Contribution of Research and Extension to Productivity Change in Indian Agriculture

Rakesh Mohan

An attempt is made here to estimate the contribution of expenditures on research and extension activities to changes in real productivity in Indian agriculture over the period 1952-53 to 1970-71. Particular attention is paid to the Intensive Agriculture Districts Programme as an example of the package approach to extension.

The major conclusions that emerge are:

(1) Total factor productivity gains in agriculture in some parts of India have been truly extraordinary.

(2) Regional disparities have become greater over the period under review and these may well have been partly caused by governmental allocational decisions.

(3) The gains realised have not been associated exclusively with the 'Green Revolution' both in space as well as time, or with the extent of irrigated acreage.

(4) The major determinant of productivity change in Indian agriculture has been the Indian Agricultural Research System and the investment in the research system has yielded social rates of return far in excess of those realised in other developmental activities.

(5) Extension programmes are successful where significant economic slack exists: they do not discover new technology but can merely make production more efficient. Their marginal contribution in areas of high productivity is therefore low.

IN these days of pervasive gloom it is pleasant to report results of research which indicate that at least one sector of public endeavour has been productive in India. Now that the initial euphoria over the 'Green Revolution' has died down more sober perspectives are likely to be accorded more attention. The almost simultaneous discovery of Mexican wheat varieties and IRRI rice varieties, while clearly an economic boon, was unfortunate in two respects: it induced an unwarranted optimism concerning increases in world food production and, secondly, it distracted efforts to understand the real processes of technology discovery and diffusion in the agricultural sector. Here we report an effort to estimate the contribution of expenditures on research and extension activities to changes in real productivity in Indian agriculture over the period 1952-53 to 1970-71. Particular attention is paid to the Intensive Agriculture Districts Programme as an example of the package approach to extension. Such an effort, we believe, is important to provide policy-makers with better information on which to base allocational policy decisions.

Our major conclusions are as follows:

(1) Total factor productivity gains in agriculture in some parts of India have been truly extraordinary.

(2) Regional disparities have become greater over the period in review and these may well have been partly caused by governmental allocational decisions.

(3) The gains realised have *not* been associated exclusively with the 'Green Revolution' both in space as well as time, or with the extent of irrigated acreage.

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Framework for Analysis

The most widely used indicator of agricultural productivity for comparisons over time and across regions has been crop output per unit land. Output per man-hour has also often been used. Such partial measures are incomplete because they implicitly indentify one factor as *the* scarce or productive factor implying a fixed co-efficients production function. In analysing productivity change it is more appropriate to use the total factor productivity concept which is an index of output per unit of total input. The total factor productivity index (TFP) is specifically designed to measure output changes net of the contribution of all conventionally measured inputs. It is therefore a measure of the contribution to production of activities such as technology discovery and diffusion activities and efficiency inducing activities not normally measured in terms of inputs.

We develop the TFP index as follows: consider the production function

$$Y = F(X_1 Q_1 T_1, X_2 Q_2 T_2, \ldots, X_n Q_n T_n) \quad (1)$$

where F is homogeneous of degree 1. Y is a measure of output, $X_1 \ldots X_n$ are conventionally measured inputs: land, labour, fertiliser, etc, — $Q_1 \ldots Q$ are indexes of measurable quality $T_1 \ldots T_n$ are indexes of factor augmenting technical change.

The implication is that while Q can, in principle, be measured, T cannot. Under the assumption that F is homogeneous of degree 1 and that producers maximise profits, we differentiate (1) with respect to time and obtain

$$\frac{\dot{Y}}{Y} = \frac{dY/dt}{Y} = \sum_{i=1}^{n} S_i \left(\frac{\dot{X}_i}{X_i} + \frac{\dot{Q}_i}{Q_i} + \frac{\dot{T}_i}{T_i}\right) \quad (2)$$

where the S_i are input shares in total cost. The TFP index $\frac{\dot{P}}{P}$ is defined as

$$\frac{\dot{P}}{P} = \frac{\dot{Y}}{Y} - \sum_{i=1}^{n} S_i \frac{\dot{X}_i}{X_i} = \sum_{i=1}^{n} S_i \left(\frac{\dot{Q}_i}{Q_i} + \frac{\dot{T}_i}{T_i}\right) \quad (3)$$

The appropriate productivity index is a chain linked index of weighted growth

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TABLE 1: GROWTH IN AGRICULTURAL OUTPUT AND INPUTS IN SELECTED INDIAN STATES 1953-54 TO 1970-71

