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ARTICLES

Sources of Output Growth in Indian Agriculture

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INTRODUCTION

While reviewing India's agricultural performance since Independence, Vaidyanathan (1994) cautioned that urgent attention should be paid to technological innovation and to removing non-price and institutional constraints which do not permit the full exploitation of the chosen technology at the farm level. In the course of discussion of what agricultural reform measures should be included in the New Economic Policy, Ahluwalia (1996) identified technology as one of the most important issues. Though technology played a crucial role in alleviating India's poverty trap in the seventies, its contribution to agricultural growth has not been impressive. India's average growth rate of 2.3 per cent per annum of Gross Domestic Product (GDP) originating in agriculture over two decades of the Green Revolution (1968-88) compares very modestly with trend growth rates for green revolution crops (paddy and wheat) in most other Asian countries over that period (Ahluwalia, 1991). China, Malaysia, Thailand and Myanmar each achieved 4 per cent per annum. Indonesia followed closely with 3.9 per cent, while the Philippines and Pakistan recorded between 3.5 per cent and 4 per cent respectively.

International comparisons reveal a wide gulf in India's performance between achievements in output and productivity. While India compares favourably in terms of total output, it compares poorly in terms of yield per hectare. For example, India has 60 million hectares of land under irrigation compared with just 47 million in China, but its foodgrain production is barely 40 per cent of China's output. Broadly, the following table shows India's relative world ranking in production and yields of a range of agricultural commodities:

INDIA'S WORLD RANKINGS FOR SELECTED AGRICULTURAL COMMODITIES, 1990

Crop	Rank	
	Total output	Yield per hectare
(1)	(2)	(3)
Groundnut	1st	68th
Jute	1st	10th
Rice	2nd	52nd
Wheat	2nd	35th

A recent study by Garnaut (1996) argues that effective agricultural reforms might have a larger effect in raising farm incomes and output in India than in China. Another study by

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The authors gratefully acknowledge the anonymous referee's comments and suggestions which improved the presentation of this paper.

Shand and Kalirajan (1994) concludes that the possibility of India being a substantial net exporter of agricultural commodities, including foodgrain is very high if India globalises its agriculture. However, if this dynamic future for Indian agriculture is to be achieved, a number of critical requirements must be met. The first is to secure and sustain high production growth rates (see, for example, Bhalla, 1994). The second is to achieve and maintain high growth rates in rural incomes through the integration of Indian agriculture with the rest of the Indian economy and with the world economy (Thimmaiah, 1994). The first calls for continuous improvement in productivity. This can be achieved through sustained improvement in technologies, by more efficient use of those technologies, by institutional change to facilitate technological innovations and by public investment in rural infrastructure (Kalirajan and Shand, 1994). In a recent IFPRI study, Rao and Gulati (1994) strongly argued that liberalisation would help accelerate grain production only if supply side constraints with respect to the efficient use of the technology are removed to facilitate exploitation of the full potential of Indian agriculture. The importance of technology in the production of individual crops such as rice and wheat in India has been highlighted in the works of Kumar and Rosegrant (1994) and Kumar and Mruthyunjaya (1992) respectively. In this context, it becomes imperative to examine the sources of agricultural output growth in the pre-reform period. It is our hypothesis that such an examination will reveal the necessity to address the technology issue if meaningful reforms are to be designed and implemented in Indian agriculture.

DECOMPOSITION OF TOTAL FACTOR PRODUCTIVITY (TFP) GROWTH

Evaluation of agricultural growth performance can be made in several ways. One important method is to identify the sources of output growth so as to gauge whether it is the increase in inputs or increase in input use efficiency or improvements in technology contributed more to output growth. In accounting for output growth, the conventional Solow 'residual' approach fails to recognise and estimate effectively the key role of technical change within the components of TFP growth. As technological change is obtained as the 'residual', it is a 'catch all' measure for not only technological progress, but also other factors such as missing inputs and quality variations in inputs.¹ Further, at any point in time, TFP is the combined result of technical progress and technical efficiency; or the efficiency with which factors are used, given the technical progress, to produce output (Fan, 1991). As the measure of technical efficiency is highly correlated with the level of human capital development, it assumes particular significance in the reform process.² From the perspective of long-run policy, it is crucial to distinguish the increment in productivity that occurs from technical progress from that which results from improved technical efficiency in the application of already established technologies.³ Existing studies of TFP in Indian agriculture have not made this distinction in their analyses (see, for example, Rosegrant and Evenson, 1992; Dholakia and Dholakia, 1993; Kumar and Rosegrant, 1994).⁴

