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COMPONENTS OF CROP OUTPUT GROWTH IN INDIA

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INTRODUCTION

Quantitative assessment of the contribution of the various factors to the growth of crop output at the national level or by States and smaller areas is helpful in reorienting the programmes and priorities of agricultural development so as to achieve higher rates of growth. The factors the effect of which on the growth of crop output could be studied would be area sown, proportion of irrigated area, rainfall, fertilizers, improved seeds, land development, soil conservation, improved method of cultivation, improved implements and extent of mechanized cultivation, etc. The introduction of a multiplicity of factors in any mathematical model to identify and evaluate their contribution to the growth of crop output is, however, limited by the absence of comparable time series or cross-sectional data on a factor. The limited number of years for which time series data are available, also restrict the number of factors that could be included in the analysis unless suitable transformations are applied.

RESUME OF SOME EARLIER STUDIES AT STATE LEVEL

The non-availability of comparable time series or cross-sectional data on the various components of growth of crop output has thus been a limitation on the scope of such studies. Using the production function of Cobb-Douglas type, an attempt was made to separate the contributions of irrigated area, unirrigated area and rainfall on the growth of crop output in Punjab during two periods, *viz.*, 1913-14 to 1945-46 and 1939-40 to 1956-57.[1] This study revealed that the crop output increased at an annual rate of 1.1 per cent in the first period and 4.2 per cent in the second period. Whatever slow growth in crop output was achieved in the first period, was ascribed almost entirely to expansion of irrigation; but only about one-third of the faster growth in crop output in the second period was attributed to increase in irrigation and the rest to other productivity-raising factors.

A subsequent study[2] of cross-sectional data which also employed production function of Cobb-Douglas type, for measuring the impact of total inputs and rainfall on crop output showed that the coefficient of total inputs was insignificant in those districts of Punjab where agriculture was more dependent on rain-

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1. Raj Krishna "The Growth of Aggregate Agricultural Output in Punjab," *Indian Economic Journal*, Vol. XII, No. 1, July-September, 1964.
2. C. H. Hanumantha Rao, "Growth of Agriculture in Punjab during the Decade 1952-62," *Indian Journal of Agricultural Economics*, Vol. XX, No. 3, July-September, 1965.

fall; in other districts which were comparatively free from dependence on rainfall, the crop output responded significantly to increase in the value of total inputs. Among the factors studied, *viz.*, land, labour input and bullock and tractor power, the coefficients of the first two factors were found to be not significant for Punjab as a whole; but in the selected 10 districts which had recorded large increases in cropped area and immigration of agricultural workers leading to intensive use of labour and capital inputs, the coefficients for labour and capital were found significant.

A Statewise analysis[3] covering the States of Bihar, Kerala, Madhya Pradesh, Madras, Mysore, Rajasthan, Uttar Pradesh and West Bengal was made to measure the contributions to the growth of crop output of land, extent of irrigation, rate of fertilizer application and time-trend or catch-all variable representing the sum total of slowly changing factors and technological developments not covered by the specified factors. The production function of Cobb-Douglas type was fitted to the indices of the different variables, their first differences and to the productivity per acre of sown area as a function of the other two independent variables, *i.e.*, irrigation and fertilizer. In one or more models, the coefficient of land was found to be positive and significant in all the States except Madras. The growth of crop output was explained by land to the extent of 70 per cent or more in more than half of the States and 20 to 50 per cent in the remaining States. The coefficient of irrigation was positive in Madras, Bihar, Kerala and Uttar Pradesh, but it was significant in Madras alone; in other States it was negative being significant also in Rajasthan. The contribution of irrigation to the growth of crop output was worth mentioning in Kerala, Madras and Mysore only. Fertilizer had positive coefficient in all the States except Uttar Pradesh; and in about half of these States this coefficient was significant. In Uttar Pradesh, this coefficient was negative but not significant. The contribution of fertilizer was 49 per cent in Kerala, 31 per cent in Madras, 14 per cent in Bihar and less than 8 per cent in all other States.

PRESENT STUDY AT ALL-INDIA LEVEL

Such analysis for States, and better still for smaller homogeneous agricultural regions, helps to locate the imbalances in the existing programmes and indicate the specific aspects of development on which efforts have to be intensified. The analysis of this type at the national level is expected to reveal for the country as a whole the overall impact of a programme on increasing the crop output which has been implemented and has responded differently and has thus varying impacts in the different areas. In this paper, an attempt has, therefore, been made to study at the all-India level the contributions of land, irrigation and fertilizer to the growth of crop output. The analysis covers the period 1951-52 to 1962-63 for which complete data on all the variables are available.