State	Period I		Period II		Period III	
	1953-56 to	1958-61	1958-61 to	1963-65	1963-65 to	1969-71
Andhra Pradesh						
Annual output growth		2.42		2.63		—.24
Annual input growth		1.57		2.52		1.29
Traditional inputs	1.48		1.09		.18	
Modern inputs	.09		1.41		1.11	
Residual productivity growth		.85		.11		—1.05
Gujarat						
Annual output growth		3.00		4.71		7.13
Annual input growth		2.26		1.90		2.35
Traditional inputs	1.83		1.16		1.62	
Modern inputs	.43		.74		.73	
Residual productivity growth		.74		2.81		4.78
Haryana						
Annual output growth		4.73		1.23		20.40
Annual input growth		2.32		1.93		4.30
Traditional inputs	1.15		.48		2.60	
Modern inputs	1.37		1.45		1.70	
Residual productivity growth		2.41		—.70		16.10
Maharashtra						
Annual output growth		3.59		.85		.08
Annual input growth		1.48		1.78		2.21
Traditional inputs	1.36		1.34		1.46	
Modern inputs	.22		.44		.75	
Residual productivity growth		2.11		—.93		—2.13
Karnataka						
Annual output growth		3.97		2.96		1.93
Annual input growth		2.94		2.27		1.66
Traditional inputs	2.79		.75		.28	
Modern inputs	.15		1.52		1.34	
Residual productivity growth		1.03		.69		0.27
Punjab						
Annual output growth		4.73		3.60		19.20
Annual input growth		2.32		3.08		5.80
Traditional inputs	1.32		1.28		2.64	
Modern inputs	1.00		1.80		3.16	
Residual productivity growth		2.41		.52		13.40
Tamil Nadu						
Annual output growth		4.48		1.77		3.08
Annual input growth		2.99		3.26		2.47
Traditional inputs	2.91		1.26		1.04	
Modern inputs	.08		2.00		1.43	
Residual productivity growth		1.49		—1.43		.61
Uttar Pradesh						
Annual output growth		1.87		2.47		4.87
Annual input growth		1.44		1.81		1.96
Traditional inputs	1.06		1.13		.76	
Modern inputs	.38		.68		1.20	
Residual productivity growth		.43		.66		1.93

Source: Evenson and Jha (1973), Table I.

rates of inputs (and outputs) with the weights changed often.

This formulation can be modified slightly to incorporate departures from profit maximisation by adding a term for economic 'errors':

$$\frac{\dot{P}}{P} = \sum_{i=1}^{n} S_i \left(\frac{\dot{Q}_i}{Q_i} + \frac{\dot{T}_i}{T_i}\right) + \alpha_i \left|\frac{\dot{F}_i}{F_i} + \frac{\dot{W}_i}{W_i}\right| \quad (4)$$

F is the marginal productivity of input: W_i is the input's price.

For our purposes we note that factor quality improvement, factor augmenting technical change and economic error reduction are the consequence of the systematic effort of researchers, extension agents and factor suppliers to discover and diffuse technology. This is therefore a convenient unified framework with which to evaluate the contributions of both research and extension. The 'partial' effect of the introduction of improved technology will result in an increase in the economic errors, holding constant extension activity and producer learning activity. The partial effect of an increase in extension effort, and of improved marketing of inputs will be to reduce these errors, but at a diminishing rate.

The rate of measured total factor productivity growth in a particular area would be determined by:

(1) The application by producers of *new* economically relevant technology which originates from three sources:

(a) Discovery activity directed toward producing technology suited to use under the soil, climate and economic conditions of the area.

(b) Discovery activity toward technology development suited to economic, soil and climate conditions significantly different from those of the area, but which is, nonetheless, superior to existing technology.

(c) Discovery activity by producers themselves who modify and 'adapt' new technology to farm specific conditions.

(2) The reduction of economic 'slack' or economic and technique choice errors. These improvements can result from:

(a) Improvements in technique choice by farmers, that is, the adoption of

TABLE 2: SUMMARY — STATE PRODUCTIVITY ANALYSIS 15 INDIAN STATES: 1953-71
Dep Variable: TFP Index: 285 obs

Regression	1	2
R^2	.587	.548
Const	1042.3	976.7
DDR	−177.0	−170.2
	(−10.8)	(−10.0)
D53-59	−28.1	−31.11
	(−1.51)	(−1.58)
D64-71	−4.7	−46.7
	(−0.23)	(−2.19)
D N West	55.0	121.4
	(2.04)	(5.86)
RI	.300	
	(2.5)	
RR	.107	
	(2.74)	
RR/Exp (.01RI)	−4.99	
	(−4.84)	
(RR + RI) Ext	.0017	0338
	(2.83)	(5.54)
L		268.0
		(2.00)
(RR + RI) L		−3.72
		(2.14)
RR/Exp (PI)		−.120
		(3.24)

t-statistics in parenthesis
D/DR: Dummy variable for drought years.
D/53-59, D/64-71: Period dummies
D/N West: Dummy Punjab, Haryana, Gujarat, Rajasthan.
EXT: .25 x stage I extension blocks + .75 x stage II blocks + stage III blocks/Total delineated blocks in the State.
PI: Average number of publications (1960-65) in Agricultural Science from Indian Science Abstracts (15).
Dependent variable: Productvity index = 1000 for 1953 to 1958 average.

existing technology which is superior to that in use.

