Journal of Business and Economics, ISSN 2155-7950, USA
February 2015, Volume 6, No. 2, pp. 360-370
DOI: 10.15341/jbe(2155-7950)/02.06.2015/014

http://www.academicstar.us

An Analysis of Total Factor Productivity, Factor demand, and Profit of India's Agriculture*

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Abstract: In 2012-2013 the share of agriculture and allied activities declined to about 13.7 percent of India's GDP[1]. Due to rising competition in international markets and increasing costs of production, sustaining efficiency in farm production necessitates estimation of both technical and economic efficiencies. In this paper, we examine India's agrarian performance in terms of restricted profit functions and factor demand equations, using village-level panel data for years 1999 and 2006. We also attempt to decompose output growth between the two periods into technical progress, technical efficiency, and input growth using a translog production function following Kalirajan, Obowa and Zhao (1996) to examine whether output growth was input-driven or technology driven. The decomposition analysis is important from a policy perspective to understand whether the given technology has been applied to its full potential. We find that the technical change between 1999 and 2006 has been negative, while the technological progress is positive, therefore we can infer that full potential of technological change between 1999 and 2006 could not be leveraged due to the decline in technical efficiencies. To fully leverage the same, policy prescriptions should target increasing farm level technical efficiencies.

Key words: agriculture; factor demand; total factor productivity growth; technical efficiency

JEL codes: Q1, D24, P27, O13

1. Introduction

Agriculture plays an important role in the process of economic development of less developed countries like India. Besides providing food to the nation, agriculture is the main source of rural livelihood, absorbs large unskilled labourers, generates savings, contributes to the market for industrial goods, expands international trade

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* This paper is part of the IDRC–NCAER research program on "Building Policy Research Capacity for Rural Governance and Growth in India" (grant number 105223). The findings, interpretations and conclusions expressed here are those of the authors and do not necessarily reflect the views of NCAER or its Governing Body. (Grant number 105223).

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1 The Economic Times, August 2013.

and earns foreign exchange reserves. Agricultural development is an integral part of overall economic development. In India, agriculture was the main source of national income and occupation at the time of Independence. Agriculture and allied activities contributed nearly 50 percent to India's national income. About 72 percent of total working population was engaged in agriculture. These confirm that Indian economy was basically an agriculture based economy at the time of Independence. After 61 years of Independence, the share of agriculture in total national income declined from 50 percent in 1950 to 18 percent in 2007-08, although in recent times more than 60 percent of workforce is engaged in agriculture (Nerkel et al., 2013). In spite of this, agriculture plays a significant role in the performance of other sectors of the economy and therefore continues to be a dominant sector of the Indian Economy.

Since independence Indian agriculture has made considerable progress. Agriculture, which grew at the rate of about 1 percent per annum during the fifty years before Independence, has grown at the rate of about 2.6 percent per annum in the post-Independence era (Tripathi et al., 2009). The annual growth rate of agriculture rose sharply during the period 1981-1982 to 1990-1991 and decelerated during the period 1950-1951 to 1970s (Mohan, 2008). Expansion of land was the main source of growth in the period of fifties and sixties following which the contribution of greater land area under agricultural production has declined over time and increase in productivity became the main source of growth in agricultural production. For all crops, the annual rate of growth of productivity per hectare rose from 2.07 percent in mid 1980s to 2.51 during mid 1990s (Mahadevan, 2003).

Since productivity has been the key source of agricultural growth in India during the last two decades, it is important to review some of the findings of previous studies related to productivity growth of Indian agriculture.

Dholakia and Dholakia (1993) estimate the sources of Indian agriculture for three sub-periods during 1950-1951 to 1988-1989. They also study the contribution of adverse weather conditions and intensity of resource use to total factor productivity growth. The study finds that any policy changes which affects the use of modern agricultural inputs directly or indirectly would have a bearing on total factor productivity (TFP) growth and hence on growth performance. The important inputs which have a strong indirect influence on other general inputs like land, labour and capital and hence overall TFP growth are irrigation, fertiliser, and high yield varieties of seeds. The study concludes that traditional inputs such as land, labour and capital have no strong impact on TFP growth in Indian agriculture rather modern inputs like HYV seeds, fertiliser and irrigation have successfully raised the TFP growth rate.

