Total Factor Productivity in Indian Agriculture: Some Conceptual and Methodological Issues

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TOTAL FACTOR PRODUCTIVITY IN INDIAN AGRICULTURE: SOME CONCEPTUAL AND METHODOLOGICAL ISSUES[♣]

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ABSTRACT

The productivity growth in agriculture is both a necessary and sufficient condition for the development of the sector as well as the economy. This paper has reviewed the different methodologies of measuring the total factor productivity (TFP) and focused on some of the important issues such as the issues related to index numbers, price indexes, inflation, factor shares, value added vs. gross value of output, etc. related to measurement of TFP in agriculture. It also focuses on the determinants of TFP growth in agriculture and the trends in TFP growth in Indian agriculture.

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TOTAL FACTOR PRODUCTIVITY IN INDIAN AGRICULTURE: SOME CONCEPTUAL AND METHODOLOGICAL ISSUES

1. INTRODUCTION

The productivity growth in agriculture is both a necessary and sufficient condition for the development of the sector as well as the economy. It is a necessary condition in the sense that it enables agriculture to avoid a trap in to Ricardo's law of diminishing returns to which the sector is more prone. On the other hand it is a sufficient condition because it increases production at reduced unit cost/prices in real terms. The term "productivity", however, is often misused in the literature: it is used as synonyms to "labour productivity" in case of manufacturing sector, while used as synonyms to "yield productivity" in the case of Agriculture. But, the consideration of yield alone as a measure of productivity provides misleading indication of the degree of productivity improvement in agriculture (Coelli, 1996).

There are two concepts of productivity: partial productivity and total factor productivity. Partial productivity measures the contribution of one factor (say labour or capital) to output growth keeping the other factors constant. As such we have the concepts of labour productivity, capital productivity, which estimate the efficiency of resource use. But, partial productivity does not truly reflect whether it (productivity growth) is because of more use of inputs or improvement in the efficiency of their use or technology improvement.[1] Further, it also ignores time, secondary products, inputs other than land, labour and capital and externalities, all of which should be included in a sustainability measure (Barnell et al., 1995). Therefore the interest shifts to the Total Factor Productivity (here after TFP). Any growth in output that is not explained by some index of input growth is attributed to changes in technology or more broadly Total Factor Productivity. TFP measures the net growth of output per unit of total inputs. As such, its level is determined by how

[1] Technological progress did not get importance in the work of classical economists like Malthus, Ricardo and Mills. It has got some importance with varied degrees in the works of Marx and Schumpeter, and later on, the concept came to the fore after the works of Tinbergen (1942), Schmookler (1952), Kendrick (1956), Fabricant (1954), Abramovitz (1956) and Solow (1957). Today, technological progress is considered to be the major determinant of economic growth (Chattopadhyay, 2004).

efficiently and intensely the inputs are utilized in production. Thus, TFP growth is a catch-all measure that captures changes in efficiency in addition to pure technical change in the sense of shifts in the production function. TFP is regarded as the more accurate productivity measure than the partial productivity measure. As Fabricant (1959) pointed out, "As a general rule ….. it is better not to limit productivity indexes that purport to measure change in efficiency to a comparison of output with a single resource. The broader the coverage of resources, generally, the better is the productivity measure. The best measure is one that compares output with the combined use of all resources" (cited in Chandel, 2007).

The present paper examines some of the conceptual and methodological issues relating to the estimation of TFP in agriculture. It also focuses on the trends of TFP in agriculture in India. The paper is organized in the seven sections. This introduction is followed by an analysis of different methodologies and some of the conceptual and methodological issues to relating the estimation of TFP in agriculture. Section 3 discusses the determinants of TFP in agriculture. Section 4 explains the decomposition of TFP into technical change and change in technical efficiency. Section 5 underlines the problems with the TFP. Section 6 explains the trends of TFPG in Indian agriculture. Section 7 concludes our discussion.

2. METHODOLOGIES OF MEASURING TFP

There are three main approaches for estimating the TFP, namely the Production Function Approach (PFA), Growth Accounting Approach (GAA) and the most recent one being the Non-parametric Approach. This section explains the various approaches to measure the TFPG.

