Intensive Agricultural District Programme was launched in 1960-61, it is not mentioned anywhere whether or not chemical fertilizers were used before the period 1960-61. During the period 1960-61 to 1962-63, we have some data on chemical fertilizers at the district level and this has been compiled as nitrogen and phosphorus used rather than as an index of chemical fertilizers. Index numbers will have disadvantages in a cross-section study because for the base year all figures will appear as constant even though the amount of fertilizer used is varying. Hence the prices have been applied as weights. In each State, the price of nitrogenous and phosphatic fertilizers has been fixed by the Government of India and therefore, there are no variations in official prices at the district level. The weighted average value of nitrogenous and phosphatic fertilizers using their prices as weights is known as chemical fertilizers. This measure is very approximate but the chances of improving them with suitable weights for an adequate and maximum use in cross-section study are unfortunately limited. This measure of chemical fertilizers is divided by area in order to obtain the per acre use of chemical fertilizers. This is the amount of chemical fertilizers per acre used on all crops. As we have cropwise output functions, we have to assume that most of the chemical fertilizers are used on paddy and groundnut as these are grown under irrigated conditions. This allocation is not possible and hence we consider

2. Intensive Agricultural District Programme, Report (1961-63), Expert Committee on Assessment and Evaluation, Ministry of Food and Agriculture (Department of Agriculture), Government of India, New Delhi, 1963

that all our coefficients associated with chemical fertilizers will be over-estimated. Data on rainfall observed at the district centre are compiled in the Season and Crop Report. Originally, this was collected from the Meteorological Office. Rainfall is one of the critical components of weather and though ideally precipitation, temperature and humidity should be used in compiling a weather index, we have used rainfall as the only variable affecting crop output considerably. This is owing to lack of data on various other related aspects such as precipitation and humidity and again their timing at sowing and between sowing and harvesting stages. The level of rainfall in each district is quite different and to a large extent rainfall determines the cropping pattern of a district. It is not actually the amount of rainfall alone that determines the cropping pattern or farmers' choices concerning crop. The percentage departure from normal rainfall will to a certain extent incorporate uncertainty and if there is a large departure from normal rainfall in a district over a long period, farmers may not plan to allocate area for a crop where a normal condition is necessary. For example, if paddy requires a fair amount of rainfall in an unirrigated district, and if there are large fluctuations from normal leading to drought condition every year, farmers may increase the cropped area for dry crops or other crops. This may or may not be revealed in the actual amount of rainfall. It will be reflected if normal rainfall for a district over the years has remained constant and since it is so for the districts of Madras, it has been decided to use one of the two rainfall variables in the models of crop output. The percentage departure from normal will estimate the rolé of uncertainty up to a point.

VARIABLES, SPECIFICATION OF THE MODELS AND ESTIMATION

Y_t = Output of a crop (in terms of physical units)
X_{1t} = Area (in acres)
X_{2t} = Irrigated area (in acres)
X_{3t} = Actual rainfall (in millimeters)
X_{4t} = Time variable
X_{5t} = Percentage departure from normal rainfall
X_{6t} = Chemical fertilizers.

MODELS

A. Time-Series Models

$$\frac{Y_t}{X_{1t}} = a + b_1 \left(\frac{X_{2t}}{X_{1t}}\right) + b_3 X_{3t} + U_t \quad \ldots\ldots (1)$$

$$\frac{Y_t}{X_{1t}} = a + b_1 \left(\frac{X_{2t}}{X_{1t}}\right) + b_3 X_{3t} + b_4 X_{4t} + U_t \quad \ldots\ldots (2)$$

$$\frac{Y_t}{X_{1t}} = a + b_1 \left(\frac{X_{2t}}{X_{1t}}\right) + b_4 X_{4t} + b_5 X_{5t} + U_t \quad \ldots\ldots (3)$$

$$\frac{Y_t}{X_{1t}} = a + b_1 \left(\frac{X_{2t}}{X_{1t}}\right) + b_5 X_{5t} + U_t \quad \ldots\ldots (4)$$

$$\log\left(\frac{Y_t}{X_{1t}}\right) = a + b_1 \log\left(\frac{X_{2t}}{X_{1t}}\right) + b_3 \log X_{3t} + b_4 \log X_{4t} + U_t \quad \ldots\ldots (5)$$

$$\log\left(\frac{Y_t}{X_{1t}}\right) = a + b_1 \log\left(\frac{X_{2t}}{X_{1t}}\right) + b_3 \log X_{3t} + U_t \quad \ldots\ldots (6)$$

$$\log\left(\frac{Y_t}{X_{1t}}\right) = a + b_1 \frac{X_{2t}}{X_{1t}} + b_5 X_{5t} + U_t \quad \text{.......................(7)}$$

$$\log\left(\frac{Y_t}{X_{1t}}\right) = a + b_1 \frac{X_{2t}}{X_{1t}} + b_3 \log X_{3t} + U_t \quad \text{....................(8)}$$

$$\log\left(\frac{Y_t}{X_{1t}}\right) = a + b_1 \frac{X_{2t}}{X_{1t}} + b_3 \log X_{3t} + b_4 X_{4t} + U_t \quad \text{...........(9)}$$

$$\log\left(\frac{Y_t}{X_{1t}}\right) = a + b_1 \left(\frac{X_{2t}}{X_{1t}}\right) + b_4 X_{4t} + b_5 X_{5t} + U_t \quad \text{...........(10)}$$