(b) Improvements in allocative efficiency by farmers; i e, utilising resources in a more cost minimising fashion.

(c) Improvements in factor supply efficiency including credit. Our basic formulation of explanation of productivity change is

$$\frac{\dot{P}}{P} = G\left(\sum_{i=0}^{n} W_i R_{t-i}, \sum_{j=0}^{n} V E_{t-j}, D_t\right) \quad (3)$$

where the first term in the function is some weighted average of research expenditures over a number of years, the second term a weighted average of extension expenditures. D_t represents managerial activities. Variations of this are used in different regressions to be described later.

In an analysis of productivity change in agriculture one other important variable to be accounted for is the region specificity of research and extension. When evaluating the contribution of research to productivity we have to identify which is the relevant research. That the transferability of research is limited across regions is now fairly well established (Evenson and Kislev, 1973). We can assume that new technology (e g, a new maize variety) discovered in one state would be adopted in other states as well, but only if their geo-agro-climatic conditions are such that this can be done. Thus we can say that productivity in a given state is determined by the research devoted to technology discovery specific to the geoclimate conditions of that state and to extension and other information supply activities which may speed diffusion of their technology. We also have to model indirect technology transfer. A new variety of a grain produced in one state may be used as a parent variety in the production of improved varieties in another region. Advances in plant physiology and pathology are applicable everywhere. Experimental design improvements can be transferred across states. This process can be modelled only imperfectly and we do this defining 2 kinds of regions. First, we have a geo-climate classification based on the work of Papadakis (1967). It is a broad climate classification designed to identify climate regions of sufficient similarity that technology transfer can be expected to take place within the region. The geo-climate regions in India are located in other countries as well and some degree of international technology transfer is involved in the determination of productivity change in India. We aggregate research expenditures of different states in the same geo-climate region in our analysis. We also investigate some interaction effects. The second classification — that of agro-climate regions — is a narrower one and is designed to identify small regions with reasonably homogeneous cropping patterns and soil and climate conditions. This classification is made use of in the evalution of the Intensive Agriculture District Programme and is based on the work of Easter (1972). The objective is to control for unmeasurable factors which can be considered uniform over a small region.

EVIDENCE ON PRODUCTIVITY CHANGE

Table 1 presents a summary of changes in output, modern and traditional inputs and productivity for some Indian states for 3 time periods. [See Evenson and Jha (1973) for more complete coverage, the annual output and input series, detailed notes on data sources and calculations].

The total input growth rate is disaggregated into the contribution of traditional inputs, land (including canal irrigation), labour and animal power; and of modern inputs: fertiliser, tractor and pump-set irrigation. The productivity growth rate is the residual; the difference between the growth rates of output and that of inputs.

In period I the recorded residual productivity growth is of respectable proportions for almost all states. Moreover, there is little regional disparity.[1] Modern inputs were relatively unimportant except for Punjab and Haryana.

A very uneven pattern appears in period II with

(a) TFP increases being lower than period I for most states

(b) the contribution of modern inputs being significant for most states.

Period III shows phenomenal growth rates for Punjab-Haryana and Gujarat while the rest are either negative or mildly positive.

Overall it can be said that period I probably exhausted efficiency increasing possibilities and the utilisation of unused traditional inputs like land. The increments in production since then are increasingly dependent on new technology and the use of modern inputs. The research system thus assumes vital importance in the prognosis for the future.

EXPLANATION OF PRODUCTIVITY CHANGE

(1) *Research Programmes*

In principle, in a perfect information world we could measure quality changes in enough factors so that growth in output could be explained by measured inputs. In practice, this is impossible so we attempt to explain the residual productivity change as the outcome of research and extension activities.

Our specification is then

$$TFP_i\,(t) = H\,(DDR,\ DT_j,\ REG_i,\ RI_i,\ EXT_i,\ L_i,\ PI_i) \quad (6)$$

where DDR_i is a dummy for drought years i e, years in which production dropped more than 10 per cent below trend;

DT_j is a dummy variable for time period: specifically $DT_{53\text{-}59}$ and $DT_{64\text{-}71}$

$DREG_i$ is a dummy for region: specifically for the North west region,

RI_i is indigenous state expenditure on research cumulated from 1953 to t and deflated by the 1960 value of resources devoted to agricultural production in the state;

RR_{it} is the cumulated research expenditure of research programmes conducted outside the state, but within the same geo-climate region, deflated in the same way as RI.