A study by Rosegrant and Evenson (1995) examine the total factor productivity of Indian agriculture based on primary data of 271 districts covering 13 states in India during 1956-1987. The study computed Tornqvist-Theil index for measuring the total factor productivity. The study finds that substantial productivity gains have been realized in India's agriculture. These gains have varied in different periods, being highest in the green-revolution period. Further, the study finds that total factor productivity growth has contributed roughly 1.1 percent per year to crop production growth in India.

Tripathi and Prasad (2008) examine the impact of some production variables (input) on the agricultural productivity growth (output) in India from 1969-1970 to 2005-2006 using Cobb-Douglas (C-D) model. The study finds that labour, capital and land significantly impacted agricultural productivity growth. In another paper, Tripathi (2009) examines the performance of agricultural productivity in India during the last 37 years. Using the arithmetic index for measuring TFP, they find that between 1969 and 2005, agricultural growth relied almost entirely on increased in conventional factors while growth in productivity was negative. For only initial periods of reforms, agricultural TFP growth is positive.

One of the pioneer studies on productivity analysis by Kalirajan and Shand (1997) identifies various sources of agriculture growth in India during the pre-reforms period. The study uses state level data of 15 major states for the period 1980 to 1990. Using a C-D function, the study finds that TFP was negative in 4 out of 15 states. The contribution of technology to output growth declined substantially between 1988 and 1990. The improvement of technical efficiency was also slow during the study period. Therefore, the study emphasised that there is need of more investment and innovation in R&D to improve the technical efficiency and progress, which will foster the agriculture growth in the long run.

In a more recent study Shanmugam and Soundararajan (2008) examine the source of agriculture output changes in 15 major states in India for the period 1994-1995 to 2003-2004. The study mentions that there could be three possible reasons of output changes such as input growth, technical progress and improvement in technical efficiency. Using the random coefficients frontier production function model, the study finds that the efficiency has declined over time for all the states and the average technical efficiency is only 72 percent. The study infers that the potential output can be increased by another 28 percent without increasing inputs. Authors find that in most of the states, the resulting growth was from higher input usage.

To sum up, the above review of previous studies suggest that technical progress and technical efficiency are two important factors that influence agriculture growth in India. The link of input driven growth is weak, therefore necessitates more emphasis on technical efficiency and progress to sustain agriculture growth in the long run. The present study re-examines the same issue using the translog production function. In addition to TFP, the study also estimates profit and factor demand functions for agriculture sector. The analysis of the study is based on a wide range of primary survey data collected at the household level in India. The objectives of the study are:

(1) To estimate a translog profit function of Indian agriculture for the year 2006.

(2) To estimate factor demand function of agriculture for the year 2006.

(3) To infer whether output growth between 1999 and 2006 is technology driven or input driven by estimating technical efficiencies, technological progress and input growth, using the pooled data.

The paper is organized as follows: Section II discusses the data, Section III gives the estimation methodology, Section IV presents the empirical results, Section V discusses decomposition of output change between two time periods (1999 and 2006), and Section VI concludes.

2. Data Description

The research project makes use of the rural household data as compiled under the Additional Rural Incomes Survey (ARIS) and Rural Economic and Demographic Survey (REDS). The ARIS/REDS data sets form a village and household data base providing information on sample villages spread across various states in India, collected in four rounds conducted between the years 1971 and 2006. These data sets allow us to analyze the various micro characteristics of these households and their interaction with a range of environments (village, district, state, and the entire country). In addition to this, the panel nature of these data sets enables us to understand both the evolution of policy as well as trace the impact of different policy regimes on household. Moreover, they document the changes in terms of the entire gamut of economic, socio-economic and demographic parameters that have occurred in the rural population of India over the last three decades. They also permit in-depth analyses of the determinants of these of changes and, in particular, illuminate the role of agricultural progress in shaping rural life.