(a) Production Function Approach (PFA)

The production function approach (PFA) models the state of technology by including a time trend in the production or cost functions and the partial differentiation with respect to time to get estimates of technological changes. In this approach, TFP growth (here after TFPG) indicates technical progress, which represents shift in the production function or the cost function over time. Apart from improvements in techniques of production, advancement in knowledge and greater efficiency of production, betterment in the management practices, improvement in

the quality of inputs and increase in degree of utilization of resources are also included in the concept of TFP, defined in the PPA framework. However, since the outward shift in the production function is equivalent to the downward shift in the cost function (as the duality theory suggest), another way to estimate the TFP growth is in terms of the difference between the changes in total cost and the weighted changes in total input prices. Thus, the TFPG measure from the production function is equal and opposite in sign to the TFPG measure from the cost function.

However, different economists pointed out that there are various problems associated with the production function approach like multicollinearity, autocorrelation and degree of freedom (Trivedi *et al.*, 2000).

(b) Growth Accounting Approach (GAA)

Solow (1957) was the first to propose a growth accounting framework and then Denison (1967 and 1985) refined the approach. In this approach, TFP is measured as a residual factor, which attributes to that part of growth in the output that is not accounted for by the growth in the basic factor inputs. This approach approximates the technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices (Christensen, 1975). The TFP index is measured as the ration of the index of net output and the index of total factor inputs. The index of total factor inputs is derived as weighted average of indices of labour inputs, capital inputs and land inputs with relative income shares of the three factors as respective weights. The key feature of the GAA is separation of change in production on account of changes in the quantities of factors of production from residual influences, which include technological progress, learning by doing, *etc.* Basically there are three main indices used in the GAA: (i) Kendrick Index (KI), (ii) Solow Index (SI), and (iii) Translog Index (TLI).

The Solow residual is defined as [$g_y - \alpha \times g_k - (1-\alpha) \times g_l$], where g_y is the growth rate of output, g_k is the growth rate of capital, g_l is the growth rate of labour and α and $(1-\alpha)$ stand for share of capital and labour respectively. The Solow residual accurately measures TFP growth if (i) the production function is

neoclassical, (ii) there is perfect competition in factor markets, and (iii) the growth rates of the inputs are measured accurately.

The Divisia-Tornqvist index or translog index of TFP is commonly used for computing the total output, total input, and TFP indices can be specified as-

Total Output index: $TOI_t / TOI_{t-1} = \Pi_j (Q_{jt} / Q_{jt-1})^{(R_{jt}+R_{jt-1})^{1/2}}$ .....(1)

Total Input index: $TII_t / TII_{t-1} = \Pi_i (X_{it} / X_{it-1})^{(S_{it}+S_{it-1})^{1/2}}$ .....(2)

Here, R_{jt} is the share of j^{th} output in total output,

Q_{it} is output of the j^{th} commodity,

S_{it} is share of the i^{th} input in total input cost, and

X_{it} is quantity of the i^{th} input.

For the productivity measurement over a long period of time, chaining indexes for successive time periods is preferable. With chain linking, an index is calculated for two successive periods, t and t-1, over he whole period 0 to T (sample from time t=0 to t=T) and the separate indexes are then multiplied together:

$$TOI(t) = TOT(1).TOI(2).....TOI(t-1) \quad .....(3)$$
$$TII(t) = TII(1).TII(2).....TII(t-1) \quad .....(4)$$

Finally, the TFP index is computed as

$TFP_t = TOI_t / TII_t$ .....(5)

However, Kendrick index and Solow index suffer from some limitations. In contrary, the Translog index is superior to both Kendrick and Solow indices because Translog index numbers are symmetric in data of different time periods and also satisfy the factor reversal test approximately. It is based on Translog Production Function characterized by constant returns to scale. It allows for variable elasticity of substitution and does not require the assumption of Hicks-neutrality.

(c) The Nonparametric Approach

The most recent approach one being the Nonparametric Approach, which was developed by Chavas and Cox (1988) and Cox and Chavas (1990). The

Nonparametric Approach identifies a group of implied linear inequalities that a profit-maximizing (or cost minimizing) firm must satisfy and estimates the rate of technological change using linear programming. Data Envelopment Analysis (DEA) falls under this category. DEA is a linear programming methodology, which uses data on the input and output quantities of a group of countries to construct a piece-wise linear production frontier for each year over the data points.

All these above three approaches have their respective advantages and disadvantages. However, the GAA is the most popular one in the empirical research because it is easy to calculate, requires no econometric estimation and data requirement is minimal (Kumar *et al.,* 2004).