EXTi is a measure of the extension programme in the state: (.25 X stage I blocks + .75 X stage II blocks + 1.0 X stage 3 blocks)/ Total blocks.

L_i is per cent made literacy in rural areas (interpolated between census years); and

PI_i is average number of publications in the agricultural sciences for the 1960-65 period, which are abstracted in "Indian Sciences Abstracts".

Information on RR, and PI has been compiled and presented in an earlier paper in this journal (Mohan, Jha and Evenson [1973]).

The best regressions obtained are reported in Table 2.

An explanation of the particular specification is in order. The ideal construction of the research variables would involve various distributed lags estimating techniques (e g, Evenson [1971], Fishelson [1971]) which would reflect lags in the discovery and dissemination process as well as depreciation and obsolescence. These parameters are not easy to identify, however, because of collinearity with time.

Two terms in regressions 1 and 2 need elaboration. Research conducted outside the state, it is hypothesised, manifests itself through research within the state as is illustrated by the examples given in the earlier section. This is captured by the interaction term RR/Exp (.01RI). (The .01 was estimated by interaction). As RI increases the gains from RR increase.

The ratio of actual gains to potential gains from regional research approaches unity as RI increases. We expect the co-efficient of this term to be negative since the term gets smaller as RI increases. Finally we add an interaction term for research and extension.

Regression 1 reported here is the best from various formulations tried. All variables have the expected signs and are highly significant. The dummy for drought years is negative. There is no exogenous 'green revolution' effect since the dummy for 1964-71 is insignificant. However, the North West region dummy is positive and significant. It could, therefore, be capturing the 'green revolution' effect but that is doubtful since the results were almost identical when the green revolution years were excluded in estimation. The NW dummy may, indeed, be capturing other socio-economic characteristics, e g, propensity for hard work, entrepreneurship which Punjabis are popularly known for. In another exercise, a variable measuring the extent of irrigated acreage was included but was negative and insignificant in all cases.

Regression 2 is exploratory and is really a suggestion for further directions in research. We introduce literacy, L and a measure of research quality, PI. Both have net positive effects. Literacy has a positive direct effect but negative interaction effect with research. The publications variable apparently helps along indirect transfer of technology. The negative literacy interaction with research indicates that literacy is a kind of substitute for research. Highly literate farmers could be conducting experiments much as agriculture experiment stations. It would, however, be more instructive to use more sophisticated indicators of levels of education than base literacy which does not really reflect skills of farm managers adequately. Similarly, our publications data may be incomplete and it may not be the best proxy for research quality.

(2) *Extension Programmes: The Intensive Agriculture Districts Programme*

Readers of this journal need no introduction to the IADP. We need only point out here that the Programme was based on two main premises: first it supposed that significant economic slack existed in these districts. It supposed that economically relevant technology was available but that farmers had not adopted it for reasons of ignorance or from lack of complemen-

TABLE 3: DISTRICT TOTAL FACTOR PRODUCTIVITY MEASURES: INDIAN AGRICULTURE, 1959-60 TO 1970-71

Agro-Climate Region	Number of Districts in Region	Annual Regional $\triangle$TFP 1960-71	Annual $\triangle$TFP for IADP 1960-71	Average Level of Food Grain Yields Tonnes/ha	Input Shares L	K	Fert
Northern Regions							
(1) North Punjab wheat area	9	2 03	1.65	.523	.39	.13	.041
(2) Punjab-Haryana-UP dry wheat area	9	6 07	1.80	.356	.40	.09	.017
(3) Western UP wheat-sugarcane area	12	5.00	—	.313	.38	.18	.026
(4) South-Central UP wheat-bajra area	13	2.23	—.5	—.343	.41	.17	.018
(5) East Central UP rice-pulses area	16	4.95	—	.292	.47	.18	.018
(6) SE UP rice-grain	5	—.6	—	.259	.35	.18	.007
Central and Southern Regions							
(7) AP Coastal	7	—.01	2.80	.400	.41	.11	.047
(8) Tamil Nadu Coastal	7	.29	—.7	.512	.43	.18	.016
(9) Maharashtra, Karnataka Coastal	6	.20	—	.421	.45	.14	.013
(10) East Central Mah Black soils area cotton-jowar	10	1.28	0.0	.314	.44	.13	.017
(11) West Central Mah Black soils area Jowar-pulses-Bajra	13	2.08	—	.291	.47	13	021
(12) Northern Karnataka Black soils area jowar-cotton	6	1.53	—	.214	.35	.10	.020
(13) Interior AP Jowar Red soils-oilseeds-rice	14	—.50	—	.254	.38	.13	.021
(14) Southern Karnataka-TN red soils area	13	3.10	2.47	.357	.45	.14	.045

Source: Mohan and Evenson (1974).