The first round of the survey for which complete village and household information is available is the 1971 round of the ARIS. In 1982, 250 of the original 259 villages were revisited (the state of Assam was excluded due to local political disturbances rendering survey activity impossible) and 4979 surveyed, approximately two-thirds of which were the same as in 1971. In 1999, all of the 1971 villages were surveyed, excluding the 8 sample villages from Jammu and Kashmir (again, owing to problems of local insurgency). In this survey round, all of the surviving households in the 1982 survey were surveyed again, including all split-off households residing in the same village, plus a small random sample of new households. Because of household divisions and the new sample design incorporating all village-resident male household members surveyed in the 1982 round, the number of households in the 1999 round increased to 7474. The current round of 2006 (agricultural season 2005-2006) has a sample size of 9500 and includes all of the households surveyed in 1999 and the split-off households residing within these villages. Each village has approximately 8 new randomly selected households. Each round of the survey has three components: listing questionnaire, village questionnaire, and the household questionnaire. For the present analysis we are using the household data collected for years 1999 and 2006 through the household questionnaire. The household survey provided information on assets and incomes, by source, and agricultural inputs and outputs at the household level. In addition to these, there is information on household member characteristics, including educational attainment, school enrolment, and work participation as well as detailed current and retrospective information on participation in governance, impact of conflicts, and, social relations.

The variables from the two rounds that we have used for our analysis are total farm level output, total farm level cost, input (land, labor, fertiliser and machinery) quantities and prices, level of education of the household head — illiterate, primary, secondary, high secondary, under-graduate and post graduate — and finally household size. In our SUR model, we use labor, fertiliser and machinery as the three inputs and in the frontier analysis we replace machinery by land (fixed input).

For the SUR estimation and the frontier analysis we use the panel data consisting of 11770 observations spread across 241 villages of India.

3. Methodology

We estimate a translog profit function with factor demand equations for labor, machinery and fertilizers using seemingly Unrelated Regression estimation method (SURE). Hence we estimate a system of three equations — profit function, labor share, and machinery share-using SUR. The factor share equations are derived from the first order profit maximizing conditions. We estimate the system using one less equation. Here we drop the fertilizer share equation from the system.

In SUR method we assume contemporaneous correlations. That is, the equations are correlated through the error terms. Hence we use a generalized least square (GLS) estimation method. The GLS applies to the stacked model consisting of several equations. We could specify the SUR system as:

$$\mathbf{Y}_1 = \mathbf{X}_1\boldsymbol{\beta}_1 + \boldsymbol{\varepsilon}_1$$
$$\mathbf{Y}_2 = \mathbf{X}_2\boldsymbol{\beta}_2 + \boldsymbol{\varepsilon}_2$$
$$\mathbf{Y}_m = \mathbf{X}_m\boldsymbol{\beta}_m + \boldsymbol{\varepsilon}_m$$

In matrix notation:

$$\begin{bmatrix} \mathbf{Y}_1 \\ \mathbf{Y}_2 \\ . \\ . \\ \mathbf{Y}_m \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & 0 \ldots\ldots\ldots\ldots\ldots\ldots & 0 \\ 0 & \mathbf{X}_2 \ldots\ldots\ldots\ldots & \ldots 0 \\ . & & \\ . & & \\ 0 & 0 \ldots\ldots\ldots\ldots & .\mathbf{X}_m \end{bmatrix} \begin{bmatrix} \boldsymbol{\beta}_1 \\ \boldsymbol{\beta}_2 \\ \\ \\ \boldsymbol{\beta}_m \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_1 \\ \boldsymbol{\varepsilon}_2 \\ \\ \\ \boldsymbol{\varepsilon}_m \end{bmatrix}$$ where m = number of equations

The variance-covariance matrix in the above system of equations is given by $\mathbf{\Omega}$ where:

$$\mathbf{\Sigma} = \begin{bmatrix} \sigma_{11}\ \sigma_{12} & & \sigma_{1m} \\ \sigma_{21}\ \sigma_{22} & & \sigma_{2m} \\ & & \\ \sigma_{m1}\ \sigma_{m2} & & \sigma_{mm} \end{bmatrix} \text{ and } \mathbf{\Omega} = \mathbf{\Sigma} \otimes \mathbf{I} \quad \text{where } \mathbf{I} = \text{identity matrix.}$$

That is, in SUR we assume, $E(\varepsilon_i \varepsilon_j \mid \mathbf{X}_1, \mathbf{X}_2, .., \mathbf{X}_m) = \sigma_{ij}$ *or* $E(\boldsymbol{\varepsilon\varepsilon} \mid \mathbf{X}_1, \mathbf{X}_2, .., \mathbf{X}_m) = \mathbf{\Omega}$. The GLS estimator is:

$$\hat{\boldsymbol{\beta}}_{GLS} = [\mathbf{X}'\mathbf{\Omega}^{-1}\mathbf{X}]\mathbf{X}'\mathbf{\Omega}^{-1}\mathbf{Y}$$

The greater the correlation between the disturbances, the greater is the efficiency gain accruing to GLS.