3. SOME ISSUES RELATED TO MEASUREMENT OF TFP IN AGRICULTURE

3.1 Index Number Procedure

The TFPG index is computed as the ratio of output index to the total input index. To construct an index of all outputs over all inputs, we must be able to aggregate the inputs together and the outputs together. The Laspeyres index was the most popular method of constructing such output and total input indices until Diewert (1976, 1978) proved that the Theil-Tornqvist is the superlative index. But, the basic problem of Laspeyres index is that it implicitly assumes that the production function is linear (Kumar *et al.*, 2008). The restrictive properties of linear production function such as constant marginal product and perfect substitutability between inputs, suggest that the TFPG measure based on Laspeyres index is suffer from certain fundamental deficiencies.

Since Diewert proved that the Theil-tornqvist index (which is exact for the linear homogeneous translog production function) is a superlative index- the use of translog index has become quite common to calculate the output and total inputs indices for estimating TFPG index. The principle advantage of the translog index is that it is not based upon simplistic linear production function assumptions, as are Laspeyres and Paasche indices. A further advantage of the translog index is that it accounts for changes in quality of inputs. Because current factor prices are used in constructing the weights, quality improvements in inputs are incorporated, to the extent that these are reflected in higher wage and rental rates (Rosegrant and

Evenson, 1995). The disadvantage is that- it is more difficult to compute and is not as intuitive as Laspeyres to interpret and also it requires extra data (e.g. prices from all the years). However, the Tornqvist index can probably be safely used in analyzing most production situations (Christensen, 1975).

3.2 Value Added of Output vs. Gross Output

It is important to consider whether value added or gross value of output will be considered for calculating the output index of TFPG index. The use of value added for measuring the TFPG index means exclusion of intermediate inputs in the measurement process. The exclusion of intermediate inputs assigns all measured technical progress to capital and labour inputs, ruling out increased efficiency in the use of physical inputs (Hulten, 1974, cited in Christensen, 1975). As a result the TFPG index based on the value added understates the TFPG. So, TFPG estimation should be for gross output, rather than for value added.

3.3 Issues Related to Factor Shares

One of the major problems with the estimation of factor share in India agriculture is that the income of a large number of self-employed farmers represents a mixed-income category that comprises of labour income as well as property income including rent, interest and profit. It is difficult to break up of the mixed income into the corresponding components of labour income and property income, and further, the property income into interest payment, profit share and rent. Thus, the presence of mixed income in Indian agriculture makes it difficult to compute TFP growth.

3.4 Scope of the Agricultural Sector

Agriculture, in general, includes crop farming, animal husbandry, plantation, fishery and logging, which can be divided into two categories: *farm sector and non-farm or livestock sector*. There are inseparable interlinks between the farm sector and these other sectors, and sometimes their inputs are joint products in the sense that inputs used for their production are practically inseparable. So, it is important to specify the scope of the agricultural sector since what agricultural output will be considered for computing the output index, is one of the important issues of computing TFPG index. However, there are studies those estimating the TFP for different sectors (e.g. farm sector, livestock sector etc.) or different crops (e.g. rice, wheat etc.)

Further, what agricultural inputs will be considered for computing the total input index is another issue of concern in estimating the TFP index. Desai and Namboodiri (1997) have considered 11 farm inputs namely land, labour, seeds, organic manure, fertilizers, pesticides, diesel, electricity, irrigation charges, private and public capital (that consists of land improvements, farm equipments and tools, public and private irrigation, agricultural machinery, farmhouses, livestock, and inventories) for computing the TFP index for the agriculture and allied sectors. The point is that the higher the coverage of the inputs used in the production process, the better will be the representation of the contribution of technological change by the TFP index. But, the problem is that of lack of a comprehensive long run time series data set on agricultural statistics in India. Again, the aggregation of all the inputs together for computation of the total input index and outputs together for computing output index has raised further problem, as all the inputs and outputs are not measured in a common unit.

3.5 Prices of Inputs and Outputs

What prices outputs and inputs to be used to aggregate the inputs and outputs is another important issues relating to the estimation of TFPG in agriculture. There has been debate in the literature whether to use the wholesale prices or farm prices for aggregating the inputs and outputs. However, since the units of measurement of different outputs and inputs are not same, some normalization of the prices is necessary before used for aggregating the outputs and inputs.