VARIABLES STUDIED AND DATA UTILIZED

The independent variables studied are gross area sown(x_1), proportion of gross irrigated area to gross area sown (x_2) and total quantity of fertilizer (in terms

3. Ashok Parikh, "Statewise Growth Rate in Agricultural Output—An Econometric Analysis," *Artha Vijnana*, Vol. 8, No. 1, March, 1966.

of N) per unit of irrigated area (x_3). The dependent variable is the total crop output (Y). In order to reduce multicollinearity and specification bias, proportion of gross irrigated area to gross sown area has been taken as a variable, instead of gross irrigated area as such; similarly quantity of fertilizer used per unit of irrigated area has been taken as another variable, instead of quantity of fertilizer used per unit of total sown area. The absolute data on the variables have been converted into index numbers with 1951-52 as the base in which allowances for changes in coverage and methods of reporting and estimation have been made to provide the comparable time series.

While the indices of gross irrigated area as proportion of gross sown area (x_2) and of fertilizer per unit of irrigated area (x_3) with 1951-52 as the base have been constructed afresh, the indices of crop output and gross sown area with 1949-50 as the base constructed by the Directorate of Economics and Statistics, Ministry of Food, Agriculture, Community Development and Co-operation[4] have been taken and the base has been shifted to 1951-52 to make these series comparable with the series on irrigated area and fertilizer. The indices of fertilizer use per unit of irrigated area have been arrived at by first constructing the indices of total fertilizer consumed and then deflating these indices with the indices of gross irrigated area, assuming that the fertilizer has been utilized mostly on irrigated lands. These indices utilized in the analysis are given in Table I.

TABLE I—INDICES OF CROP OUTPUT, GROSS AREA SOWN, PROPORTION OF GROSS AREA IRRIGATED TO GROSS AREA SOWN, AND CONSUMPTION OF FERTILIZER (N) IN TERMS OF PER UNIT OF IRRIGATED AREA

Year	Index of crop output (Y)	Index of gross area sown (x_1)	Index of proportion of gross area irrigated to gross area sown (x_2)	Index of proportion of consumption of N to gross irrigated area (x_3)	Time-Trend (t)
(1)	(2)	(3)	(4)	(5)	(6)
1951-52	100.000	100.000	100.000	100.000	1
1952-53	104.615	103.487	97.151	97.314	2
1953-54	117.231	109.257	96.198	143.173	3
1954-55	120.000	110.370	97.623	153.594	4
1955-56	119.795	113.062	97.867	164.556	5
1956-57	127.467	114.126	97.203	199.399	6
1957-58	118.872	112.771	101.894	215.070	7
1958-59	136.923	117.300	99.108	247.967	8
1959-60	133.641	118.781	99.662	264.298	9
1960-61	145.846	118.882	101.154	300.147	10
1961-62	148.513	121.866	100.408	335.200	11
1962-63	141.026	120.566	105.346	407.391	12

4. Growth Rates in Agriculture 1949-50 to 1964-65, Economic and Statistical Adviser, Ministry of Food and Agriculture (now Ministry of Food, Agriculture, Community Development and Co-operation), March, 1966.

MODELS EMPLOYED

The usually employed production function of Cobb-Douglas (Double-Log) type has been fitted to (*i*) the indices of the variables, (*ii*) the first differences of these indices and (*iii*) the productivity per unit of gross area (Y/x_1) as dependent variable and irrigated area and fertilizer used (x_2 and x_3) as independent variables. In addition, the production function of linear multiple regression type has also been fitted. Symbolically, the models used are :

$$\log Y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\triangle \log Y = a + b_1 \triangle \log x_1 + b_2 \triangle \log x_2 + b_3 \triangle \log x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\log (Y/x_1) = \log a + b_2 \log x_2 + b_3 \log x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

The above models do not take into account the other factors like land development, soil conservation, improved methods of cultivation, improved seeds, plant protection measures, improved implements, mechanized cultivation, etc. At present, it is difficult to measure the impact of each of these factors separately for want of adequate and precise data on them. Moreover, at the present stage of development, the impact of each of these factors taken individually may be small, and it is only their combined effect which might be measured. With a view to providing a measure of this combined effect, it is necessary to introduce what is called time-trend (t) or catch-all variable representing the combined effect of all other factors unspecified in the models. This variable in the log form would indicate upward trend with decreasing steepness with the passage of time and would be valid when the saturation level has been reached. Since this stage is not expected to have been attained in Indian agriculture, it would be logical to take 't' in original. On introducing time-trend (t), model (2) above employing the first differences of variables will remain unchanged, while the other three models will take the following forms with 't' :

$$\log Y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 t \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\log (Y/x_1) = \log a + b_2 \log x_2 + b_3 \log x_3 + b_4 t \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 t \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