In contrast, following Kalirajan *et al.* (1996), the procedure adopted in this paper, in accounting for output growth, estimates technical change as a shift in the production frontiers distinguishing from improvement in technical efficiency and treats the total input growth

as the residual. The main advantage of not computing the input growth component but obtaining it as a residual is that problems usually encountered in productivity analyses, such as omission of inputs and the adjustment for input quality changes, can be avoided. Further, unlike the conventional production frontier method popularised by Aigner *et al.* (1977), and Meeusen and van den Broeck (1977), the approach followed in this paper allows technical progress to be non-neutral. Assuming a Cobb-Douglas technology,

$$\ln Y_{it} = \alpha_{lit} + \sum_{j=2}^T \gamma_{ji} D_{ji} + \sum_{k=2}^K \alpha_{kit} \ln X_{kit} \quad i = 1, \dots, N, \quad t = 1, \dots, T \quad \dots(1)$$

where $\alpha_{lit} = \bar{\alpha}_i + u_{li} + v_{li}$ where u_{li} and v_{li} are statistical error terms associated with individual firms and time respectively; $D_{ji} = 1$ if $j = t$ and zero otherwise; and Y_{it} is the output level of the i -th firm in period t ; X_{kit} is the level of the k -th input used by the i -th firm in period t ; α_{li} is the intercept term for the i -th firm; α_{ki} is the actual response of the output to the method of application of the k -th input by the i -th firm; γ_{ji} accounts for inter-year differences in production of the i -th firm.

Let $\alpha_{kit} = \bar{\alpha}_k + u_{ki} + v_{ki}$; $k = 1, 2, \dots, K$; $i = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$

$$\gamma_{ji} = \bar{\gamma}_j + w_{ji}$$

where

$$E(\alpha_{kit}) = \bar{\alpha}_k, \quad E(\gamma_{ji}) = \bar{\gamma}_j$$

$$E(u_{ki}) = 0, \quad E(v_{ki}) = 0, \quad E(w_{ji}) = 0$$

$$\text{Var}(u_{ki}) = \sigma_{ujk}^2 \text{ for } j = k \text{ and } 0 \text{ otherwise,}$$

$$\text{Var}(v_{ki}) = \sigma_{vjk}^2 \text{ for } j = k \text{ and } 0 \text{ otherwise, and}$$

$$\text{Var}(w_{ji}) = \sigma_{wjk}^2 \text{ for } j = k \text{ and } 0 \text{ otherwise.}$$

With these assumptions, model (1) can be written as

$$\ln Y_{it} = \bar{\alpha}_i + \sum_{j=2}^T \bar{\gamma}_j D_{ji} + \sum_{k=2}^K \bar{\alpha}_k \ln X_{kit} + \varepsilon_{ki} \quad \dots(2)$$

where

$$\varepsilon_{ki} = \sum_{k=2}^K u_{ki} \ln X_{kit} + \sum_{k=2}^K v_{ki} \ln X_{kit} + \sum_{j=2}^T w_{ji} D_{ji} + u_{li} + v_{li}$$

$$E(\varepsilon_{ki}) = 0 \text{ for all } i \text{ and } k.$$

$$\text{Var}(\varepsilon_{kit}) = \sigma_{u11}^2 + \sigma_{v11}^2 + \sum_{k=2}^K \sigma_{ukk}^2 \ln^2 X_{kit} + \sum_{j=2}^K \sigma_{vjk}^2 \ln^2 X_{kit} + \sum_{j=2}^T \sigma_{wkk}^2$$

$$\text{COV}(\varepsilon_{ki}, \varepsilon_{ji}) = 0 \text{ for } k \neq j.$$

Following the estimation procedures suggested by Hildreth and Houck (1968), the mean response coefficients $\bar{\alpha}$'s, $\bar{\gamma}$'s and the variances can be estimated and the individual response coefficients α_{ki} 's and γ_{ji} 's can be obtained as described in Griffiths (1972).

Drawing on Kalirajan and Obwona (1994), the assumptions underlying model (2) are as follows:

(a) Technical efficiency, which is defined as the ability and willingness of the firm to produce the maximum possible output from the given set of inputs and technology, is achieved by adopting the best practice techniques which involve the most efficient use of inputs. Technical efficiency stems from two sources: (1) the efficient use of each input which contributes individually to technical efficiency and can be measured by the magnitudes of the varying slope coefficients α_{ki} 's; and (2) any other firm-specific intrinsic characteristics which are not explicitly included but may produce a combined contribution over and above the individual contributions. This 'lump sum' contribution, if any, can be measured by the varying intercept term and γ_{ji} 's.