Further, whether the constant prices or current prices will be used for aggregating the outputs and inputs is another important issue to be considered. In the literature, it is found that most of the studies have used the current prices (and thus, the nominal values) of the outputs and inputs for aggregating the outputs and inputs without making any adjustment for inflation. As it is well known that the use of nominal values of outputs does not reflect the actual change of output, because the change may be due to the increase in the price level without any increase in the actual output level (or even decline in output level). Therefore, adjustments for inflation should be made while estimating the TFP index, which is not done in any of the empirical studies on estimating TFP in Indian agriculture.

Again, while adjusting for the inflation it is necessary to consider whether the single deflation method is used or the double deflation method is used. In the single deflation method, only one price index (say, either output or input price index) is used for deflating both the inputs and output values, where as in the double deflation method both the output price index is used for deflating output values and input price index is used for deflating the input values. The literature suggests that the double deflation method is more appropriate than the single deflation method (Balakrishnan and Pushpangadan, 1994).[2] However, the problem (of necessity of deflating the values of inputs and outputs) is serious only if the prices (either input-price or output price) actually do fluctuate. If the fluctuation of prices is not significant, then there is no need for adjustment for price inflation. In India, since the agricultural prices (both input and output prices) are administered by the government, the fluctuations of prices are very low. That is why; most probably the existing studies on TFP in agriculture did not adopt any methodology to adjust for the price inflation. But, in order to get the actual increase in productivity, it is necessary to consider the real values (of output and inputs), rather the nominal values, and therefore, the adjustment for price inflation is important.

3.6 Database Issues

Another problem relating the estimation of TFPG of agriculture in India is lack of a reliable and comprehensive long run time series database of agricultural statistics. A long run time-series data on variables like HYV seeds, irrigation-water by new methods (like more efficient pumping devices), etc. are rarely available. Therefore, though data on fertilizers and pesticides are available they cannot be separately considered to capture their impact in terms of technical change, as they are also complementary to HYV seeds, irrigation-water, etc. So, technical change in practice is to calculate for the growth in all inputs.

4. DETERMINANTS OF TFP IN AGRICULTURE

[2] The study by Balakrishnan and Pushpangadan (1994) is related to the Manufacturing sector. In the literature, none of the study relating to TFP in agriculture has used any adjustment procedure for the inflationary prices, as far as our knowledge.

Technical progress in agriculture is invariably embodied in new inputs like irrigation, HYV seeds, modern agriculture machinery and equipments, fertilizers, etc. The use of modern inputs imposes the marginal productivity of the land, labour and capital. They also induced better utilization of these basic inputs, which gets reflected in increased cropping intensity. Moreover, it would also capture the effect of proper timing, improved quality of labour, better farm management practices, greater utilization of resources, like land equipment, which leads to increased crop intensity, changes in cropping pattern in favour of high value added crops, etc. The former represents new physical inputs, while the latter represents scientific knowledge. Therefore, technical progress in agriculture captures the growth in output associated with both of these (Dholakia and Dholakia, 1993).

Technical change in agriculture is influenced by both the price factors and non-price factors like government investment in agricultural research, education, extension, and infrastructure like rural roads, regulated markets, etc (Desai and Namboodiri, 1997). While the role of price incentives to induce technical change is obvious, that of non-price factors arises from the shifts in structural change in agriculture. These shifts, as Dantwala (1967) observed could be from (1) antiquated to modem scientific knowledge-based farming, (2) isolated farms to those integrated with the rest of the economy, and from (3) oppressive to egalitarian land tenure system (cited in Desai and Namboodiri, 1997) and these shifts are facilitated by the policy instruments such as government expenditure on R & D, farm inputs and credit; institutional infrastructure for access to product, inputs and credit markets; and land reforms, etc.

Desai and Namboodiri (1997) have specified a following multivariate model to explain the TFPG in agriculture including the variables Barter terms of trade (BTOT), Government expenditure on R & D (GERD), P_2O_5 to N fertilizer ratio (PNR), Share of canal irrigated land (CIS), Rural literacy ratio (RLR), Marketing and banking infrastructure density (MBID), Density of rural roads (RRB), Gini ratio of distribution of own land (ONLE), Gini ratio of distribution of operational land (OPLE) and Average annual rainfall (ARF) and found that the specified model

explains about 98 percent variation in the TFPG.[3] Similarly, Dholakia and Dholakia (1993) pointed out that TFPG in agriculture is most likely to be governed by the application of modern agricultural inputs like irrigation, fertilizers, HYV seeds etc.[4] Their specified model explains 99 percent variation in the TFPG for the period 1950-51 to 1988-89. The model finds that the basic determinants of TFPG in Indian agriculture are the use of modern agricultural inputs and weather. As per their estimate, TFPG index would increase by 0.21 percent point when the modern inputs index increases by one percent.