Our translog profit function with the factor demand equations can be represented by the following equations:

$$\ln \pi = a_0 + \beta_p \ln P + \beta_w \ln w + \beta_r \ln r + \beta_f \ln f + \frac{1}{2}[\gamma_w (\ln(w))^2 + \gamma_r (\ln(r))^2 + \gamma_f (\ln(f))^2] + \frac{1}{2}[\gamma_{wr} \ln w . \ln r + \gamma_{rf} \ln r . \ln f + \gamma_{wf} \ln w . \ln f] + \lambda_h hh + \boldsymbol{\lambda}_{ed} \mathbf{ED} \tag{1}$$

$$\frac{\partial \pi}{\partial w} = \frac{wL}{\pi} = a_1 + \beta_w + \gamma_w \ln(w) + \gamma_{wr} \ln(r) + \gamma_{wf} \ln(f) + \lambda_h hh + \boldsymbol{\lambda}_{ed} \mathbf{ED} \tag{2}$$

$$\frac{\partial \pi}{\partial r} = \frac{rM}{\pi} = a_2 + \beta_r + \gamma_r \ln(r) + \gamma_{wr} \ln(w) + \gamma_{rf} \ln(f) + \lambda_h hh + \boldsymbol{\lambda}_{ed} \mathbf{ED} \tag{3}$$

$$\frac{\partial \pi}{\partial f} = \frac{fF}{\pi} = a_3 + \beta_f + \gamma_f \ln(f) + \gamma_{wf} \ln(w) + \gamma_{rf} \ln(r) + \lambda_h hh + \boldsymbol{\lambda}_{ed} \mathbf{ED} \tag{4}$$

Where Equation (1) is the translog profit function, Equations (2), (3), and (4), respectively, are the factor demand equations for labor (L), machinery (M) and fertilizer (F). P is the output price, w is the price of labor, r is the price of machinery, and f is the price of fertilizer. First order conditions of profit maximization from Equation (1) yields the factor demand equations where Equation (2) is the share of labor in total profit, Equation (3) represents share of machinery in total profit and Equation (4) shows share of fertilizer in total profit, hh representing household size and ED representing education dummies are used as the controls in the equations.

We start with estimating an iterative SUR system followed by a 3SLS system, where the latter gives the most efficient estimates.

In the next section of the paper, we estimate technical efficiency, by considering a production function,

$$y_{it} = f(x_{it})\exp(-u_{it}), \quad 0 < u_{it} < \infty \tag{5}$$

Where y_{it} is the observed (actual) output produced by the i^{th} firm in period t while x_{it} is the vector of inputs used in the production process, $f(.)$ is the frontier production function and u_{it} is the non-negative residual term following $N(0, \sigma_u^2)$. u_{it} is zero if the production unit produces the potential output (technically efficient) and is less than zero when production is below the frontier (technically inefficient). A measure of technical efficiency of the i^{th} firm in t^{th} period can be expressed as the ratio of the observed (y_{it}) to the potential output [f(.)] level. The firm's objective is to maximize profit, for which knowledge of the appropriate input-output technical relationship is necessary. Therefore, is important to examine whether "firms are able to apply the technical aspects of production successfully". Therefore, the technical efficiency (TE) measure can be expressed by (using Equation 5),

$$TE = \frac{y_{it}}{f(x_{it})} = \exp(-u_{it}) \tag{6}$$

In India economic reforms took place in the 90s, which influenced the agricultural sector with varying degrees of intensity through newly available technology. The level of improvement in technical efficiency will vary across firms. TE takes a value within the interval (0, 1), where 1 indicates a fully efficient firm. The potential (maximum possible) output may vary across firms depending upon their knowledge and capability of technology diffusion.

4. Results

Tables 1-3 shows the translog profit function estimates with factor demand equations for labor and machinery using iterative SUR. Tables 4-6 shows the 3 stage least square estimates with the same system of equations. We estimate the equations imposing the appropriate symmetry and linear homogeneity restrictions. The coefficient estimates in the iterative SUR and 3 SLS models turn out to be quite close.