B. Cross-Section Models

$$\frac{Y_i}{X_{1i}} = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_3 X_{3i} + b_6 \frac{X_{6i}}{X_{1i}} + U_i \quad \text{...........(11)}$$

$$\frac{Y_i}{X_{1i}} = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_3 X_{3i} + U_i \quad \text{.....................(12)}$$

$$\frac{Y_i}{X_{1i}} = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_6 \left(\frac{X_{6i}}{X_{1i}}\right) + U_i \quad \text{.................(13)}$$

$$\frac{Y_i}{X_{1i}} = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_6 \left(\frac{X_{6i}}{X_{1i}}\right) + b_5 X_5 + U_i \quad \text{..........(14)}$$

$$\frac{Y_i}{X_{1i}} = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_5 X_5 + U_i \quad \text{.....................(15)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log X_{1i} + b_2 \log X_{2i} + b_3 \log X_{3i} + U_i \quad \text{.........(16)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log X_{1i} + b_2 \log X_{2i} + b_3 \log X_{3i} + b_6 \log X_{6i} + U_i \text{..(17)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log\left(\frac{X_{2i}}{X_{1i}}\right) + b_2 \log X_{1i} + b_6 \log\left(\frac{X_{6i}}{X_{1i}}\right) + U_i \text{....(18)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log\left(\frac{X_{2i}}{X_{1i}}\right) + b_3 \log X_{3i} + U_i \quad \text{................(19)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log\left(\frac{X_{2i}}{X_{1i}}\right) + b_6 \log\left(\frac{X_{6i}}{X_{1i}}\right) + U_i \text{...............(20)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log\left(\frac{X_{2i}}{X_{1i}}\right) + b_5 X_5 + b_6 \log\left(\frac{X_{6i}}{X_{1i}}\right) + U_i \text{........(21)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \log\left(\frac{X_{2i}}{X_{1i}}\right) + b_5 X_5 + U_i \quad \text{....................(22)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_5 X_5 + U_i \quad \text{...................(23)}$$

$$\log\left(\frac{Y_i}{X_{1i}}\right) = a + b_1 \left(\frac{X_{2i}}{X_{1i}}\right) + b_5 X_5 + b_6 \log\left(\frac{X_{6i}}{X_{2i}}\right) + U_i \text{.......(24)}$$

All the models are estimated by the method of ordinary least squares under the usual assumptions.

Both the time-series and cross-section models use the same variables excepting that the data on chemical fertilizers for a continuous time-series are not available. Models with chemical fertilizer variable can be used for cross-section studies. Logarithmic and semi-logarithmic functions are also used. We have not used directly the output under a crop as a dependent variable because in cross-section studies this creates problems of heteroscedasticity[3] and in time-series studies, most of the variation is explained by area variable even though it may not be so. At a district level, perhaps a geographical expansion in acreage or an extension of reporting area may yield higher absolute output though in reality the output per acre may not have increased. When total output is related to total acreage, it is found that all the other variables play a very minor role in explaining output. With these considerations, we have not used dependent variable in the absolute sense.

Models (1) to (15) and (18) use percentage of irrigated area to total area as one of the explanatory variables. This remains so in many logarithmic forms. Models (16) and (17) have absolute irrigated acreage and area variables. Two separate reasons may be given for treating irrigated area as percentage of irrigated area to total area in most of the models. Firstly, this variable is intended to show the effect of increased availability of water. If the area under a particular crop has not gone up but the same area has been made irrigated through tanks, wells or canals, the percentage of irrigated acreage to total acreage will go up. In the absolute sense, irrigated acreage may go up but there is a possibility that if both area and irrigated acreage have gone up, in the absolute sense, irrigated acreage will go up while the percentage of irrigated area to total may not. We have not even a crude measure of how many millions of gallons of water are available for a particular crop and in the absence of any data on availability of water, the percentage of irrigated area to total area is intended to fulfil this function partly as a proxy to availability of water. If irrigated acreage and total area are used as separate variables, there is a double-counting as total area accounts for irrigated and unirrigated area. In addition, statistically, if these two variables are used in time-series, there will be a problem of multicollinearity as over a period of time both irrigated area and total area are increasing. Rainfall and the percentage departure from normal rainfall are used in both cross-section and time-series models. For rainfall (X_{3t} or X_{3i}), either a logarithmic form or a simple absolute rainfall variable is used in cross-section and time-series studies. Time-trend variable (X_{4t}) is expected to catch the effect of slowly changing factors and this has been used only in time-series analysis.