Thus, we can see that the contribution of improved technology, which is measured as TFPG, can be further decomposed into several factors, viz. research, extension, education, infrastructure, health of natural resources and so on. The input growth is also influenced by several factors like input-output prices, technological innovations, institutions, infrastructure, policy initiatives, etc. The sources of growth in TFP in agriculture can be understood through TFP decomposition analysis. The decomposition of TFPG is discussed in the next section.

5. DECOMPOSITION OF TFPG

We have already seen that the TFPG always estimated as a residual factor, after accounting for the growth of inputs and its (TFPG) contribution is often interpreted as the contribution of technical progress. This implies that improvement in productivity arises only from technical progress. However, this presumption holds only under the assumption of technical efficiency[5] of resource allocation. But, so far as firms (farmers) do not operate on their production frontier due to various non-price and organizational factors, but somehow below the frontier, technical progress

[3] The specified model can be stated as

$$TFP = f(BTOT, GERD, PNK, CIS, RLR, MBID, RRD, ONLE, OPLE, ARF)$$

[4] The model specified by Dholakia and Dholakia (1993) is given as-

$$\mathrm{TFP} = \mathrm{f}(\mathrm{CI}, \mathrm{IRRI}, \mathrm{FERT}, \mathrm{HYV}, \mathrm{D}), \quad \text{where, } \mathrm{CI} = \mathrm{g}(\mathrm{IRRI}, \mathrm{FERT}, \mathrm{HYV}, \mathrm{D})$$

Here, CI, IRRI, FERT and HYV stand for cropping intensity, irrigation, fertilizer and HYV seeds respectively and D is the dummy variable for adverse weather condition.

[5] Technical efficiency of a farm can be defined as the ability and willingness of the farm to obtain the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the technology and environmental conditions surrounding the farm.

cannot be the only source of TFPG. A substantial increase in TFPG still can be realized by improving the method of application of the given technology. Thus, if the firms are not operated under full technical efficiency, then increase in TFPG may be due to improvement in either technical efficiency or technological progress or a combination. The changes in the technical efficiency can be substantial and outweigh the gains from technical progress itself. The studies by Shanmugam, and Soundararajan (2008) have found that the mean technical efficiency change has contributed roughly72 percent of the TFP in Indian agriculture in the post reform period.

Following Kalirajan, Obwona and Zhao (1996) and Kalirajan and Shand (1997), Figure 1 illustrates the decomposition of total output growth into input growth, technical advancement and technical efficiency improvement. F1 and F2 are the frontier production functions in period 1 and 2 respectively. yl* and y2* are technically efficient levels of production and y1 and y2 are actual output levels in the respective periods. Technical inefficiency (TI) in any given period is indicated by the output gap (the difference between actual and frontier output levels). Suppose there is technological advancement (TA) in period 2, the frontier function will shift to F2 at the end of period 2 and if the decision making unit keeps up with the advancement, decision making unit's output will be y1*" from the given X1 input. Therefore, technological advancement can be measured by the distance between the frontier F1 and F2 (i.e., y1*"-y1* evaluated at X1). Let, ΔYx be the contribution of input growth to output growth (between periods 1 and 2). Then, the total output growth, G (=y2-y1) can be decomposed into three components: input growth, technological progress and technical efficiency change. That is-

$$G = (TI1 - TI2) + TC + \Delta Yx$$

Output Growth = Technical efficiency change + Technology change
+ Input growth

Further, following Kalirajan and Shand (1997) the TPF growth consists of two components: technical efficiency change and technological change. That is,

