Ind. Jn. of Agri. Econ.
Vol.73, No.4, Oct.-Dec. 2018

Total Factor Productivity in Indian Agriculture

K. Shanmugan and Baria Bhagirath Prakash*

ABSTRACT

Agricultural growth and development since economic reforms pose interesting propositions regarding the structural and behavioural characteristics of total factor productivity in the Indian context. Productivity and growth rate of agricultural output are largely influenced by the conventional inputs such as land, labour and capital and also by the contribution of non-conventional factors including technology. The combined effects of these non-conventional factors influence the dynamic change in total factor productivity. Utilising growth accounting framework with production function approach for aggregation of inputs, this study undertook a modest attempt to estimate and analyse total factor productivity (TFP) with and without constant returns to scale restrictions and their determinants respectively in Indian agriculture as a whole since 1991-92 up to 2016-17. Interesting inferences were derived regarding the nature and trend of estimated productivities, their determinants and important policy implications while noticing a falling trend in total factor productivity with constant returns to scale restriction and observing no conclusive linear trend in total factor productivity without constant returns to scale (CRS)restriction.

Keywords: Agricultural economics, Agricultural productivity, Total factor productivity.

JEL: Q00, Q11, D24.

I

INTRODUCTION

Growth and agricultural development are not mutually exclusive outcomes in the process of both market as an institution for fostering development and policy as an instrument for long term sustainable steady rate of growth. The co-movements that have been observed between growth rate of agricultural output and economic growth in the context of developing countries is propelled by strong base of agricultural sector. The strong base is supported by mutually dependent terms of trade between agriculture and industry including the fact that the sector has been contributing to exports also. Cross section of fertilities embodied in the amount of cultivable land and appropriate use of technology consistent with agro climatic conditions might throw long term implications for not only the determinants of agricultural growth but also to the stable productivity. It is well known that the productivity in agriculture is an area of concern not only for consistent growth of agricultural sector but also for the agricultural labour market and cross-migration problems. Low productivity in agriculture is a well-recognised issue which has not been addressed adequately in terms of proper investigation of determinants of productivity and the policy measures that are required to raise the level of productivity.

---

*Associate Professor and Research Scholar, respectively, Department of Business Economics, Faculty of Commerce, The Maharaja Sayajirao University of Baroda, Vadodara-390 002 (Gujarat).

The authors are thankful for the valuable comments from the anonymous referee. The usual disclaimer applies.

A close look at the development of agricultural sector unfolds considerable amount of debate on the importance of agriculture in the stability of growth trajectory and also on the productivity of agricultural sector that can sustain long term growth and produce shift in the trend growth. A detailed investigation of the developments in Indian agriculture especially after economic reforms reveal several analytical insights into the forces governing the behaviour of agricultural productivity as well as the significance of agricultural sector for the Indian economy. Some of the issues can be organised as follows:

First, elementary statistics reveal that the contribution of agricultural sector to the national income has declined manifold from the beginning of first five-year plan while its share in labour force has remained relatively stable since last ten years, although one can notice a marginal decline.[1]

Second, available evidences from disaggregated studies suggest that productivity has been largely governed by the use of fertilisers, agro climatic conditions, use of pesticides and both private and public investments made in agriculture. The use of fertiliser has an enormous implication on fertiliser subsidy and, the size and amount of fertiliser subsidy has grown manifold adding to serious implications on fiscal deficit. It can be argued that one has to make serious trade-off between reducing the fiscal deficit, which is not the focus of the study here, and making fertiliser available for cross section of farmers especially to small and marginal farmers. However, the anomaly in determining the appropriate level of fertiliser use consistent with different rates of growth in agricultural sector has been a matter of debate. The issue becomes imperative when productivity is largely influenced by the use of fertilisers.

Third, the variation and volatility in agro-climatic conditions have been posing serious problems for the stable growth rate of agricultural sector (Bhalla and Alagh, 1983, and Dev, 2012) and this issue has become more complex of late considering the clearance of agricultural labour market in terms of not quickly adjusting to the segmented differential labour market wages and their determinants. Variation in the agricultural growth can be traced back to the various factors and agro climatic conditions remain a key factor even today. Inter-state migration has not been smooth enough to reduce wage disparities in the labour market in a dualistic model that we invariably presume for a developing economy like India and the movement of labour has not been made market oriented to accommodate possible opportunities for easy and smooth migration.

Fourth, private and public investments in agriculture have been major areas of debate in analysing the issues such as agricultural development, raising the level of ground water table, technological development, use of high yielding varieties (HYVs), etc. and it remains to be seen, depending upon the way one can investigate the matter, what has been the extent of influence of investment on agricultural productivity. Although there are considerable empirical evidences on the impact of investment on productivity, in our opinion, it remains inconclusive.