RESULTS

The regression coefficients of the different independent variables, the standard errors and significance or otherwise of these coefficients and the coefficient of multiple determination (R^2) for each of the above mentioned seven models employed, are given in Table II. In all the models, 87 per cent or more of the variation in the crop output is explained by the variables included. The coefficient of gross area sown (x_1) is positive in all the models without (t) and is statistically significant (at 5 per cent level of significance) in one of these models. This coefficient is negative in all the models with 't', but is not significant in any one of them. The coefficient of proportion of gross irrigated area to gross area sown (x_2) is negative in all the models, but in no model it is statistically significant. Fertilizer consumption per unit of irrigated area (x_3) has positive coefficient in all the models and it is statistically significant in one model. The coefficient of time-trend (t) is also positive in all the models in which it is introduced, but it is significant

TABLE II—REGRESSION COEFFICIENTS OF GROSS AREA SOWN (x_1), PROPORTION OF GROSS IRRIGATED AREA TO GROSS AREA SOWN (x_2), CONSUMPTION OF FERTILIZER (N) PER UNIT OF IRRIGATED AREA (x_3) AND TIME-TREND (t) AND COEFFICIENT OF MULTIPLE DETERMINATION (R^2) FOR DIFFERENT PRODUCTION FUNCTION MODELS STUDIED

Model No.	Model	Gross area sown (x_1)			% gross irrigated area to gross area (x_2)			Fertilizer use (x_3)			Time (t)			Coefficient of multiple determination (R^2)
		Regression coefficient	Standard error (S.E.)	Sig. (S) or Not Sig. (NS)	Regression coefficient	S. E.	Sig. (S) or Not Sig. (NS)	Regression coefficient	S. E.	Sig. (S) or Not Sig. (NS)	Regression coefficient	S. E.	Sig. (S) or Not Sig. (NS)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1.	$\log Y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3$	.0994	.9909	NS	—1.6363	.9165	NS	.3100	.1594	NS	—	—	—	0.96
2.	$\triangle \log Y = a + b_1 \triangle \log x_1 + b_2 \triangle \log x_2 + b_3 \triangle \log x_3$	1.5415	.5147	S at 5% only	—.7785	.3951	NS	.5978	.0853	S	—	—	—	0.89
3.	$\log (Y/x_1) = \log a + b_2 \log x_2 + b_3 \log x_3$	—	—	—	—.9043	.4356	NS	.1681	.0773	NS	—	—	—	0.87
4.	$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3$	.9493	.6569	NS	—1.9828	1.1384	NS	.1267	.0632	NS	—	—	—	0.96
	With 't' as fourth independent variable													
5.	$\log Y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 t$	—.4824	1.0748	NS	—2.2575	1.0263	NS	.2361	.1663	NS	.0095	.0078	NS	0.97
6.	$\log (Y/x_1) = \log a + b_2 \log x_2 + b_3 \log x_3 + b_4 t$	—	—	—	—.9805	.4647	NS	.0851	.1281	NS	.0048	.0023	NS	0.88
7.	$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 t$ ..	—.1947	1.2301	NS	—2.9138	1.4098	NS	.0878	.0719	NS	3.5547	3.2473	NS	0.96

in none of these models. The negative, but insignificant coefficient of irrigation may be interpreted as approximating to zero. The effect of irrigation seems to be distributed among those of area sown, fertilizer use and technical improvement all of which are promoted, among other things, by irrigation.

Since irrigation (x_2) is found uniformly to have negative coefficient, it is eliminated and the coefficients of the other variables, *viz.*, area sown (x_1), fertilizer consumption (x_3) and time-trend (t) are recalculated in the following models which exclude the earlier models (3) and (6) in which fertilizer (x_3) alone, with or without time-trend (t), is left after elimination of irrigation (x_2):

$$\log Y = \log a + b_1 \log x_1 + b_3 \log x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$\triangle \log Y = a + b_1 \triangle \log x_1 + b_3 \triangle \log x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$Y = a + b_1 x_1 + b_3 x_3 \quad \ldots\ldots\ldots\ldots\ldots \quad (10)$$

$$\log Y = \log a + b_1 \log x_1 + b_3 \log x_3 + b_4 t \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$Y = a + b_1 x_1 + b_3 x_3 + b_4 t \quad \ldots\ldots\ldots\ldots\ldots \quad (12)$$