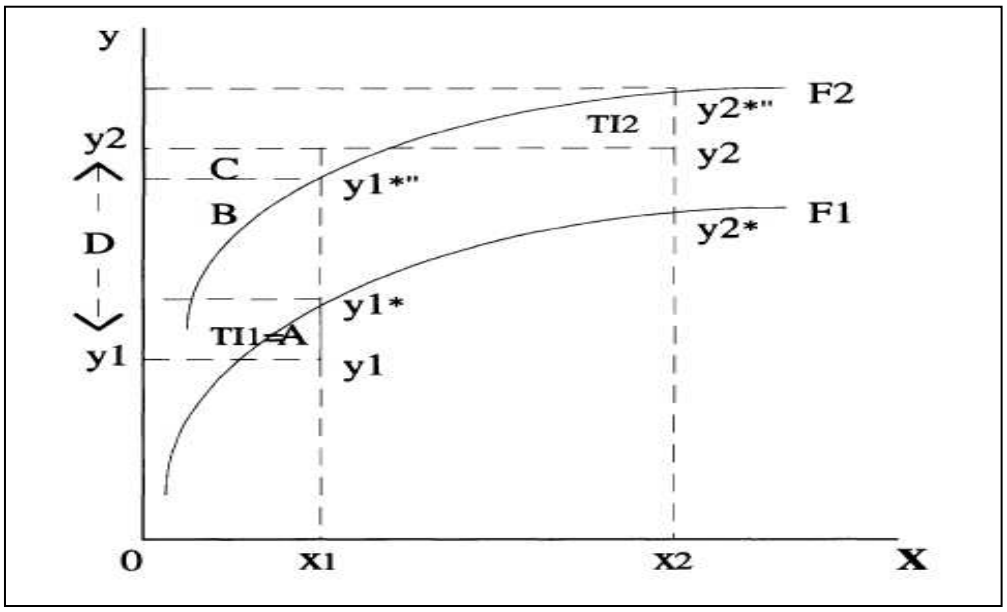
$$TFPG = TI1 - TI2 + TC$$

Thus, the TFP growth between period (t-l) and t for the i^{th} firm can be estimated as-

$$\Delta TFP_i = In\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right)$$

$$= \{(y1_{i,t-1}^{*X1} - y1_{i,t-1}^{X1}) - (y2_{it}^{*'X2} - y2_{it}^{X2})\} + (y1_{it}^{*X1} - y1_{i,t-1}^{*X1})$$

Figure 1: Decomposition of Total Factor Productivity Growth



Note: Here, $y2 - y1 =$ output growth

TI1-TI2= technical efficiency change

TC= Technical change

$\Delta Yx =$ Output Growth due to input growth

Source: Kalirajan and Shand (1997), Kalirajan, Obwona and Zhao (1996)

The TFP growth can further be decomposed into several factors, viz. research, extension, technology, institutional reform, education, infrastructure development, human resource development, health of natural resources and so on. The input growth is also influenced by several factors like input-output prices, technological innovations, institutions, infrastructure, policy initiatives, etc. (Kumar et al., 2008). The decomposition of TFPG provides more information on the status of production

technology applied by firms (Kalirajan *et al*., 1996). Such decomposition analysis facilitates examining whether technological progress is stagnant over time and whether the given technology has been used in such a way as to realize its potential fully. Further, this decomposition has different policy implications. This is in the sense that, since high rate of technical change can exist with declining technical efficiency and vice versa, it needs different policy actions for different sources of variation in productivity. The decomposition of TFPG into technical change and changes in technical efficiency is useful in distinguishing innovation or adaptation of new technologies by 'best practice' firms from the diffusion of new advance technology, which leads to improved technical efficiency amongst the firms.

6. PROBLEMS WITH THE TFP MEASURE IN AGRICULTURE

The TFP concept has come under question of its adequacy in recent years (Sengupta and Kundu, 2008). Critics have pointed out that, in the conventional framework[6] technical change is incorporated as a type of shift parameter that enhances output per unit of input used. In such a framework, technical change, which is neutral and independent of the time trends of the factor inputs and their prices in nature, is implicitly assumed to be an over all technical change. But, the concept of over all technical change is very little use from its practical and policy purposes. Forsund (1993) pointed out that problem with the TFP occurs when we have to dealing with the intersecting technical changes and in such circumstances the overall technical change is clearly inadequate (cited in Sengupta and Kundu, 2008). It is, however, intuitive that technical change should incorporate changes in productivity or efficiency of individual inputs. But in the TFP framework, it is not possible to estimate the contribution each of the input factor to TFP growth.