We cannot interpret the coefficient estimates of the profit function as it is defined as a translog functional form unlike in a Cobb-Douglas form. However, we can interpret the household size and educational dummies from Tables 1 and 4. We find that as household size increases, profit increases because more members in a household contribute to farming activities thus raising farming profitability, ceteris paribus. We also find that as one receives more education, agricultural profit goes up. Our results find support from previous evidence that farmers' education levels influence their efficiency (Idiong, 2007). This is because advanced knowledge translates into better use of farming techniques and therefore higher profits. We find that profit peaks at the graduate level. The coefficient on the postgraduate dummy, although significant, is less than the graduate dummy, which implies that at the post graduate level fewer household members contribute to farming activities, thus generating lower profits, all other variables held constant.

The labor share equations (Tables 2 and 5) show positive coefficients on machinery and fertilizer prices, which imply that as the price of each of these inputs rise, they are substituted for labor. Therefore, as labor demand rises, the share of labor in total profits goes up. The machinery share equations (Tables 3 and 6) show a similar trend. Household size reduces factor shares. A rise in household size could be due to child births in families which raise the number of dependents and at the same time larger family size could mean people from the same family employed in farming activities, such as a farmer employing his children where the latter are unpaid laborers. Therefore, larger household sizes could lead to a decline in factor shares. Finally we find that as one's education level rises, his share in the total profit drops, implying that with higher education individuals switch from the agricultural sector, hence their returns from farming decline.

Results from estimation of Equations (1)–(3) are shown in the tables below [we drop Equation (4) from the SUR estimation]

Table 1 Estimates of Profit Function Using Iterative SUR

Variable name	Parameter	Coefficient	t-ratio
Price of output	β_p	0.349^{*}	-0.07
Price of labor	β_w	-1.42	-0.30
Price of machinery	β_r	-0.22^{*}	-0.02
Price of fertilizer	β_f	-1.43^{*}	-0.22
Square of labor	γ_w	0.30^{*}	-0.04
Square of machinery	γ_r	-0.08^{*}	-0.01
Square of fertilizer	γ_f	0.05	0.07
Labor*fertilizer	γ_{wf}	0.01	0.07
Labor*machinery	γ_{wr}	0.00	0.03
Machinery*fertilizer	γ_{rf}	0.28^{*}	0.05
Household size	λ_{hh}	0.18^{*}	0.03
Primary	λ_p	0.58^{*}	0.22
Secondary	λ_s	0.67^{*}	0.20
Higher secondary	λ_{hs}	0.95^{*}	-0.31
Graduate	λ_g	1.40^{*}	-0.32
Post graduate	λ_{pg}	1.17^{*}	-0.60
Constant	a_0	10.35^{*}	-0.34

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%. We use no education as the base dummy.

Table 2 Estimates of Factor Demand Equation for Labor

Variable name	Parameter	Coefficient	t-ratio
Price of labor	β_w	1.41^{*}	0.03
Price of machinery	β_r	0.21^{*}	0.03
Price of fertilizer	β_f	1.20^{*}	0.04
Household size	λ_{hh}	0.10^{*}	-0.01
Primary	λ_p	-0.25^{**}	-0.14
Secondary	λ_s	-0.37^{**}	-0.12
Higher secondary	λ_{hs}	-0.65^{*}	-0.19
Graduate	λ_g	-0.75^{*}	-0.20
Post graduate	λ_{pg}	-0.54	-0.38
Constant	a_1	1.42^{*}	0.03

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%. We use no education as the base dummy.

Table 3 Estimates of Factor Demand Equation for Machinery

Variable name	Parameter	Coefficient	t-ratio
Price of labor	β_w	0.02^{*}	0.02
Price of machinery	β_r	-0.22	-0.13
Price of fertilizer	β_f	0.24^{*}	0.02
Household size	λ_{hh}	-0.02^{*}	-0.01
Primary	λ_p	-0.11	-0.07
Secondary	λ_s	-0.14^{*}	-0.07
Higher secondary	λ_{hs}	-0.21^{*}	-0.10
Graduate	λ_g	-0.19^{***}	-0.11
Post graduate	λ_{pg}	0.13	-0.22
Constant	a_2	-0.22	-0.02

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%. We use no education as the base dummy.