(b) The highest magnitude of each response coefficient and the intercept represent the production responses of following the best practice techniques, and they constitute the production coefficients of the potential frontier production function. Let α^* 's and γ^* 's be the estimates of the coefficients of the frontier production function, that is,

$$\alpha_{kt}^* = \max_{1 \leq i \leq N} \{\alpha_{kit}\}; \gamma_{jt}^* = \max_{1 \leq i \leq N} \{\gamma_{ji}\}; k = 1, \dots, K; i = 1, \dots, N \text{ and } t, j = 2, \dots, T.$$

Now the potential frontier output for individual observations can be calculated as:

$$\ln Y_{it}^* = \alpha_{it}^* + \sum_{j=2}^T \gamma_{jt}^* D_{ji} + \sum_{k=2}^K \alpha_{kt}^* \ln X_{kit}; i = 1, \dots, N \text{ and } t = 2, \dots, T. \quad \dots(3)$$

where X_{kit} is the actual level of k -th input used by the i -th firm in period t . A measure of technical inefficiency denoted by say, TE, can be defined as:

$$TE_{it} = (\ln Y_{it}^* - \ln Y_{it}) \quad \dots(4a)$$

and alternatively a measure of technical efficiency denoted by EF_{it} can be defined as:

$$EF_{it} = \frac{Y_{it}}{\exp(\ln Y_{it}^*)} \quad \dots(4b)$$

where the numerator refers to the realised output and the denominator shows the potential frontier output calculated from model (3).

Figure 1 illustrates the decomposition of total output growth into input growth, technical progress and technical efficiency improvement. In periods 1 and 2, the firm faces production

frontiers F_1 and F_2 respectively. If a given firm has been technically efficient, output would be y_1^* in period 1 and y_2^* in period 2. On the other hand, if the firm is technically inefficient and does not operate on its frontier, then the firm's realised output is y_1 in period 1 and y_2 in period 2. Technical inefficiency (TE) is measured by the vertical distance between the frontier output and the realised output of a given firm, that is, TE1 in period 1 and TE2 in period 2 respectively. Hence, the change in technical efficiency over time is the difference between TE1 and TE2. Now suppose, there is technical progress, due to the improved quality of human and physical capital, so a firm's potential frontier shifts to F_2 in period 2. If the given firm keeps up with the technical progress, more output is produced from the same level of input. So, the firm's output will be y_1^{**} from x_1 input shown in the figure. Technical progress in this paper is measured by the distance between two frontiers ($y_1^{**} - y_1^*$) evaluated at x_1 . Denoting the contribution of input growth to output growth (between periods 1 and 2) as Δy_x , the total output growth, ($y_2 - y_1$), can be decomposed into three components: input growth, technological progress and technical efficiency change.

Referring to Figure 1, the decomposition can be shown as follows:

$$\begin{aligned}
 D &= y_2 - y_1 \\
 &= A+B+C \\
 &= [y_1^* - y_1] + [y_1^{**} - y_1^*] + [y_2 - y_1^{**}] \\
 &= [y_1^* - y_1] + [y_1^{**} - y_1^*] + [y_2^* - y_1^{**}] - [y_2^* - y_2] \\
 &= \{[y_1^* - y_1] - [y_2^* - y_2]\} + [y_1^{**} - y_1^*] + [y_2^* - y_1^{**}] \quad \dots (5) \\
 &= \{TE1 - TE2\} + TC + \Delta y_x
 \end{aligned}$$

where $y_2 - y_1$ = output growth,

TE1 - TE2 = technical efficiency change,

TC = technical change and

Δy_x = output growth due to input growth.