There are models of first-differences where some of the qualitative long run factors are cancelled out. All our specifications for each of the crops and each of the districts will have specific variables such as dynamism of farmers, leadership qualities, spread of knowledge from a leader to the group and these characteristics may be specific with respect to each district. Such long run factors will cancel out if we make the assumption that between two consecutive periods these qualitative variables hardly change. Consequently, our specification will be the net

3. Heteroscedasticity is defined as the larger districts having large residual variance and smaller districts having small residual variance or vice versa. In a cross-section study, the danger of heteroscedasticity is extremely high and this will be minimized if we divide the explained variable by area as size is measured by the area of a district.

of these effects. In addition, if soil conditions peculiar to a crop play an important part in a district this will also cancel out in the first-differences of cross-section data. The variables to be explained and the explanatory variables will take the meaning of changes in output, changes in the percentage irrigated area to total area, changes in rainfall or the percentage departure from normal rainfall and changes in the consumption of chemical fertilizers.

RESULTS AND INTERPRETATION

A. TIME-SERIES RESULTS

Paddy

For paddy, all the ten time-series models have been fitted for nine districts of Madras State over the period 1953-54 to 1962-63. For Coimbatore, Thanjavur and Chingleput districts R^2 was very low and hence none of the coefficients turned out to be statistically significant at five per cent level. Thanjavur has about 80 per cent of the area under paddy and it was chosen as an I.A.D.P. district in 1960-61. Increased yield per acre is not explained by any of the accountable factors in the study. This is quite possible because almost the entire area under paddy is irrigated in Thanjavur. In addition there was very little increase in area and as the district's paddy output is not heavily dependent upon rainfall, it seems that these variables do not play any important role. The use of chemical fertilizers has increased tremendously since the I.A.D.P. programme and as we have no time-series data for Thanjavur district, it is not possible to quantify the impact of chemical fertilizers on yield per acre. This is not accounted for in the trend variable and therefore even the time-trend variable fails to catch the effect of a sudden rise in productivity per acre after 1960. For Coimbatore, it can be stated that hardly 15 per cent of the area is under paddy. The output per acre shows a discernible negative trend for the first few years and thereafter from 1959-60 an increase to some extent. Analysing the results for Chingleput, about 74 per cent of the total area is devoted to paddy cultivation. About 70 to 80 per cent of the area is irrigated. There is a small decline in paddy output per acre for the first six years and thereafter the output per acre is rising. The latter impact may be due to qualitative improvements in irrigation facilities and the use of chemical fertilizers on which data are not available over the period 1953-54 to 1962-63. Linear trend-term does not catch this effect as there is a negative trend for the first few years and positive trend thereafter.

For South Arcot, none of the variables excepting time-trend variable plays a significant role. This happens only in the case of one model and though the trend variable has a negative coefficient indicating a strong decline in output per acre, this merely shows that earlier years have a dominating influence. None of the other real variables is statistically significant in explaining output per acre. In *all models* for Salem, rainfall variable is highly influential in determining output per acre. Both rainfall in millimeters and percentage departure from normal rainfall play a dominating role in affecting the output per acre. A negative coefficient with respect to percentage departure from normal rainfall implies that output per acre declines while a positive coefficient implies that if departure from normal increases, output per acre will increase. The former is easy to understand but the latter implies that drought conditions from year to year may have led to a deficit of water in the area. Most of the sources of irrigation in Madras are rain-fed and scarcity of water may have consequently resulted in drought which may have a long-term effect reflected in increased productivity per acre on account of excess rainfall. As a second possibility, the crops where the rainfall requirements are not strict will be intensively grown and as a result the increase in the percentage departure from normal rainfall will lead to an increase in output per acre. For North Arcot, the trend variable has a negative coefficient and this is highly significant for almost all models. It alone explains about 76 per cent of variations in productivity per acre. For Ramanathapuram, the negative trend coefficient reveals decline in output per acre. About 50 to 60 per cent of variations in output per acre are explained by trend variable. For Tiruchirapalli, rainfall variable and percentage departure from normal rainfall show significant influence on output per acre. If the rainfall increases by 1 per cent, we get an increase in paddy output per acre by 80 per cent in Tiruchirappalli. For Madurai, the increase in the percentage of irrigated area to total area shows a significant impact in increasing paddy output per acre. Perhaps, the output per acre has largely increased on account of a large area being made irrigated during the decade.

Groundnut

For Chingleput, the percentage of irrigated area to total area plays a dominating role in explaining fluctuations in output per acre, it increases output per acre by about .85 per cent if the availability of water increases by about one per cent. In the case of South Arcot, the percentage departure from normal rainfall has a significant influence on yield per acre. For North Arcot, none of the variables plays any important role and this is because of low coefficient of determination. For Coimbatore, time-trend variable and the percentage of irrigated area to total area explain significant variations in output per acre. The trend effect is positive and yield per acre has increased over a period of time. Groundnut apparently is not an irrigated crop and it is largely a rain-fed crop. Hence, if the availability of water increases, the groundnut output per acre declines at the margin as the good qualitative land may be used for other crops such as paddy, sugarcane, or tobacco. For Tiruchirapalli, the percentage of area under groundnut is 13 per cent and none of the variables explains the fluctuations in output per acre. For Thanjavur, like paddy, none of the considered variables plays any significant role in influencing productivity per acre. However, the area devoted to groundnut is less than five per cent. For Madurai, 16 per cent of area is devoted to groundnut but none of the variables explains fluctuations in output per acre. R^2 is not very low though none of the coefficients of the estimated equation is statistically significant. Similarly, the results for Ramanathapuram and Tirunelveli are of no great significance as either R^2 is low or none of the coefficients is statistically significant.