TABLE 4: DISTRICT REGRESSION ANALYSIS
140 Districts: 14 Agro-Climate Regions: 1960-71

Regression	Dependent Variable: Total Factory Productivity (1960 = 100) (1)	(2)	Dependent Variable: Foodgrain Yield Index (1960=100) (3)	(4)
Independent Variable				
State Research (SR)	.655		.97	
	(3.54)		(5.71)	
Regional Research (RR)	.373		1.15	
	(4.72)		(12.78)	
(SR) x (RR)	—.0042		—.024	
	(3.23)		(6.00)	
DDISTR it		.721		3.65
		(2.95)		(16.59)
NDISTR it		1.017		2.14
		(3.55)		(19.45)
Early Period TFP (TFP5661)	—7.45	—7.56	—9.2	—7.6
	(4.54)	(4.61)	(6.13)	(4.6[illegible])
Dummy for IADP (DIADP)	2.00	7.06	14.2	—1[illegible]0
	(.78)	(1.49)	(5.92)	(3.79)
R^2	.44	.44	.51	.53

Notes: "t" ratios in parentheses
All regressions include dummy variables for 14 Agro-climate Regions
DDISTR it defined as DIADP multiplied by
[.655 SR + .373 RR —.00042 (SR) x (RR)] (from eq 1)
NDISTR it defined as (1 — DIADP) times
[.655 SR + .373 RR — .0042 (SR) x (RR)] (from eq 1)
A dummy variable for drought years when output was more than 10 per cent below trend is included as an independent variable. Dummy variables for Agro-climate regions are also included in the regressions.

tary inputs. Second, it was supposed that an intensive effort which 'packaged' several programmes would have a higher pay-off than diffused programme activities, i e, scale economies to the programme were presumed.

While there have been a large number of reviews of the programme — e g, by D Brown (1972), GOI [(1963, 1965, 1967, 1970)] — there has been no real economic evalution based on some systematic specification. Our evaluation based on more recent data than these earlier reviews also uses a more appropriate methodology. We conclude from our analysis that the programme induced a very significant increase in the use of modern factors of production and of agricultural production. It did not, however, result in a major gain in real total factor productivity.

The programme was, in general, a massive effort. It was also relatively expensive. The actual expenditures by the Ford Foundation and the Government of India on IADP districts are a little difficult to disentangle from their publications but we can come up with a reasonable estimate. D Brown reported a figure of 30 million dollars for the first five years of the programme. (Brown, 1971, p 14.) This is consistent with the state budget data for this period, which indicates a 1 1/2 to 2 million rupee annual expenditure in each of the 15 districts. (These data do not include general administrative and training expenditures). The state budget data reflect an increase in spending in the second five years of roughly 50 per cent. To data (1971), then, this programme has been a 100 million dollar (Rs 75-80 crore) experiment. It cost roughly half as much as the research activities in Indian devoted to improved crop production for the entire country during the 1960s. (Mohan, Jha and Evenson, 1973, Table 1.) Its magnitude is, therefore, large enough to merit special attention — particularly since it was a much vaunted effort to transfer new technology in India.

THE EVIDENCE

Our framework for analysing the effect of IADP on productivity change is essentially the same as for research. Basically, the test of the contribution of IADP which is chiefly designed to reduce economic slack, has to be made in terms of associated increased total factor productivity with IADP activities, holding constant the contributions of technology discovery and geo-climate factors and controlling the initial level of economic slack. The prior reviews of Brown and the GOI did not attempt to take into account the fact that the level of economic slack existing at the beginning of the programme in 1961 was in all probability *lower* in the IADP districts than in the non-IADP districts. This was the result of the selection process used.[2] As a consequence of this selection, the IADP districts had the least scope for realising the gains that IADP was designed to achieve. Our hypothesis is that without IADP these districts would have done less well in terms of productivity growth than non-IADP districts in the 1960s.

Our econometric specification is of the form:

$$
\begin{aligned}
TFP_{it} = (&+ b_1\, DIADP + b_2\, DREG_i \\
&+ b_3\, DDR_{it} + b_4\, SR_{it} \\
&+ b_5\, RR_{it} \\
&+ b_6\, (SR \times RR)_{it} \\
&+ b_7\, TFP5661_i + \varepsilon
\end{aligned}
$$

Here

TFP_{it} is a district TFP index (1960-60 = 100)

$DIADP_i$ is a dummy variable for IADP districts (1 for IADP districts, 0 for others)

$DREG_i$ is a set of 13 dummy variables for agro-climate regions

DDR_{it} is the dummy for drought years as before.

$$
SR_{it} = \frac{1}{D} \sum_{1948}^{t-5} R^t + .8\, R_{t-4}
$$

$$
+ .6\, R_{t-3} + .4\, R_{t-2}\ .2\, R_{t-1}
$$

where R_t = research expenditure in time t in the state in which district is located

D is the deflator used (1960 value of all inputs devoted to agricultural production in the state).[3]

RR_{it} is a measure of research outside the state but within the same *geo-climate* region. (constructed in the same way as SR_{it}.)