Table 4 SUR Estimates of Profit Function Using 3SLS

Variable name	Parameter	Coefficient	t-ratio
Price of output	β_p	0.49^{*}	-0.08
Price of labor	β_w	-1.41^{*}	-0.30
Price of machinery	β_r	-0.22^{*}	-0.02
Price of fertilizer	β_f	-0.74^{*}	0.24
Square of labor price	γ_w	0.32^{*}	0.04
Square of machinery price	γ_r	-0.07^{*}	-0.01
Square of fertilizer price	γ_f	0.04^{**}	0.07
Labor*fertilizer	γ_{wf}	-0.02	-0.08
Labor*machinery	γ_{wr}	0.04	0.03
Machinery*fertilizer	γ_{rf}	0.30^{*}	0.05
Household size	λ_{hh}	0.14^{*}	0.03
Primary	λ_p	0.41^{*}	0.20
Secondary	λ_s	0.51^{*}	0.02
Higher secondary	λ_{hs}	0.74^{*}	0.27
Graduate	λ_g	1.12^{*}	0.29
Post graduate	λ_{pg}	0.89^{***}	0.52
Constant	a_0	9.12^{*}	0.38

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%. We use no education as the base dummy.

Table 5 Estimates of Factor Demand Equation for Labor

Variable name	Parameter	Coefficient	t-ratio
Price of labor	β_w	1.41	0.30
Price of machinery	β_r	0.22^{*}	0.03
Price of fertilizer	β_f	1.19^{*}	0.04
Household size	λ_{hh}	-0.10^{*}	0.01
Primary	λ_p	-0.25^{**}	-0.14
Secondary	λ_s	-0.36^{**}	-0.12
Higher secondary	λ_{hs}	-0.64^{*}	-0.19
Graduate	λ_g	-0.74^{*}	-0.20
Post graduate	λ_{pg}	-0.54	-0.38
Constant	a_1	-1.41^{*}	-0.03

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%. We use no education as the base dummy.

Table 6 Estimates of Factor Demand Equation for Machinery

Variable name	Parameter	Coefficient	t-ratio
Price of labor	β_w	0.02^{*}	0.02
Price of machinery	β_r	0.22	0.10
Price of fertilizer	β_f	0.24^{*}	0.02
Household size	λ_{hh}	-0.02^{*}	-0.01
Primary	λ_p	-0.10	-0.07
Secondary	λ_s	-0.14^{*}	-0.07
Higher secondary	λ_{hs}	-0.21^{*}	-0.10
Graduate	λ_g	-0.18^{***}	-0.11
Post graduate	λ_{pg}	0.13	0.21
Constant	a_2	0.22*	0.02

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%. We use no education as the base dummy.

5. Decomposition of Output Change between Two Time Periods

Now we come to the next part of our analysis — decomposing the change in output for a production unit across two periods into input growth, technical change/progress, and technical efficiency change/improvement. The data sets harnessed for this exercise are the ARIS/REDS 1999 and 2006 rounds. In the first section, the theoretical basis of this decomposition is explained, and the second section presents the findings from the data.

5.1 Theoretical Background

The following analysis describes this decomposition. In doing so, we follow Kalirajan, Obwona, Zhao's (1996) decomposition methodology.