Cholam

Chingleput has less than one per cent area under *cholam*. In South Arcot, about six per cent of area is allotted to *cholam*. Simple output per acre functions explain about 93 per cent variations and the coefficient with respect to the percentage of irrigated area to total area is positive and highly significant. We find that 1 unit increase in the percentage of irrigated area to total area under *cholam* increases output by about 2 units. All models yield significant coefficient with percentage of irrigated area to total area. In the case of Salem, all models yield low R^2. For Coimbatore, all models yield statistically significant coefficient with respect to the percentage of irrigated area to total area. One per cent increase in the availability of water leads to about 4 per cent increase in output per acre. None of the results are perverse. For Ramanathapuram, all models have very low R^2 and none of the coefficients is statistically significant. In the case of Tirunelveli, both the percentage of irrigated area to total area and time-trend variable explain 78 per cent of the variations in output per acre. They both have positive statistically significant coefficients. Simple models have higher coefficient of determination than logarithmic models. Coefficients are fairly stable from one regression equation to another. For Madurai, 20 per cent of its area is devoted to *cholam*. The percentage of irrigated area to total area under *cholam* and time-trend variable explain 90 per cent of variations in output per acre. Coefficients with respect to both these variables are statistically significant. One per cent increase in availability of water seems to increase the output of *cholam* per acre by about 4.64 per cent. For Tiruchirapalli, about 16 per cent of the area is under this crop. Rainfall has a significant effect on crop output. One per cent departure in normal rainfall decreases the crop output by about .02 per cent. With the rainfall variable in absolute sense, the crop output decreases by about 1.73 per cent if there is an excess rainfall by 1 per cent.

Cumbu

For South Arcot, Salem and Tiruchirapalli, the coefficient of determination is very low and none of the coefficients is statistically significant. For Coimbatore *cumbu* commands 9 per cent of the total area. The coefficient of determination is about 80 per cent for some of the models with time-trend variable and this shows a positive trend coefficient. For Madurai, trend coefficient is positive and significant and the percentage of irrigated area to total area under *cumbu* has a negatively significant coefficient, which means that if the availability of water increases, the output per acre declines. This may cause flooding or it may lead to an increase in output per acre for some other crops as the availability of water may lead the farmers to allocate land to crops where water requirement is fairly high. All the results, however, are subject to serial correlation bias. For Ramanathapuram, models with time-trend variable explain about 65 to 73 per cent of variations in output per acre. All these models reveal that time-trend variable plays an important role in explaining variations in output per acre. The coefficient is positive which indicates that productivity per acre has increased. For Tirunelveli, models with rainfall or departure from normal rainfall explain about 75 to 85 per cent variations in output. Rainfall and the percentage departure from normal rainfall variables have positive and statistically significant coefficients. All these are free of serial correlation bias. One per cent increase in rainfall leads to about .93 per cent increase in output of *cumbu*.

Ragi

For Chingleput, South Arcot, North Arcot, Salem, Tiruchirapalli and Ramanathapuram, all models yield very low R^2 and none of the coefficients is statistically significant. For Coimbatore, the percentage of irrigated to total area under *ragi* and rainfall variable or the percentage departure from normal rainfall explain about 85 to 87 per cent of the variations in output per acre. Coefficients with respect to both these variables are statistically significant and with respect to the availability of water it is of negative sign while with respect to rainfall or the percentage departure from normal, they are of positive signs. If water is available in larger quantity, there may be a tendency among the peasants to allocate land to some other crops where water input may be used more profitably. Hence the output per acre declines at margin if the percentage of irrigated area to total area increases. A positive coefficient with the percentage departure of actual rainfall to normal will have the interpretation of either increased productivity on account of qualitative land coming under cultivation for *ragi* as this is forced by the inadequate rainfall for some other crops like paddy or tobacco, or a thirsty land's productivity increases when the drought conditions are followed by successive high rain monsoons. For Madurai, the same two variables play a dominant role but this time both these coefficients are positive. These two variables explain about 80 to 90 per cent variations together. For Tirunelveli, rainfall variable and time-trend variable explain 77 per cent of the variations in output. The percentage departure from normal rainfall variable has a statistically significant coefficient in some models. Time-trend coefficient is negative which indicates a decline in productivity per acre.