$(SRXRR)_{it}$ is an interaction term and is the multiple of SR_{it} and RR_{it}. We include it to take account of the interaction between SR and RR since one is, to some extent, a substitute for the other. This term also introduces non-linearity.[4] TFP5661 is the rate of change in TFP in the disrtict from 1956 to 1961. It is a proxy measure of economic slack existing in 1961 — the beginning of the programme.

The parameters of this specification were estimated with data from 140 districts (i) for the years 1960-71 (t). The 140 districts are located in 7 states and

TABLE A

Subtropical Monsoon Geo-Climate Region		
Agro-Climate Region	1	North Punjab Wheat Area (IADP Dist Ludhiana)
„ „ „	2	Punjab-Haryana UP Dry Wheat Area (IADP Dist Karnal)
„ „ „	3	Western UP Wheat Sugarcane Area
Hot Subtropical Geo-Climate Region		
Agro-Climate Region	4	South Central UP Wheat-Bajra Area (IADP Dist Aligarh)
„ „ „	5	East Central UP Rice-Pulses Area
„ „ „	6	South East UP Rice-Grain Area
Hot Equatorial Geo-Climate Region		
Agro-Climate Region	7	AP Coastal Area (IADP Dist West Godavari)
„ „ „	8	Tamil Nadu Coastal (IADP Dist Thanjavur)
Humid Equatorial Geo-Climate Region		
Agro-Climate Region	9	Maharashtra-Mysore Coastal
Semi-Arid Equatorial Geo-Climate Region		
Agro-Climate Region	10	East Central Maharashtra Black Soils Area (IADP Dist Bhandara)
„ „ „	11	West Central Maharashtra Black Soils Area
„ „ „	12	Northern Mysore Black Soils Area
„ „ „	13	Interior AP Red Soils Area
„ „ „	14	Southern Mysore-TN Red Soils Area (IADP Dist Mandya)

include 7 IADP districts. The delineation of 14 agro-climate regions into which the districts are grouped and the further aggregation of the 14 agro-climate regions into 5 geo-climate regions are indicated below in Table A.

The calculation of total factor productivity measures for Indian districts necessarily involves some interpretation of data series and some degree of judgment in resolving inconsistencies between alternative data series. The input data covers land, fertiliser, pump irrigation, tractors, implements, bullock labour and human labour. (see Mohan and Evenson [1974] for details on data sources and calculations). The output series includes almost all commodities reported in GOI publications and is a price weighted Laspeyres index (base-year: 1960). The input series is computed as an input share weighted index of the Divisia type of rates of input growth. (Table 3 reports the mean shares of the period). Input shares were computed for 1961, 1966 and 1971 and applied to corresponding periods. Each input is priced at market prices (or the best estimates of market prices available). Different wage rates for males and females for each state was used and NSS data on number of days worked per year were utilised to obtain labour shares. The justification for using market prices is, of course, that they are reasonable approximation to marginal products.[5]

Table 3 provides a comparison of rates of change in measured productivity for each of the 14 agro-climate regions and for the IADP districts included in the study. We note that only one of the seven IADP districts actually realised a higher rate of change in productivity than the average for the region in which it was located. We also note that there is little relationship between the average shares of capital (tractors and implements) and fertiliser and average yields of foodgrains or total factor productivity gains.

Table 4 reports 4 sets of regression estimates based on the available data for 140 districts. Two alternative dependent variables, the TFP index and an index of foodgrain yields per hectare are utilised. The basic regressions are regressions (1) and (3). We note that the state and regional research variables are significant contributors to the statistical explanation of both productivity change and foodgrain yields. The state and regional research interaction variable is negative and significant thus confirming our expectations. The early period productivity index has a significantly negative co-efficient, as expected, on the grounds that the higher the early period productivity gains, the lower the economic slack at the beginning of the period and therefore the lower the potential for TFP gains in future periods.[6]

The IADP effect in regression (1) and (3) is picked up by the IADP dummy co-efficient. It is positive in both cases. In the case of regression 1, however, the estimated co-efficient is not significant. In regression 3, the estimated co-efficient is not significant. In regression 3, the estimated contribution to foodgrain yields is highly significant both from a statistical and economic point of view. This is what should have been expected of the programme. By inducing increased use of modern inputs like fertiliser a large effect in yield levels should have been forthcoming. As we have noted, however, the real test of the contribution of the programme is in terms of productivity change. Our estimate shows this contribution to have been positive.