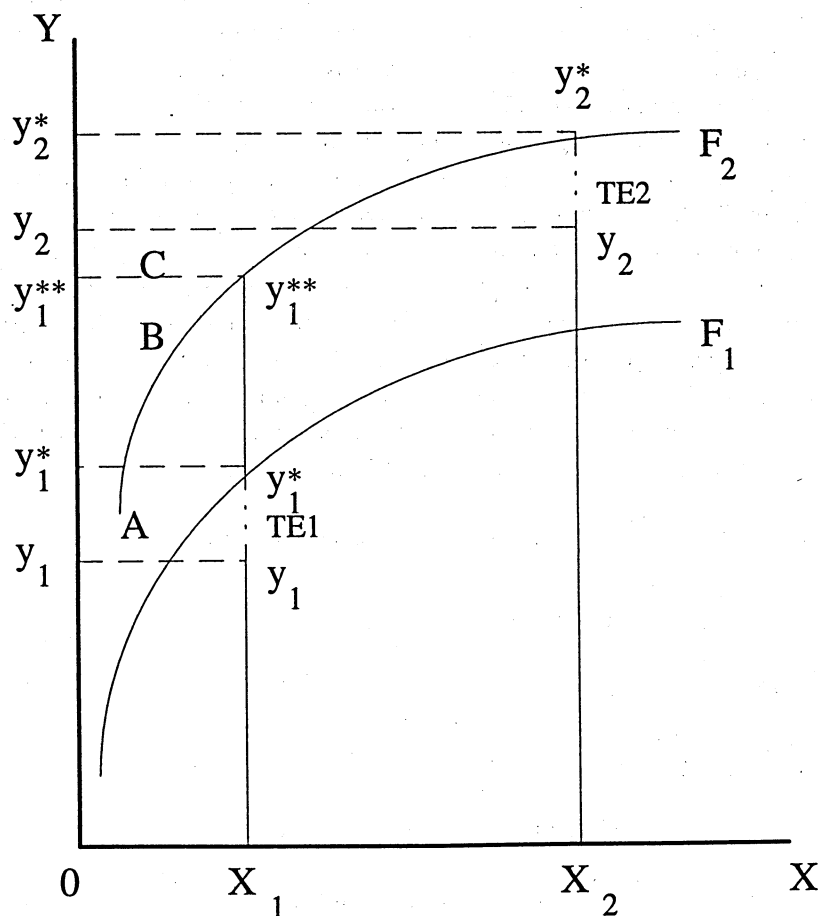


Figure 1. Decomposition of Output Growth

The decomposition in model (5) enriches Solow's dichotomy by attributing observed output growth to movements along a path on or beneath the production frontier (input growth), movement towards or away from the production frontier (technical efficiency change), and shifts in the production frontier (technological progress).

TFP Growth Components

Following the conventional conceptualisation of total factor productivity, TFP growth can be defined as the growth in output not explained by input growth. Thus from model (5), TFP growth consists of two components: technical efficiency and technical changes,

$$TFP = (TE1 - TE2) + TC \quad \dots (6)$$

Now, TFP growth in model (6) between period (t-1) and t for the i-th firm can be estimated as:

$$\begin{aligned}\Delta TFP_i &= \ln \left(\frac{TFP_{i,t}}{TFP_{i,t-1}} \right) \\ &= \left\{ (y_{li,t-1}^{*x_1} - y_{li,t-1}^{x_1}) - (y_{2it}^{*x_2} - y_{2it}^{x_2}) \right\} + (y_{li,t}^{*x_1} - y_{li,t-1}^{*x_1})\end{aligned}\quad \dots(7)$$

where y^{*x_1} and y^{*x_2} (in logarithms) are respectively the frontier outputs calculated using x_1 (period 1) and x_2 (period 2) input levels (see Figure 1). These two TFP components are analytically distinct and may have quite different policy implications (Nishimizu and Page, 1982). High rates of technological progress, on the one hand, can co-exist with deteriorating technical efficiency performance. On the other hand, relatively low rates of technological progress can also co-exist with improving technical efficiency performance. As a result, specific policy actions are required to address the different sources of variation in productivity.

Empirically, TFP growth is calculated in the following way for each observation: First, as explained above, using the computer program TERAN, the stochastic varying coefficients frontier is estimated separately from the pooled data for the chosen two time periods (see, Kalirajan and Obwona, 1994). Secondly, as defined in equation (4a), technical inefficiency in each time period is worked out as the difference between the frontier output and the realised output. Thirdly, the difference between these two technical inefficiency measures will indicate the contribution of technical efficiency improvement (deterioration) to TFP growth. Let the contribution be C1 [which is equal to TE1 - TE2 in equation (5)]. Fourthly, a simulation using the inputs in the first period and the frontier coefficients of the second period, gives the frontier output for the first period as y_1^{**} in equation (5) with the assumption that the improved (second period) technology is used. The difference between this simulated frontier output and the estimated frontier output y_1^* (with inputs in the first period and the frontier coefficients of the first time period) will show the contribution of technological progress to TFP growth. Let this contribution be C2 [which is equal to $y_1^{**} - y_1^*$ in equation (5)]. Finally, adding C1 with C2, the TFP growth is obtained. When this summation (C1+C2) is subtracted from the output growth between the two periods, the contribution of input growth to output growth is obtained.