B. CROSS-SECTION ANALYSIS

The criteria used in the above analysis were lack or absence of multicollinearity, absence of serial correlation, high coefficient of determination, statistical significance of coefficients and low standard error of the estimate. In cross-section analysis, serial correlation criterion will not be applied. Most of the models we have interpreted and the results, which are shown in Tables I to VI, are free from serial correlation. We have used district as an observation and have carried out cross-section regressions with models outlined earlier. Such regressions are only carried out for paddy because paddy is the most important single crop at the State level commanding 30 to 40 per cent of cropped area. For 1953-54, the percentage of irrigated area to total area along with rainfall explains about 79 per cent of the variations in output per acre. Total output functions with total irrigated area, area and rainfall have higher R^2 but there is a danger of collinearity between irrigated area and total area and also a problem of double counting. For 1954-55, the percentage of irrigated area to total area under paddy has almost the same coefficient as 1953-54 and it is statistically significant. Additionally, rainfall variable also plays an important role as the coefficients with respect to rainfall and the percentage departure from normal rainfall are negative and statistically significant. If rainfall departs from normal, output declines. R^2 is fairly high in all models. For 1955-56, none of the variables seems to play a very important role in explaining fluctuations in output per acre. For 1956-57, the percentage of irrigated area to total area has a statistically significant coefficient and 1 per cent increase in the proportion of irrigated area to total area adds 0.45 units of output per acre. R^2 is not high enough for all models. For 1957-58 and 1958-59 none of the results seem to be statistically significant. For 1959-60, the percentage of irrigated area to total area has a statistically significant and positive coefficient. Rainfall does not play any significant role in determining output per acre. With respect to irrigated area alone, the coefficient is statistically significant in total output model. Though R^2 as expected is high enough for the output function, it is subject to collinearity between irrigated area and total area. For 1960-61,

TABLE I—PADDY—TIME-SERIES RESULTS

REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND R^2

Model No.	Name of the district	Constant	Coefficients associated with $\frac{X_2}{X_1}$	X_3	X_4	X_5	$\log\left(\frac{X_2}{X_1}\right)$	$\log X_3$	$\log X_4$	R^2	D—W	S^2
(2)	Salem	3.38725	—3.06932	0.01170*	—0.00189					0.66554	2.70385	0.00220
		(2.36096)	(2.43846)	(0.00376)	(0.00551)							
(5)	Salem	—2.28751*					—4.13331	0.55421*	—0.00858	0.69874	2.67822	0.00382
		(0.61856)					(3.14531)	(0.16734)	(0.03119)			
(8)	Salem	1.79118	—4.15513	0.57246*						0.69498	2.61964	0.00332
		(2.78967)	(2.97175)	(0.14335)								
(10)	Salem	3.80686	—4.17384		—0.00156*	0.00539*				0.66169	2.67113	0.00429
		(3.35175)	(3.40077)		(0·00767)	(0.00171)						
(2)	North Arcot	0.50294	0.29939	—0.00033	—0.02486*					0.78988	1.56741	0.00233
		(0.47274)	(0.57664)	(0.00368)	(0.00532)							
(10)	North Arcot	—0.69435	0.46714		—0.03758*	—0.00026				0.79642	1.75666	0.00512
		(0.81958)	(0.85391)		(0.00788)	(0.00207)						
(2)	Ramanathapuram	1.92403*	—1.56737*	0.00207	—0.05078*					0.78480	2.48030	0.00702
		(0.59007)	(0.57504)	(0.00304)	(0.01370)							
(5)	Ramanathapuram	—0.16306					—1.95617*	—0.13528	—0.43007*	0.75260	2.68179	0.03535
		(1.29715)					(0.89573)	(0.35187)	(0.11956)			
(9)	Ramanathapuram	2.09448	—3.41555*		—0.10535*			0.11272		0.73580	2.47785	0.03775
		(1.92082)	(1.31747)		(0.03083)			(0.32665)				
(1)	Madurai	—0.59763	1.33189*	—0.00068						0.42327	1.32688	0.00835
		(0.57374)	(0.59180)	(0.00521)								
(3)	Madurai	—0.50174	1.26410*		—0.00964	—0.00081				0.48663	1.36353	0.00868
		(0.60680)	(0.60812)		(0.01121)	(0.00185)						
(6)	Madurai	—0.22079					2.00751*	—0.03598		0.51359	1.35926	0.00160
		(0.76981)					(0.74143)	(0.22304)				
(8)	Madurai	—2.42691	2.21025*					—0.03685		0.51440	1.36131	0.00160
		(1.01935)	(0.81497)					(0.22290)				
(1)	Tiruchirapalli	—0.43416	0.58467	0.01597*						0.49448	1.93212	0.01041
		(0.98619)	(1.03362)	(0.00614)								
(6)	Tiruchirapalli	—3.21379*					1.01075	0.80896*		0.46764	2.04242	0.03084
		(1.12899)					(1.67240)	(0.33015)				
(2)	Tirunelveli	—2.99616	3.74151	0.00362	—0.01619*					0.48942	1.38692	0.00543
		(3.76205)	(3.92039)	(0.00705)	(0.00626)							