Factor Augmenting (FA) Approach

An alternative approach to the TFP approach is the Factor Augmenting (FA) approach. In the FA framework, technical change comes through improvement in the efficiency of inputs. As such, inputs should be measured in efficiency units. A factor augmenting technical change can be specified as-

[6] In the conventional framework the production function is specified as $Y = Af(X)$, where Y stands for output, X stands for vector of inputs and A stands for the efficiency matrix.

$$Y = f(\tilde{X}), \qquad where\ \tilde{X} = AX$$

Where Y stands for output, $\tilde{X}$ stands for vector of inputs in efficiency units, A is the efficiency index and X is the variable of inputs. With the FA model, it is possible to examine the contribution of individual factors to overall technical change. Visualizing the technical change as a FA process helps us to identify factor contributions to aggregate changes that are missing in a TFPG analysis.

7. TRENDS IN TFPG IN INDIAN AGRICULTURE

Various empirical studies show that the TFPG in Indian agriculture has declined over the years. In their empirical study on the TFP growth in Indian agriculture, Dholakia and Dholakia (1993) have found that the contribution of TFPG to agricultural output growth has declined during 1980-89. The TFP index in Indian agricultural is given in Table 2. The annual compound growth rate of TFP, given in Table 1, indicate that TFP as estimated by Dholakia and Dholakia (1993) increased at the rate of 1.77 percent per annum during 1967-68 to 1977-78 as against 1.73 percent per annum during 1978-79 to 1988-89. However, in the pre-green revolution period of Indian agriculture during 1952-53 to 1964-65, TFP had grown only at the rate of 0.53 percent per annum. As per the estimates of Fan, Hazell and Thort (1999), the growth in TFP works out to be at the rate of 1.39 percent per annum during 1970-71 to 1980-81, as against 1.36 percent per annum during1981-82 to 1990-91. However, their study shows that in the early years of economic reforms (for the years 1991-92 to 1994-95) the TFP growth of Indian agriculture has registered at 2.67 percent per annum.

Table 1: Average Annual Compound Growth Rate (AACGR) of TFP in Indian Agriculture

Dholakia & Dholakia (1993)		Fan, Hazell and Thort (1999)	
Year	**AACGR of TFP**	**Year**	**AACGR of TFP**
1952-53 to 1964-65	0.53	1970-71 to 1980-81	1.39
1967-68 to 1977-78	1.77	1981-82 to 1990-91	1.36
1978-79 to 1988-89	1.73	1991-92 to 1994-95	2.67

Source: V. N. Misra (2004) "State of Indian farmers", Vol. 15, pp. 157, Table: 9.5

However, the empirical study by Sivasubramonian (2004) has shown that the trend growth rate TFP in Indian agriculture, which was recorded at 1.65 percent during 1950-50 to 1960-61, has declined to 0.88 percent during 1960-61 to 1970-71 and further declined to –0.35 percent during 1970-71 to 1980-81 (Table 3). Further, during 1980-81 to 1990-91 the growth rate TFP increased to 1.89 percent and then again declined to 1.68 percent during 1990-91 to 1999-2000. However, all the three studies show that the growth rate of TFP in Indian agriculture has fallen during the 1970s.

Table 2: Indices of Total Factor Productivity in Indian Agriculture

Year	Dholakia &Dholakia (1993)	Fan, Hazell & Thort (1999)
1950-51	100.00	
1951-52	100.28	
1952-53	101.28	
1953-54	107.04	
1954-55	108.47	
1955-56	105.73	
1956-57	109.70	
1957-58	103.75	
1958-59	112.29	
1959-60	109.41	
1960-61	115.31	
1961-62	113.31	
1962-63	109.28	
1963-64	110.46	
1964-65	118.73	
1965-66	103.88	
1966-67	100.54	
1967-68	113.93	
1968-69	112.56	
1969-70	118.01	
1970-71	124.60	100.00
1971-72	120.33	98.51
1972-73	112.66	90.70
1973-74	117.91	99.38
1974-75	115.11	95.59
1975-76	127.46	109.28
1976-77	117.86	103.74
1977-78	127.19	112.82
1978-79	128.19	114.82
1979-80	109.66	98.84
1980-81	121.93	112.08
1981-82	126.93	117.71
1982-83	123.08	115.85

1983-84	134.73	128.48
1984-85	134.20	124.83
1985-86	133.74	128.07
1986-87	130.69	123.85
1987-88	130.27	126.23
1988-89	148.97	148.25
1989-90		140.18
1990-91		138.64
1991-92		138.75
1992-93		144.11
1993-94		146.10
1994-95		151.80

Source: V. N. Misra (2004) "State of Indian Farmers", Vol. 15, pp. 156, Table 9.4

Table 3: Growth Rate of TFP in Agriculture (1950-51 to 1999-2000)