The technological change component of productivity growth (C2) captures shifts in the technology and can be interpreted as providing a measure of innovation. This decomposition of TFP growth into technical efficiency improvement (catching-up) and technological advance is, therefore, useful in distinguishing innovation or adoption of new technology by 'best practice' firms from the diffusion of new advanced technology which leads to improved technical efficiency amongst firms 'catching-up'. Co-existence of a high rate of technological progress and a low rate of change in technical efficiency may reflect failures in achieving technological mastery or effective diffusion of best technical practices. It may also reflect high levels of technological dynamism in an industry with rapid obsolescence rates for technology.

DATA AND EMPIRICAL ANALYSIS

State-level data were used for empirical illustration in this paper and comprise observations from 15 of the 25 states and Union territories in India covering the period from 1980 to 1990. These 15 states account for 95 per cent of national foodgrain production, and 85 per cent of national agricultural output. Gross agricultural production value at 1980 constant prices measures aggregate total output. The sub-aggregates are (i) crop production, (ii) forestry, and (iii) livestock. Inputs comprise the four categories of land, labour, machinery and chemical fertiliser. In the literature, irrigation is used either as a generic input or as a proxy for technical change. Technological progress in the Indian context is very highly correlated with irrigation. Therefore in this study, irrigation is used as a proxy for technical change. However, irrigation is not included as a proxy input here because the methodology used in this study allows technical progress to be measured directly by measuring the shift in the production frontier from one period to another. Further, the coefficients of time dummy variables are allowed to vary across states and over time for a state, which to a certain extent reflects the changing impact of irrigation over time on agricultural output at state levels. Also, in this methodology, the contribution of inputs growth to output growth is calculated as a residual, which takes care of the omitted variables and quality variations in inputs. Land refers to sown acreage and pasture areas (calculated in sown land area equivalence). Labour refers to workers in the cropping sector. Machinery includes tractors and draft animals measured in horsepower. Chemical fertiliser refers to the gross weight of nitrogenous, phosphate and potash fertilisers that each state consumed annually.⁵

Let the production technology be represented by a Cobb-Douglas function.⁶ Using time-specific dummies, D , to account for inter-year differences, we can express in logarithmic form the temporal firm-specific production function as:

$$\ln Y_{it} = \alpha_{it} + \sum_{j=2}^{11} \gamma_{ji} D_{jit} + \sum_{k=2}^5 \alpha_{ki} \ln X_{kit} \quad \dots(8)$$

$i = 1, \dots, 15$ and $t = 1$ (1980), ..., 11 (1990)

where the parameters α_{ki} 's and γ_{ji} 's are as defined earlier;

$D_{jit} = 1$ if $j = t$ and zero otherwise; and

Y = aggregate total agricultural output using the 1980 constant prices,

X_2 = land (sum of sown areas and pastures) in hectares,

X_3 = labour measured by the number of persons employed at year end,

X_4 = machinery measured by total horsepower at year end, and

X_5 = chemical fertiliser measured in kg.

For a given t , employing the specifications and estimation procedures described above, the variance-covariance matrix of the random components of the γ 's and α 's as in model (8), their means and individual response coefficients were obtained. Due to brevity, only the mean response coefficients with standard errors are given in Table 1. All the core input coefficients and most of the year dummy coefficients are also significant at 5 per cent level.⁷ From the yearwise estimates, frontier outputs for each period t were calculated. Finally, TFP growth for each state was obtained using model (7) for periods 1980-83, 1984-87 and 1988-90 (Table 2).

The results suggest that the pre-reform farming performance was not impressive. Eleven out of 15 states showed substantial positive but declining contributions of growth in TFP during the period. The contribution of TFP growth was negative throughout in the other four states. Some authors argue that the dynamism which was generated by the Green Revolution had worked its way fully into production in the 1980s, and there was no alternative source of strong productivity growth (Bhalla, 1995). In this context, an important question is whether farmers have been able to achieve the best practice potential of the chosen technology without wasting resources. Decomposition of total output growth in agriculture into technical efficiency change, technological progress and input growth helps to explain these changes (Table 3).