TABLE II—GROUNDNUT—TIME-SERIES RESULTS

REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND R^2

Model No.	Name of the district	Constant	Coefficients associated with									
			$\frac{X_2}{X_1}$	X_3	X_4	X_5	$\log\left(\frac{X_2}{X_1}\right)$	$\log X_3$	$\log X_4$	R^2	D—W	S^2
(6)	Chingleput	—0.42787	0.83153*			—0.12110				0.38374	2.57419	0.02810
		(1.45891)	(0.41613)			(0.37983)						
(9)	Chingleput	—0.92206	1.10082*	0.02233	—0.02014					0.44433	2.74682	0.02956
		(1.61627)	(0.54130)	(0.42802)	(0.02490)							
(3)	South Arcot	0.52692*	—0.28508		0.00270	0.00075*				0.47983	3.41769	0.00028
		(0.05514)	(0.33210)		(0.00283)	(0.00032)						
(4)	South Arcot	0.49413*	—0.04508			0.00065				0.40093	2.99175	0.00028
		(0.04284)	(0.21541)			(0.00030)						
(7)	South Arcot	—0.70151*	—0.11029			0.00141*				0.40047	3.01298	0.00131
		(0.09344)	(0.46984)			(0.00065)						
(10)	South Arcot	—0.63036*	—0.63117		0.00587	0.00163*				0.47866	3.43361	0.00133
		(0.12035)	(0.72490)		(0.00619)	(0.00070)						
(2)	Coimbatore	0.37704*	—0.94192*	0.00487	0.01644*					0.57090	1.67899	0.00195
		(0.11532)	(0.45734)	(0.00364)	(0.00834)							
(3)	Coimbatore	0.51253*	—0.96365*		0.01653	0.00125				0.54946	1.69473	0.00205
		(0.03306)	(0.46641)		(0.00853)	(0.00104)						
(10)	Coimbatore	—0.67152*	1.83843*		0.03126*	0.00230				0.55824	1.73381	0.00704
		(0.06134)	(0.86539)		(0.01583)	(0.00193)						

TABLE III—CHOLAM—TIME-SERIES RESULTS

REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND R^2

Model No.	Name of the district	Constant	Coefficients associated with $\frac{X_2}{X_1}$	X_3	X_4	X_5	$\log\left(\frac{X_2}{X_1}\right)$	$\log X_3$	$\log X_4$	R^2	D—W	S^2
(1)	North Arcot	0.00047	2.34118*	0.00022						0.92893	1.66383	0.00837
		(0.21217)	(0.28068)	(0.00597)								
(3)	North Arcot	—0.07883	2.40206*		0.01430	—0.00014				0.94891	2.25467	0.00703
		(0.07357)	(0.26044)		(0.00934)	(0.00208)						
(1)	Coimbatore	—0.18831	1.50373*	0.00597						0.73293	1.42689	0.00247
		(0.18523)	(0.35334)	(0.00445)								
(3)	Coimbatore	—0.04973	1.43108*		0.00765	0.00208				0.81208	1.78724	0.00203
		(0.08093)	(0.32520)		(0.00527)	(0.00115)						
(9)	Coimbatore	—2.19920*	4.00297*		0.02213	0.00587				0.80138	1.63233	0.01718
		(0.23533)	(0.94568)		(0.01553)	(0.00333)						
(2)	Tirunelveli	—0.55676	0.85011*	0.00665	0.02689*					0.78426	2.85367	0.00818
		(0.29189)	(0.33430)	(0.00676)	(0.01064)							
(3)	Tirunelveli	—0.35437	0.84939*		0.02811*	0.00213*				0.78464	2.84910	0.00817
		(0.23890)	(0.33405)		(0.01058)	(0.00216)						
(2)	Madurai	—0.15568	1.55833*	—0.00010	0.01685*					0.93913	1.26714	0.00148
		(0.15113)	(0.18789)	(0.00282)	(0.00474)							
(3)	Madurai	—0.15931*	1.55922*		0.01686*	—0.00003				0.93913	1.26625	0.00148
		(0.01725)	(0.28802)		(0.00474)	(0.00091)						
(4)	Tiruchirapalli	—0.07621	1.63303			—0.00328*				0.67336	1.90495	0.00355
		(0.15080)	(0.88429)			(0.00128)						
(6)	Tiruchirapalli	7.89316*					1.99412	—1.72994*		0.62415	1.72658	0.16266
		(2.81614)					(1.06792)	(0.78834)				
(7)	Tiruchirapalli	—3.38513*	9.46769			—0.02076				0.63567	1.78819	0.15767
		(1.00546)	(5.89616)			(0.00854)						