It has sometimes been asserted that the real effect of IADP is that it made research more effective. Regressions 2 and 4 investigate whether the IADP had a strong interaction with the research programme. The state and regional research variables are combined to form a new variable.

TABLE 5: ESTIMATED MARGINAL CONTRIBUTION OF RESEARCH INVESTMENT

Estimated Income Stream Generated by Investment of Rs 1,000 (1968)			
Source	State Research	Regional Research Outside State	Extension
Regression 1[d]	6,600[a] + k. 300[b]	800	140[c]

Notes: a This can be divided into a direct contribution, (6,460 in Regression) and a "borrowing" contribution (140 in Regression).

b This is the part of the contribution which interacts with extension.

c Calculated from the co-efficient in Regression 3, Table III which implies an income stream of Rs 27,600 associated with a one unit change in the extension variable EI.

$EI = 100\ (.25\ S_1 + .75 + S_3)$/where S_1, S_2 and S_3 are the numbers of stage I, II and III blocks. In a typical State, if one district were to have introduced its extension programme one year earlier, the index would increase by 1.25. It is estimated that the cost of doing so was roughly Rs 250,000.

d Table (2).

$$DISTR_{it} = \hat{b}_4 SR_{it} + \hat{b}_5 RR_{it} + \hat{b}_6 (SR \times RR)_{it}$$

where $\hat{b}_4$, $\hat{b}_5$ and $\hat{b}_6$ are estimated co-efficients from regression (1). $DISTR_{it}$ then measures the estimated contribution of all research to TFP in district i at time t. By multiplying this by the IADP dummy we get

$$D\,DISTR_{it} = (DIADP) \times DISTR_{it}$$

and for non-IADP districts

$$N\,DISR_{it} = (1\text{-}DIADP) \times DISTR_{it}$$

We then estimate the following:

$$\begin{aligned} TFP_{it} = C &+ b_8 \, D\,DISTR_{it} \\ &+ N\,DISTR_{it} \\ &+ b_{10}\, TFP5661_i + b_{11} \, DDR_{it} \\ &+ b_{12}\, DRRG_i + b_{13} \, DIADP_{it} + E \end{aligned}$$

The co-efficients b_8 and b_9 test whether research affected the IADP districts and non-IADP districts in a different way. Regression (2) indicates that the marginal contribution of research toward increased productivity is not higher in IADP districts. Regression (4) has yield as the dependent variable and it indicates that the marginal contribution of research toward increased yields *is* greater in the IADP districts.

The slope co-efficient in regression 2 is greater for non-IADP districts, i e, the marginal contribution of research to non-IADP districts is greater than to IADP districts while the opposite is true for yields. These results indicate that the IADP *complemented* the research programme to increase yields but *substituted* for research in terms of the contribution to total factor productivity. This result is plausible since some of the IADP activities would be expected to substitute for research. [7]

Policy Implications

We may conclude from our econometric results that the IADP had a large and significant effect on foodgrain yields performance. It induced the adoption of significant increases in modern inputs, especially fertiliser, from an already high level to a still higher level. When, these increased inputs are 'netted out' in the TFP computation, the contribution of the IADP has been modest. In contrast, we have seen that the Indian agricultural research system has been responsible for large productivity gains.

Table 5 summarises the marginal contributions based on regression 1 in Table 2. These numbers need some interpretation. If an increase in research of Rs 1,000 is undertaken at time t the expected value of the increased production in future years would be the numbers in the Table. For example, from regresion 1, Table 2, the expected annual increase in future production from a 1,000 rupee increase in state research resources would be Rs 6,600 directly plus Rs 1,300 that is associated with the extension programme in the state and, presumably would not be realised if extension were not undertaken. A 1,000 rupee increase in the research spending by other states in the major geo-climate region would yield an income stream of Rs 800 to the state. A state's own research clearly has a much higher productivity than that done by other states.

One thousand rupees invested in extension on the other hand provides a modest income stream of only Rs 140. This is a marginal estimate and it is not inconsistent with the result indicating that the productivity of research would be much lower if extension were not undertaken. One has to be careful in interpreting these estimates since the implied internal rates of return depend crucially on the expected time shape of these benefits. Clearly a substantial time lag exists between research investment and the full realisation of the income streams. On the basis of estimates for the US [Evenson, 1968] it is reasonable to conjecture a time lag of 6-8 years between the spending of Rs 1,000 and the realisation of income streams presented in Table 5. Extension, on the other hand, has almost immediate benefits.

Taking account of these rough time-lags we obtain an internal rate of return of about 50 per cent for investment in the Indian agricultural research system. Assuming no lag for extension benefits we obtain a figure of 15 per cent.