TABLE 1. MEAN ESTIMATES OF THE STOCHASTIC VARYING COEFFICIENTS OF FRONTIER PRODUCTION FUNCTION

States (1)	Constant (2)	Land (3)	Labour (4)	Machinery (5)	Fertiliser (6)
Andhra Pradesh	5.3879 (1.0893)	0.5854 (0.1860)	0.2328 (0.1135)	0.0632 (0.0281)	0.1236 (0.0438)
Assam	3.2890 (1.0056)	0.6210 (0.3005)	0.1926 (0.0828)	0.0345 (0.0118)	0.2526 (0.0489)
Bihar	3.3672 (1.1236)	0.6318 (0.2587)	0.1988 (0.0802)	0.0329 (0.0156)	0.2489 (0.0892)
Gujarat	6.1356 (1.2410)	0.5678 (0.2210)	0.2285 (0.1004)	0.0718 (0.0271)	0.1289 (0.0467)
Haryana	6.7826 (1.3320)	0.5872 (0.2412)	0.2475 (0.1132)	0.1027 (0.0325)	0.1006 (0.0336)
Karnataka	5.8964 (1.2550)	0.5634 (0.2441)	0.2285 (0.1065)	0.0835 (0.0338)	0.1443 (0.0372)
Kerala	5.1089 (1.5324)	0.5289 (0.2501)	0.2486 (0.1200)	0.0678 (0.0242)	0.1332 (0.0524)
Madhya Pradesh	3.6798 (1.2280)	0.6216 (0.2678)	0.1856 (0.0824)	0.0578 (0.0241)	0.2158 (0.0632)
Maharashtra	6.6734 (1.7230)	0.5238 (0.2008)	0.2108 (0.0834)	0.1056 (0.0343)	0.1560 (0.0624)
Orissa	4.6732 (1.0864)	0.5832 (0.2134)	0.2007 (0.0732)	0.0976 (0.0354)	0.2278 (0.0785)
Punjab	7.1436 (1.5647)	0.5542 (0.1875)	0.2502 (0.0830)	0.1056 (0.0432)	0.0872 (0.0379)
Rajasthan	5.8792 (1.4532)	0.5703 (0.1678)	0.1896 (0.0779)	0.1228 (0.0547)	0.2486 (0.0678)
Tamil Nadu	5.7259 (1.5890)	0.5309 (0.1560)	0.2122 (0.0679)	0.1006 (0.0442)	0.1578 (0.0558)
Uttar Pradesh	6.0237 (1.6732)	0.5693 (0.1448)	0.1936 (0.0665)	0.1156 (0.0369)	0.1328 (0.0485)
West Bengal	6.0034 (1.5890)	0.5489 (0.1523)	0.2208 (0.1004)	0.1020 (0.0410)	0.1406 (0.0508)

Note: Figures in parentheses are standard errors of estimates.

TABLE 2. CONTRIBUTION OF TOTAL FACTOR PRODUCTIVITY GROWTH TO TOTAL OUTPUT GROWTH IN INDIAN AGRICULTURE, 1980-1990

States (1)	Total factor productivity growth (per cent)		
	1980-83 (2)	1984-87 (3)	1988-90 (4)
Andhra Pradesh	53.74	48.34	32.21
Assam	-42.08	-42.32	-44.86
Bihar	-36.87	-41.76	-42.32
Gujarat	33.38	32.79	28.26
Haryana	54.82	45.75	33.22
Karnataka	43.38	38.76	30.27
Kerala	30.21	22.56	20.24
Madhya Pradesh	-28.42	-30.12	-32.67
Maharashtra	33.64	28.14	22.48
Orissa	-30.74	-32.09	-32.88
Punjab	64.45	52.67	45.24
Rajasthan	53.35	46.87	32.55
Tamil Nadu	53.22	47.02	34.42
Uttar Pradesh	56.41	46.78	38.58
West Bengal	53.88	47.11	39.73

First, an examination of the contribution of TFP growth to total output growth between states from 1980 to 1983 shows some states with high performances. The best performance was recorded by Punjab with 64 per cent growth. Then followed six states with over 50 per cent TFP growth. A further four achieved between 30 and 50 per cent growth, while four recorded negative TFP growth (Bihar, Assam, Madhya Pradesh and Orissa in descending order). By comparison, the mid and end periods of the decade showed uniformly sharp declines in the contributions of TFP growth but with constancy in the relative performances of most states. At one extreme, Punjab retained its ascendancy, at the other, the same four states showed negative contributions of TFP growth.