TABLE IV—CUMBU—TIME-SERIES RESULTS

REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND R^2

Model No.	Name of the district	Constant	Coefficients associated with $\frac{X_2}{X_1}$	X_3	X_4	X_5	$\log\left(\frac{X_2}{X_1}\right)$	$\log X_3$	$\log X_4$	R^2	D—W	S^2
(2)	Coimbatore	0.22945* (0.08942)	—0.30292 (0.16048)	0.00053 (0.00273)	0.02017* (0.00410)					0.81649	2.74041	0.00114
(3)	Coimbatore	0.24354* (0.04828)	—0.30175 (0.15911)		0.02017* (0.00406)	0.00017 (0.00076)				0.81679	2.74440	0.00114
(5)	Coimbatore	—3.63713* (1.32279)					—0.68918* (0.26391)	0.25820 (0.34021)	0.38337* (0.09299)	0.75027	2.93876	0.02264
(10)	Coimbatore	—1.40852* (0.18882)	— 1.24357* (0.62490)		0.07679* (0.01594)	0.00095 (0.00298)				0.80654	2.69281	0.01754
(1)	Tirunelveli	0.03731 (0.04006)	—0.57779 (0.80066)	0.00595* (0.00129)						0.75903	2.04217	0.00030
(2)	Tirunelveli	0.01847 (0.03561)	—0.11533 (0.72534)	0.00569* (0.00111)	0.00333 (0.00175)					0.84943	2.88017	0.00022
(3)	Tirunelveli	0.18946* (0.01892)	—0.04466 (0.72225)		0.00442* (0.00173)	0.00182* (0.00035)				0.85071	2.87086	0.00022
(8)	Tirunelveli	—4.67997* (0.60480)	—3.04382 (4.67000)			0.92707* (0.17830)				0.80182	2.04939	0.00782
(9)	Tirunelveli	—1.65817* (0.10714)	—1.07344 (4.09115)		0.02348* (0.00981)	0.01019* (0.00200)				0.84707	2.76241	0.00704
(3)	Ramanathapuram	0.15435* (0.03031)	0.14218 (0.25046)		0.01208* (0.00346)	0.00083 (0.00058)				0.67382	1.95421	0.00083
(10)	Ramanathapuram	—1.82524* (0.12964)	0.73682 (1.07132)		0.05332* (0.01482)	0.00356 (0.00248)				0.68607	1.93040	0.01520
(2)	Madurai	0.13820 (0.08427)	—0.37802* (0.10423)	0.00426 (0.00234)	0.02164* (0.00455)					0.89375	1.0218	0.00136
(5)	Madurai	—3.73655* (0.87399)					—0.61149* (0.10519)	0.38128 (0.22902)	0.15081* (0.05976)	0.90436	1.47692	0.01331

TABLE V—RAGI—TIME-SERIES RESULTS

REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND R^2

Model No.	Name of the district	Constant	Coefficients associated with $\frac{X_2}{X_1}$	X_3	X_4	X_5	$\log\left(\frac{X_2}{X_1}\right)$	$\log X_3$	$\log X_4$	R^2	D—W	S^2
(2)	Tirunelveli	0.73954* (0.27103)	—0.38427 (0.25020)	0.01175* (0.00357)	—0.02664* (0.00796)					0.77490	2.22751	0.00225
(5)	Tirunelveli	—1.80861* (0.73836)					—0.12409 (0.40256)	0.42799 (0.22040)	—0.13273 (0.06134)	0.61436	2.16129	0.01200
(10)	Tirunelveli	0.24605 (0.51280)	—0.57683 (0.47828)		—0.04074* (0.01506)	0.00630* (0.00218)				0.73312	2.33393	0.00831
(9)	Tirunelveli	—1.52082 (0.77512)	—0.60282 (0.49414)		—0.04562* (0.01576)			0.52783* (0.19252)		0.71645	2.38685	0.00882
(5)	South Arcot	—2.28689* (0.79341)					—2.31327 (1.23142)	0.35807 (0.18587)	—0.09962* (0.04443)	0.67329	1.31331	0.00915
(2)	Coimbatore	0.47192* (0.05924)	—0.35979* (0.08939)	0.00686* (0.00171)	0.00762 (0.00398)					0.86160	2.54057	0.00044
(3)	Coimbatore	0.65548* (0.03788)	—0.34736* (0.08602)		0.00709 (0.00381)	0.00093* (0.00046)				0.87015	2.57864	0.00041
(9)	Coimbatore	—0.38666* (0.07670)	—0.70297* (0.17417)		0.01512 (0.00771)	0.00396* (0.00093)				0.86825	2.66163	0.00170
(9)	Coimbatore	—1.62948* (0.29178)	—0.72473* (0.17110)		0.01497 (0.00753)			0.38082* (0.08705)		0.87409	2.53626	0.00162
(7)	Coimbatore	—0.46434* (0.07785)	—0.43318* (0.12654)			0.00342* (0.00106)				0.78389	1.79885	0.00239
(2)	Madurai	0.03306 (0.06648)	0.39224* (0.05831)	0.00371* (0.00154)	0.00409 (0.00303)					0.91055	2.48759	0.00062
(3)	Madurai	0.15240* (0.04750)	0.39303* (0.05829)		0.00406 (0.00302)	0.00120* (0.00050)				0.91043	2.48329	0.00062
(5)	Madurai	—1.38035* (0.36674)					0.60722* (0.08020)	0.22161 (0.10041)	0.02417 (0.02647)	0.92044	2.25569	0.00274
(6)	Madurai	—1.21015* (0.31210)					0.62158* (0.07771)	0.18365* (0.09031)		0.90938	1.99603	0.00267
(9)	Madurai	—2.26863* (0.34284)	0.90979* (0.11805)		0.00922 (0.00611)			0.22092* (0.09618)		0.92600	2.08184	0.00255