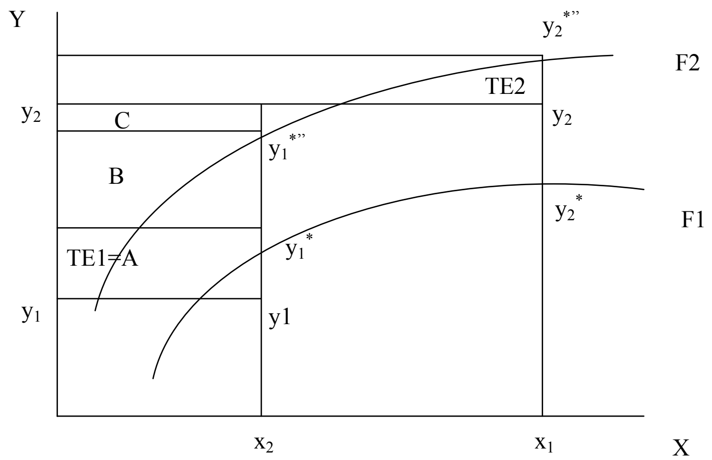

Figure 1[2] **Decomposition Methodology**

The above figure illustrates the decomposition of total output growth into input growth, technical progress, and technical efficiency improvement for a production unit/firm. If the firm is technically efficient it would be operating on the production frontier. In this case the firm faces production frontiers Fl and F2, in periods 1 and 2 respectively. The actual output produced is y_1 for period 1 and y_2 for period 2. Thus the firm is technically inefficient in both the periods. Technical inefficiency is measured by the vertical distance between the frontier output and the realized output of a given firm, that is, TI1 in period 1 and TI2 in period 2, respectively. Hence, the change in technical efficiency over time is the difference between TI1 and T12. Technological progress is measured by the distance between frontier F2 and frontier Fl, that is, $(y_2 *"- y_2*)$ using x_2 input levels or $(y_1 *"- y_1*)$ using x_1 input levels. The input growth is given by $(y_2 *"- y_1 *")$. 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.

$$
\begin{aligned}
D &= y_2 - y_1 = A + B + C = (y_1 * - y_1) + (y_1 *"- y_1*) + (y_2 - y_1 *") \\
&= (y_1 * - y_1) + (y_1 *"- y_1*) + (y_2 - y_1 *") + (y2 *"- y2 *") \\
&= (y_1 * - y_1) + (y_1 *"- y_1*) - (y_2 *"- y_2) + (y_2 *"- y_1 *") \\
&= \{(y_1 * - y_1) - (y_2 *"- y_2)\} + (y_1 *"- y_1*) + (y_2 *"- y_1 *") \\
&= \{TI1 - TI2\} + TP + \Delta y_x
\end{aligned}
$$

[2] Figure adopted from "Sources of Variations in Export Flows over Time: A Suggested Methodology of Measurement" by Kaliappa Kalirajan.

Where, $y_2 - y_1 =$ output growth

TI1 - TI2 = change in technical efficiency

TP = technical progress

Δy_x = output growth due to input growth

The decomposition in the equation above thus attributes observed output growth to movements along a path on or beneath the production frontier (input growth), movement toward or away from the production frontier (technical efficiency change), and shifts in the production frontier (technological progress).

Following the conventional conceptualization of total factor productivity (TFP), the TFP growth can be defined as the growth in output not explained by input growth. Thus from the decomposition equation, TFP growth consists of two components: technical efficiency and technical progress; that is, TFP = (TI1 - T12) + TP.

5.2 Findings from ARIS/REDS 1999 and 2006 Sample Set

Using the ARIS/REDS 1999 and 2006 panel data, we decompose the output growth in terms of technical efficiency, technological progress and input growth. The mean technical efficiencies for 1999 and 2006 are 0.79 and 0.44 respectively. The input growth $(y_2{*''}-y_1{*''})$ as shown in Figure 1 is (12.35 - 12.20) = 0.15, and the technological progress $(y_2{*''}-y_2{*})$ is (12.20 -11.57 =) 0.63. Thus Total Factor Productivity (TFP) is $\{(y_1{*}-y_1)-(y_2{*''}-y_2)\}+(y_1{*''}-y_1{*})$ is the sum of technical efficiency and technological progress [0.63 + (0.44 - 0.79) = 0.28]. Since TFP is greater than input growth we can infer that output growth between the two periods is technology driven.

In neoclassical growth models, it is assumed that the economy will always converge towards a steady state rate of growth, which depends only on the rate of technological progress and input growth. Thus, if we impose the neo-classical framework in the present productivity analysis, total factor productivity would include technological progress only and would not incorporate technical inefficiencies. Hence, the TFP growth would turn out to be much higher.

Further, we can deduce that since the technical change between 1999 and 2006 has been negative, and the technological progress positive at 0.63, the full potential of technological change between 1999 and 2006 could not be leveraged due to the decline in technical efficiencies. To fully leverage the same, policy prescriptions should target increasing farm level technical efficiencies through better adoption of the available technologies.

6. Concluding Remarks

In conclusion, policies to raise technical efficiency and improve farm productivity in the agriculture sector could be incorporated into the agricultural policy in India. A further study should be conducted to investigate the determinants of technical efficiency in the farm sector.

Acknowledgement

The authors are grateful to the International Development Research Center of Canada for the funding provided to the Council for this research. The authors are grateful to Professor Kalirajan of the Australian National University for the support provided for this research.

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