The recalculated coefficients of area (x_1), fertilizer (x_3) and time-trend (t), their standard errors and significance or otherwise, and the coefficient of multiple determination (R^2) for the above five models are shown in Table III. Model (9) gives the highest coefficient of both area (x_1) and fertilizer (x_3), but the coefficient of multiple determination (R^2) is low. In model (12) which explains 94 per cent of the variation in crop output, the coefficient of area (x_1) is almost as high as in model (9), and the coefficient for fertilizer (x_3) is in between the corresponding coefficients in the other models. Model (10) which accounts for 94 per cent of variation in crop output gives the third highest coefficient for area sown (x_1), but the lowest coefficient for fertilizer (x_3). Models (8) and (11) each account for 95 per cent of variation in crop output, but they give the lowest coefficients for area (x_1) and the coefficients for fertilizer (x_3) are also not high. The coefficient of area (x_1) is statistically significant at 1 per cent level of significance in models (9) and (10) and at 5 per cent level in models (8), (11) and (12). Coefficient of fertilizer (x_3) is not statistically significant in any of the models at both the levels.

Models (8) to (12) which give positive coefficients for both area (x_1) and fertilizer (x_3) are helpful in finding out the contributions of these variables to the growth of crop output. Model (9) which explains only 54 per cent of the variation in the crop output may not, however, be used for this purpose.

The growth equation may be symbolically expressed as

$$Y^\circ = b_1 x_1^\circ + b_3 x_3^\circ + b_4 \quad \ldots\ldots\ldots\ldots \quad (13)$$

where Y°, x_1° and x_3° are growth rates of crop output (Y), area (x_1) and fertilizer (x_3) respectively. The variables are assumed to follow the linear trend in models (10) and (12) and exponential trend in the other two models (8) and (11), such that $Y^\circ = dy/dt$, $x_1^\circ = dx_1/dt$, and $x_3^\circ = dx_3/dt$ in models (10) and (12); and $Y^\circ = 1/Y \cdot dy/dt$, $x_1^\circ = 1/x_1 \cdot dx_1/dt$ and $x_3^\circ = 1/x_3 \cdot dx_3/dt$ in the other two models (8) and (11).

TABLE III—REGRESSION COEFFICIENTS OF GROSS AREA SOWN (x_1), CONSUMPTION OF FERTILIZERS (N) PER UNIT OF IRRIGATED AREA (x_3) AND TIME-TREND (t), AND COEFFICIENT OF MULTIPLE DETERMINATION (R^2) FOR DIFFERENT PRODUCTION FUNCTION MODELS STUDIED

Model No.	Model	Gross area sown (x_1)			Fertilizer use (x_3)			Time 't'			Coefficient of multiple determination (R^2)
		Regression coefficient	Standard error (S.E.)	Significant (S) or Not Significant (NS)	Regression coefficient	S. E.	Significant (S) or Not Significant (NS)	Regression coefficient	S. E.	Significant(S) or Not Significant (NS)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
8.	$\log Y = \log a + b_1 \log x_1 + b_3 \log x_3$ ..	1.6394	.5385	S at 5%	.0504	.0721	NS	—	—	—	0.95
9.	$\Delta \log Y = a + b_1 \Delta \log x_1 + b_3 \Delta \log x_3$ ..	2.0896	.2563	S	.1282	.1559	NS	—	—	—	0.54
10.	$Y = a + b_1 x_1 + b_3 x_3$	1.8515	.4478	S	.0283	.0316	NS	—	—	—	0.94
	With 't' as third independent variable										
11.	$\log Y = \log a + b_1 \log x_1 + b_3 \log x_3 + b_4 t$	1.6420	.5637	S at 5%	.0330	.1646	NS	.0010	.0081	NS	0.95
12.	$Y = a + b_1 x_1 + b_3 x_3 + b_4 t$	1.9481	.8072	S at 5%	.0396	.0834	NS	—.4899	3.173	NS	0.94

The contributions of area (x_1), fertilizer (x_3) and time-trend (t) as worked out from the growth equations of models (8), (10), (11) and (12) are presented in Table IV.