In evaluating the economic pay-off to the IADP we have, from regression 1, Table 4, an estimated 2 per cent higher level of output for 1960-61 in the IADP districts. The value of this output in the 15 districts is approximately 75 million rupees per year (1968 prices). Presumably it is increasing over time and has continued beyond 1971, but will not be permanent. The estimated costs of the IADP were from 30 to 40 million rupees per year in the early years rising to 50 million or so in later years. It appears from these data that the flow of social returns generated by the programme has been sufficient to yield a reasonable rate of return. The actual rate will depend on the permanence of the benefits stream after 1971 and the time lag between programme spending and results. Assuming that the benefits flow extends upto 1975, the internal rate of return has been in the neighbourhood of 15 per cent. This is based on an assumption of a 2 year time-lag between IADP investment and start of benefit stream and on an estimated productivity effect which is of low statistical quality.

We note that, interestingly enough, the magnitude of returns to the community development programme of the fifties and early sixities are of the same order as those to the IADP and both are significantly less than the returns to research activity. [We are not concerned here with the non-production benefits of the community development programme]. It needs to be emphasised here that

(i) Our estimates of the returns to research are based on data for the whole period 1952 to 1971. Thus the Indian research system has been productive consistently over a long stretch of time.

(ii) We have not detected a particular green revolution effect in the contribution of research to productivity. We note, however, that the intensity of research activity (see Mohan, Evenson and Jha [1973]) has been the greatest in states with the highest productivity gains. This has been so for most of the period considered and is not confined to the green revolution years.

(iii) Based partly on the analysis of transferability of research over regions and of the interaction of local and 'outside' research we conclude that it was the Indian agricultural research system which was mainly responsible for whatever success that the green revolution had in India. Our conclusion is supported, for example, by the relative lack of rice research in India and the relative failure of new rice varieties in India.

It is important for policy makers to recognise these points and hence the nature of research activity and its contribution to productivity. Research is a cumulative process: major discoveries are few and far between. It is mostly additive. Some evidence on obsolescence of depreciation of new varieties indicates that there is 'maintenance' component of research. A certain amount of research activity is needed to merely keep up productivity levels. Our results suggest strongly that the regional allocation of research expenditures are very important in determining future productivity gains by region.

That current internal rates of return to research expenditures are of the order of 50 per cent does not imply that a vastly expanded programme will have equally high returns. We can expect diminishing marginal returns to operate here as well so we should expect an expanded programme to have lower rates of return. Indeed, the programme should be expanded to the point where the rates of return are in the order of 15-20 per cent — the comparable figure for other developmental programmes. Although we can expect a certain lumpiness in the optimum size of research institutions our analysis also indicates a dispersion of research effort over regions. To some extent this is the trend in India with the establishment of a network of new agriculture universities. The consolidation of state research efforts under the direction of these universities is also a step in the right direction. Given the time-lags involved and the uncertainty associated with research activity it would be foolish to expect quick results from such 'correct' policies. In a longer time range, though, we can be almost certain of results.

Our analysis also has clear implications for the activities of the international aid agencies. The success of CIMMYT and IRRI have induced an unwarranted optimism concerning international institutes. Such institutes *are* useful but their best use would be in 'basic' research activities whose results are not region specific. International aid agencies would do well to support national research systems for more region specific research.

Notes

[This paper draws heavily from the joint work of Robert Evenson, Dayanath Jha and the author. In particular, Evenson and Jha [1974] and Mohan and Evenson [1974] have been used. I also gratefully acknowledge the assistance of Ram Saran and R N Kaushik in data collection.]

1 The Eastern region (Arsan, West Bengal, Orissa) is the exception with negative growth rates. See Evenson and Jha [1973].

2 See GOI [1959a, b] for the selection process and Mohan and Evenson [1974] for a discussion of the process. The districts selected were supposed to have "assured water supply, a minimum of natural hazards, well developed village institutions, and maximum potential for increased agricultural production".

3 The form of the lag structure used is derived from [Evenson, 1971].

4 The expected negative sign on this term partially reflects diminishing returns to research. With a high degree of collinearity between SR and RR it functions as a squared term for SR. See [Evenson, 1973] for further discussion of technology borrowing within and across regions.

5 This is a debatable assumption but most econometric studies have reached this conclusion [Rao, 1965, Saini, 1969; Evenson, 1972].

6 An additional argument for inclusion of the early period productivity gains in that weather factors create a "regression" effect that is partially controlled for by this variable. If beginning period weather factors are exceptionally favourable, this will lower the rate of productivity growth measured in following periods. It will also be reflected in higher pre-IADP productivity growth.

7 This result is similar to the implication of the negative interaction term between state and regional research.

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