TABLE VI—CONTINUOUS CROSS-SECTION RESULTS—PADDY

MADRAS STATE

Model No.	Year	Constant	Coefficients associated with $\frac{X_2}{X_1}$	X_3	X_5	$\log X_1$	$\log X_2$	$\log X_3$	$\log\left(\frac{X_2}{X_1}\right)$	D—W	R^2	S^2
(12)	1953-54	—0.11062	0.92495*	0.00047						1.63001	0.79421	0.00185
		(0.27076)	(0.20414)	(0.00292)								
(12)	1954-55	0.00260	0.91580*	—0.00224*						2.72392	0.93866	0.00049
		(0.10593)	(0.10276)	(0.00069)								
(22)	1954-55	—0.16728*			—0.00230*				1.34134*	1.86783	0.91855	0.00119
		(0.01481)			(0.00106)				(0.15283)			
(15)	1954-55	—1.64200	1.47863*		—0.00219*					1.86865	0.90973	0.00131
		(0.16761)	(0.17794)		(0.00112)							
(15)	1955-56	—2.66650	2.04830		—0.01142					2.08552	0.56346	0.04530
		(1.17083)	(1.25790)		(0.00615)							
(15)	1956-57	—1.14588	0.65406*		0.00364					2.03316	0.49861	0.02101
		(0.26405)	(0.29631)		(0.00286)							
(16)	1958-59	—1.20695				1.83595*	—1.19669	0.88903*		2.31076	0.90891	0.03683
		(1.15661)				(0.61920)	(0.68428)	(0.36456)				
(16)	1959-60	—2.42079				1.10236*	—0.30368	0.93093		2.57084	0.93674	0.02883
		(1.72066)				(0.39960)	(0.43685)	(0.49936)				
(15)	1961-62	—0.21388	0.95077*		0.00506*					2.23859	0.49003	0.01096
		(0.33189)	(0.36658)		(0.00225)							
(19)	1961-62	—2.48568						0.61247	1.87123*	1.93201	0.50511	0.03899
		(0.90551)						(0.26615)	(0.66783)			
(22)	1961-62	—0.27953*			0.01000*				1.63230	2.26773	0.51070	0.03855
		(0.09233)			(0.00428)				(0.59774)			
(12)	1962-63	0.00804	0.92409*	—0.00639*						2.23387	0.87764	0.00233
		(0.19517)	(0.16868)	(0.00206)								
(19)	1962-63	0.95741*						—0.37070*	1.34643	2.27083	0.91597	0.00431
		(0.36828)						(0.10454)	(0.19358)			

results are not significant while for 1961-62, the percentage of irrigated area to total area and rainfall variable play a dominant role. Both coefficients have positive signs and with respect to the availability of water, if 1 per cent increase is available, output of paddy per acre increases by 1.00 ton or more than 1 ton per acre at the margin. If rainfall increases by one millimeter, then output per acre increases by .008 ton per acre. Models (6) and (7) yield highest R^2 as they are total output forms. If we interpret model (12), 1 per cent increase in the percentage irrigated area leads to 1.63 per cent increase in output per acre while 1 per cent departure from normal rainfall increases the output by .01 per cent. For 1962-63, models (1) and (2) of output per acre forms have very high R^2 and coefficients with respect to the percentage of irrigated area to total area and rainfall are highly significant. Chemical fertilizers do not show up any significant effect on productivity per acre in all models. The models having the percentage departure from normal rainfall variable do not show the importance of uncertainty. If model (9) is analysed, we find that R^2 is about 91 per cent, the coefficients with respect to the percentage of irrigated area to total area is greater than unity which means that 1 per cent increase in the percentage of irrigated area to total area leads to 1.35 per cent rise in output per acre and one per cent increase in rainfall will result in .37 per cent decline in output. This means that rainfall has a negative effect on the growth of paddy output in Madras State.

First-Order Differences Applied to Cross-Section Data

All the simple models have very low R^2 and none of them has statistically significant coefficients. All other logarithmic differences indicate that the coefficient associated with changes in area is statistically significant. This means that the contribution of increase in area in explaining output per acre is very high. Chemical fertilizers again do not have any importance for the output growth in Madras.

CONCLUSION

The above study clearly outlines the role of disaggregate analysis in the decision-making. At the State or national level, when the agriculture sector is treated as one of the sectors of the economy, some of the cancelling effects which may be important for a particular part of the country is not revealed. Hence, cropwise districtwise analysis for the Indian economy may help to guide the policy makers in formulating a suitable policy relevant to a smaller unit than the State as a whole. State level decisions are influenced by the district authorities and also by the national Planning Commission. However, district authorities have very little information and this may be because of the undue importance given to the highly aggregate analysis in the economy.

If results are summarised, we can make a general observation that rainfall is a critical variable in the disaggregate analysis and in a region where irrigation facilities are dependent on rain-fed sources, this variable cannot be ignored.