TABLE IV—GROWTH RATE OF CROP OUTPUT, GROWTH RATE OF CROP OUTPUT EXPLAINED IN DIFFERENT MODELS AND CONTRIBUTIONS OF GROSS AREA SOWN (x_1), FERTILISER (x_3) AND TIME-TREND (t) TO GROWTH RATE OF CROP OUTPUT

Model No.	Model	Growth rate of crop output, % per annum	Explained growth rate of crop output, % per annum	Percentage contribution of		
				Area	Fertilizer	Time
(1)	(2)	(3)	(4)	(5)	(6)	(7)
8.	$\log Y—\log a+b_1 \log x_1+ b_3 \log x_3$	3.5 (Compound)	3.3	75	19	—
10.	$Y=a+b_1x_1+b_3x_3$ ..	3.9 (Linear)	3.9	82	18	—
11.	$\log Y=\log a+b_1 \log x_1+ b_3 \log x_3+b_4t$ ..	3.5 (Compound)	3.5	75	13	12
12.	$Y=a+b_1x_1+b_3x_3+b_4t$	3.9 (Linear)	3.9	85	35	—20

The compound growth rate of crop output (Y) during the period under study works out to 3.5 per cent per annum. According to the growth equation of model (8), 75 per cent of this growth in crop output is explained by area sown (x_1), 19 per cent by fertilizer (x_3) and the balance of 6 per cent by other productivity-raising factors. According to the growth equation of model (11) which is the same as model (8) with time-trend (t), the contribution of area sown remains unchanged at 75 per cent, that of fertilizer is reduced to 13 per cent, and the balance of 12 per cent is accounted for by time-trend (t) representing the combined effect of other factors. A part of the contribution of the other factors which was included in that of fertilizer in model (8), gets separated in model (11) when time-trend (t) representing these factors is introduced.

The linear growth rate of crop output (Y) is estimated at 3.9 per cent per annum which is fully explained in the growth equation of model (10) by area sown (x_1) and fertilizer (x_3), their shares being 82 per cent and 18 per cent respectively. In the growth equation of model (12) which is obtained after introducing time-trend (t) in model (10), the share of area sown (x_1) is raised to 85 per cent and that of fertilizer (x_3) to 35 per cent. This implies that the effect of other factors was already included in the contributions by area sown and fertilizer in model (10), and the introduction of time-trend (t) in model (12) has only inflated these contributions, particularly the contribution of fertilizer.

CONCLUSION

The expansion of area sown through extension of cultivation and intensive cropping thus contributed about three-fourth to four-fifth of the growth of crop output in India during 1951-52 to 1962-63 which occurred at the compound rate of 3.5 per cent per annum or the linear rate of 3.9 per cent per annum. The remaining part of this growth was contributed almost equally by increase in application of fertilizers and improved techniques and technological developments resulting from land development and soil conservation measures, improved cultivation practices, improved seeds, pest and disease control, improved implements, etc. Irrigation promotes expansion in crop area by enabling both extension of cultivation and multiple cropping and also makes application of fertilizers and improved cultivation practices possible. Its contribution to the growth of crop output is naturally divided among the contributions of area sown, fertilizers applied and improved techniques practised.

This analysis reveals that land still continues to be the major contributor to the growth of crop output in India, and that irrigation and fertilizer as the chief motivating force to usher in the whole complex of modern technology in Indian agriculture have yet to play their significant role. Not only the proportion of area irrigated is low in many parts of India, but even where it is large it is seasonal and is used more to offset the adverse effects of inadequate and uneven rainfall than to increase crop productivity and cropping intensity in combination with other improved techniques that are made possible through irrigation. The fertilizer application per unit area is also one of the lowest in the world.

In 1959-60, the irrigated area in India was only about 20 per cent of the area sown, the fertilizer consumption was 2.3 kgs. per hectare and the value of crop output per hectare was $91. Countries like Japan, UAR, Israel and Taiwan which had much higher extent of irrigated area and fertilizer use had achieved much higher value of crop output per hectare. Even the countries like Philippines, Mexico, Greece, Venezuela and Yugoslavia with lower proportion of irrigated area but higher rate of use of fertilizer had achieved higher value of crop output per hectare.[5]

The modern technological break-through in Indian agriculture has yet to come in a significant way through progressively larger use of irrigation and fertilizer and the whole complex of improved techniques and practices that are feasible and effective with irrigation and fertilizer. In view of the low level of application of modern technology, one need not be amazed to see lower growth rate of crop output in India than in several other developing and developed countries. This picture, on the other hand, provides hope for the future rather than despair, and points the direction in which the efforts have to be intensified. Development efforts which will enable adequate and judicious use of irrigation and fertilizers and other supporting inputs should promote a much higher rate of growth of crop output than what has been achieved so far. In this context, the new agricultural strategy advocating adoption of improved crop varieties which are responsive to high doses of fertilizer necessitating more frequent and timely irrigation and better crop husbandry, seems to be an overdue move to usher in the long awaited technological break-through in Indian agriculture.

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5. Changes in Agriculture in 26 Developing Nations, 1948 to 1963, Economic Research Service, U. S. Department of Agriculture, 1965.