Thus overall, there was substantially diminished performance in the contributions of total factor productivity growth which broadly held true across states. Hence nationally, the 1980s was a decade of increasingly disappointing performance in these terms. The question as to how this pattern of deterioration occurred was explored here by examining the contributions of the three components of total factor productivity growth - input growth, technological change and changes in technical efficiency. The same three sub-periods within the decade of the 1980s are compared (Table 3).

TABLE 3. DECOMPOSITION OF OUTPUT GROWTH IN INDIAN AGRICULTURE, 1980-83, 1984-87 and 1988-90

States	(per cent)								
	1980-83			1984-87			1988-90		
	Output growth due to			Output growth due to			Output growth due to		
	Input growth	Techno-logy change	Technical effi-ciency change	Input growth	Techno-logy change	Technical effi-ciency change	Input growth	Techno-logy change	Technical effi-ciency change
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Andhra Pradesh	46.26	15.24	38.50	51.66	14.08	37.58	67.79	3.56	28.65
Assam	142.08	-2.08	-40.00	142.32	-2.23	-39.22	144.86	-1.36	-43.50
Bihar	136.87	-2.50	-34.37	141.76	-2.54	-39.22	142.32	-2.06	-40.26
Gujarat	66.62	13.38	20.00	67.21	13.28	19.51	71.74	3.74	24.52
Haryana	45.18	16.44	38.38	54.25	15.75	30.00	66.78	4.22	29.00
Karnataka	56.62	12.65	30.73	61.24	13.53	35.23	69.73	3.07	27.20
Kerala	69.79	10.11	20.11	77.44	6.82	14.74	79.76	2.60	17.64
Madhya Pradesh	128.42	-3.82	-24.60	130.12	-2.01	-28.11	132.67	-0.04	-32.63
Maharashtra	66.36	11.82	21.82	71.86	11.12	17.02	77.52	2.50	19.98
Orissa	130.74	-3.07	-27.67	132.09	-2.09	-30.00	132.88	-0.04	-32.84
Punjab	35.55	28.14	36.31	47.33	20.82	31.85	54.76	15.39	29.85
Rajasthan	46.65	15.25	38.10	53.13	14.47	32.23	67.45	4.17	28.38
Tamil Nadu	46.78	15.62	37.60	52.98	14.50	32.52	65.58	4.00	30.42
Uttar Pradesh	46.59	14.58	41.83	53.22	14.38	32.40	61.42	4.18	34.40
West Bengal	46.12	15.76	38.12	52.89	16.21	30.90	60.27	5.83	33.90

The analysis confirms that pre-reform output growth came increasingly from input growth. Excluding those states with negative TFP growth, input growth contributed more than 50 per cent in four states in 1980-83 and in 10 states by 1984-87. An average of only around 15 per cent could be attributed to technological change by the mid-1980s but more to gains in technical efficiency.

From 1988 to 1990, this picture intensified. The contribution of new technology declined substantially in all states. It exceeded 6 per cent only in Punjab (15 per cent). By contrast, the contributions of increasing technical efficiency to output growth remained substantial in most states, though lower than previously. But the dominant contribution came from input growth. It exceeded 60 per cent in 10 states and reached 55 per cent in Punjab. This situation parallels Chinese agriculture during the pre-reform period in which there was an excessive consumption of fertiliser (Lin, 1992). The share of fertiliser and electricity in the consumption of core inputs which enjoy heavy subsidies in Indian agriculture increased from 16.8 per cent in the seventies to 29.2 per cent in the eighties (Misra and Hazell, 1996). This increase, no doubt, contributed to the fiscal crisis of 1991.

Technical efficiency improved slowly in all the states throughout the period, but there was still potential to improve technical efficiency in 1990. Thus Indian agriculture between 1980 and 1990 experienced low rates of technological progress together with gradual improvements in technical efficiency but output growth in the sector became increasingly dependent on input growth.

There are at least two explanations for the slow improvement in technical efficiency in

India during 1984-90. First, throughout 1985-90, government intervention in the market and production intensified which resulted in deterioration in the terms of trade (ratio of prices received to prices paid by the agricultural sector), touching their lowest point at 83.4 in 1986-87. Lower real procurement prices had a negative effect on the farmers' incentives to work efficiently. Second, the deterioration of land infrastructure, particularly the existing water conservation systems, constrained the farmers from applying best production techniques (Ahluwalia, 1991). Gross fixed capital formation in agriculture at 1980 constant prices sharply declined to an average annual growth rate of 1 per cent during 1980-90 from a corresponding growth rate of 5 per cent in 1970-80.