Year	Growth Rate of GDP in Agriculture (%)	Growth Rate of TFP (%)	Share of TFP in Agricultural GDP in growth (%)
1950-50 to 1960-61	3.03	1.65	54.5
1960-61 to 1970-71	2.31	0.88	38.1
1970-71 to 1980-81	1.50	-0.35	-23.3
1980-81 to 1990-91	3.43	1.89	55.1
1990-91 to 1999-2000	2.79	1.68	56.6

Source: Sivasubramonian (2004)

Considering the share of TFP in agricultural GDP growth, as estimated by Sivasubramonian (2004) it is obvious from Table 2 that TFP growth has contributed 54.5 percent of agricultural GDP growth during 1950-50 to 1960-61 and then the share has declined to 38.1 percent during 1960-61 to 1970-71 and –23.3 percent during 1970-71 to 1980-81. However, the share has increased to 55.1 percent during 1980-81 to 1990-91 and then 56.6 percent during 1990-91 to 1999-2000. Thus it is obvious that, during the last couple of decades the agricultural GDP growth is largely explained by the TFP growth, although the growth rate of TFP has declined during the 1990s as compared to the 1980s.

The TFP growth in agriculture results predominantly from public investment in infrastructure facilities like irrigation, electricity, roads, etc. and in agricultural research and extension, education, and human resource development; and from efficient use of water and plant nutrients and institutional reform. The observed

decreases in the rate of TFPG are in large part a consequence of a substantial lessening of investments - notably public-sector investments - in India's agriculture.

The benefits of increasing TFP are felt nation-wide: *costs of production decrease, and prices fall and stabilize* and both the producers and consumers gain. Decreased food prices preferentially benefit the poor, since the poor spend proportionately much more of their income on food (particularly cereals). Further, the lower prices of home-produced agricultural products also assist India's agriculture to accommodate to the globalization of agricultural trade. However, for the families operating marginal size farms and for the rural poor, low productivity constitutes a major constraint as those rural families strive to achieve household food security. Investments and efforts to improve and sustain small-farm productivity are therefore vital. Research, technology development, and extension programmes should strengthen those of their activities that target the needs and opportunities of smallholders. Developments and investments that lead to TFPG in agriculture are likely also to lead to poverty reduction. Policies and investments that increase TFP are thus highly likely to lessen rural poverty and hunger. Additionally, *literacy* brings appreciable benefit to farm productivity and modernization, since it (literacy) correlates strongly with the adoption of cultivars, nutrients management, and mechanization, and with productivity. Increased literacy may thus be expected to generate increases in agricultural productivity and hence in household and in national food supplies.

8. CONCLUSION

The productivity growth in agriculture is both a necessary and sufficient condition for the development of the sector as well as the economy. The partial productivity does not truly reflect whether the productivity growth is because of more use of inputs or improvement in the efficiency of their use or technology improvement. Therefore the interest shifts to the total factor productivity. TFP measures the net growth of output per unit of total inputs. As such, its level is determined by how efficiently and intensely the inputs are utilized in production. This paper has reviewed the different methodologies of measuring the TFP and focused on some of the conceptual and methodological issues such as the issues related to index

numbers, price indexes, inflation, factor shares, value added vs. gross value of output, etc related to measurement of TFP in agriculture.

Considering the determinants of TFP growth in agriculture, the existing literature suggests that TFP growth in agriculture is invariably embodied in new inputs like irrigation, HYV seeds, modern agriculture machinery and equipments, fertilizers, etc., improved quality of labour, better farm management practices, greater utilization of resources, etc. The paper also focused on the trend in TFP growth in Indian agriculture. It is found the TFP growth in Indian agriculture was very low in the pre green revolution period and it declined (and even become negative) during the 1970s. However, even during the 1980s the growth rate of TFP in agriculture was relatively higher compared to the earlier period, during the 1990s the TFP growth in Indian agriculture has come down. There is considerable evidence in the literature to argue that the observed decreases in the rate of TFP growth is in large part a consequence of a substantial decrease of investments - notably public-sector investments - in India's agriculture. However, considering the share of TFP in agricultural GDP growth, it is found that the share has increased during the 1980s and 1990s. Since technological progress and technical efficiency are the two key sources of agricultural TFP growth and they declined in recent periods, our study argues for more government investment in agricultural R& D, technology development, and extension programmes and infrastructure including agricultural credit in order to sustain the growth.

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