The above findings have significant policy implications for promoting production growth in India's cropping sector. This paper supports the findings of Kumar and Rosegrant (1994), and Bhalla (1995) that increase in agricultural investments, especially in research and development, is clearly needed to stimulate technical change. Further, institutional changes should focus on achieving greater regional specialisation based on comparative advantage. For example, crops should be located in the most favourable growing conditions, breaking the conventional approach of self-sufficiency in every region.

CONCLUSIONS

The analysis in this paper shows that TFP growth in the pre-reform period was negative in four out of 15 states and that, by the end of the decade, it was small for those states where the contribution of TFP growth was positive. The contribution of technology (in its two components) to output growth declined substantially, particularly from 1988 to 1990. During the period of analysis, technical efficiency increased only slowly. It would be useful to identify the causes for such performance in technical efficiency. However, this could not be attempted for lack of appropriate data. Nevertheless, the analysis strongly supports and highlights Vaidyanathan's views that there is an urgency to adequately addressing the technology issue in agricultural reform.

The policy implications of the foregoing analysis are as follows: (1) Technological progress and technical efficiency improvement are the two key sources of long-term agricultural growth and more attention should be paid to promote them through investing in R & D and extension services. (2) To date it has been argued that input subsidies are necessary because agriculture could not afford to pay for inputs and because output prices were lower than international prices. However, increasing output prices without enabling farmers to increase output through technological change and higher technical efficiency cannot sustain high growth in agriculture. (3) The accelerated introduction of better technologies and best techniques depend on sustained investment in agricultural infrastructure including agricultural credit. The Central and State Government expenditures on subsidising inputs such as power and fertiliser would be better spent on infrastructure. (4) Removal of subsidies should be accompanied by an efficient agricultural credit system and the National Bank for Agriculture and Rural Development should be further strengthened.

One of the advantages of the above method of decomposing TFP growth is that it avoids

the restrictive assumptions inherent in both the Solow 'residual' and the conventional stochastic frontier based TFP components approaches discussed above. In the method followed in this paper, the two TFP components - technical efficiency change and technical progress - are first estimated separately. The sum of the two components is then subtracted from the total output growth to yield the input growth component as the residual. Thus the total input growth component itself is not calculated as in the Solow 'residual' or in the conventional stochastic frontier based TFP components approaches. This has a distinct advantage of avoiding the problems usually encountered in estimating the total input growth component, such as omission of inputs and the adjustment for input quality changes.

The method employed here provides important additional information to that obtained using traditional approaches to productivity measurement. It provides a means to measure the phenomenon of catching-up (with the frontier) through improvements in technical efficiency, and also of the impact of technological innovation (shifts in the frontiers).

Certain limitations of this study should be borne in mind. The major limitation is that a firm-level efficiency concept has been applied to regional level data. Individual farm data and analysis would give more effective results. Nevertheless, the present results can be interpreted as indicative aggregate efficiency measures of farms within the concerned states.

Received May 1996.

Revision accepted August 1997.

NOTES

1. Defining technical progress as the shift in the 'best practice' techniques production frontier over time, Nishimizu and Page (1982) established its rate by direct estimation by programming techniques of a deterministic translog production frontier.

2. For example, Fan (1991) found that 26.6 per cent of total output growth in Chinese agriculture from 1965 to 1985 could be attributed to technical efficiency improvement and 15.7 per cent to technical change.

3. Nishimizu and Page (1982) indicate that in half of the former Yugoslavia's social sector industries there was no perceptible movement of the frontier during the period 1965-78.

4. These studies, however, have attempted to identify the factors contributing to TFP growth which include factors contributing to improvement in technical efficiency too.

5. All data were obtained from national and state income accounts published by the Central Statistical Organisation, Department of Statistics, Ministry of Planning and Programme Implementation, and Ministry of Finance, Government of India; see *Basic Statistics of the Indian Economy, Vol. 2 (States)*, published by the Centre for Monitoring Indian Economy, Bombay.

6. In the translog form, all null hypotheses of linear and non-linear separabilities could not be rejected at 5 per cent level. Apparently, complete global separability could not be rejected. Thus the Cobb-Douglas function can be considered as an appropriate model describing the technology for the given data set.

7. Due to brevity, the time dummy coefficients are not reported in Table 1, and those who are interested can obtain them from the authors.

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