Lastly, the raising of the level of total factor productivity (TFP) in agriculture has not been successful even with serious efforts at policy front after fully taking cognisance of the issues governing agricultural productivity. It is not unidimensional that raising TFP can be achieved by discretionary policies and that the issue can be more complex than it could be surfacing at the policy levels. Therefore, it requires an exhaustive investigation of the empirical facets of how agricultural output changes over a long range and the role of TFP in inducing these changes, and also warrants an examination of the evolution of agricultural policy behaviour, especially since economic reforms.

It is thus a substantial claim to make that the behaviour, composition and determinants of TFP provide noteworthy insights into the dynamics surrounding the Indian agriculture. There is a considerable amount of literature on agricultural productivity which focuses across various empirical matters including the determinants of TFP but most of the studies do not comprehensively analyse multidimensional angles of measuring productivity and examining dynamic specifications of various determinants. As against this background the present work is undertaken to concentrate on the analysis of various aspects of TFP and subsequently its determinants.

II

REVIEW OF LITERATURE

The density of analytical thrust put upon the examination of TFP across crops, regions and the agricultural sector as a whole has been noteworthy in the Indian context. There are several studies that have contributed critically to the burgeoning literature on TFP analysis pertaining to Indian agriculture but the landmark studies that introduced the fundamental shift in understanding of the dynamics of TFP into the fold of Indian academic discourses especially after the reforms were Rosegrant and Evenson (1992, 1995), and Dholakia and Dholakia (1993) among others. Considerable importance has been attached to the measurement of TFP via multiple methodological frameworks with studies using methods ranging from growth accounting framework (such as Solow, 1957, Dholakia and Dholakia, 1993, Kalirajan and Shand, 1997, Krishna *et al*., 2017 and Tripathi, 2008 among others) and Index Number approach (such as Rosegrant and Evenson 1992, Desai and Namboodiri 1997, and, Kannan, 2011 among others), to econometric techniques (such as Reddy, 2012 and several others). Among the various frameworks for TFP measurement, the problem of aggregation of heterogeneous inputs to construct a single composite measurement of all inputs has been common to almost all the approaches. This aggregation problem is further complicated by the usage of various weighting factors which can be broadly classified into factor-price weights, cost-share weights, income-share weights and finally production elasticity weights. Among these, the last approach has been much more popular than others particularly for aggregate level analysis.

Within the research agenda on TFP analysis, the empirical assessment of the sources of TFP growth in the Indian agricultural sector has been another debatable area and various studies have modelled the determinants which vary across the time-period chosen, the methodological framework used for estimating TFP, constraints imposed by data availability, etc. Among the various studies that examined the determinants of TFP, factors such as public investment, HYVs of seeds, fertiliser, irrigation and government extension seem to be the major sources of variation in TFP.

III

DATA

Data on agricultural statistics were primarily available from the published sources of Government of India. The data adjustments which were required to suit the variables that are viewed as critical in the context of this study essentially came from challenges that lie with availability of required data, quality and reliability of available information, differences in scale and frequent changes in the definitions used for same variables, consistency of data, etc. Data used in this study are all secondary, obtained from such official published sources[2] such as *Handbook of Statistics, Agricultural Statistics at Glance, Economic Surveys*, online database of The Fertiliser Association of India and the online database of India Meteorological Department (IMD). Certain data set are expressed in constant terms by using 2004-05 prices.

IV

METHODOLOGY

There are a wide variety of methodologies available in the empirical research for analysing and estimating TFP. Some researchers have classified these methods into “parametric, accounting and non-parametric methods” (Kumar and Mittal, 2006). Although there are several methods that have been adopted for estimation of TFP, this study uses growth accounting approach to measure TFP along with production function approach for aggregation of conventional agricultural inputs such as land, labour and capital.

The popular use of growth accounting method in several studies has an advantage in respect of critical issues pertaining to data and non-availability of certain information in the agrarian economy and therefore this paper preferred to use the same methodology with certain improvements, as evident in our estimation.[3] This methodology is preferred over other methodologies for reasons such as the availability of data, practical usefulness in applying disaggregated empirical analysis, plausibility in decomposing the growth data appropriately suitable for residual factor productivity analysis in the Indian context, availability of data for estimating weighting factors for aggregation of inputs, etc.

Measurement of TFP was done by taking a ratio of total output index to total input index. This study has employed gross domestic output to construct an output index with base year 2007-08. Input index has been calculated by using two forms of the Cobb-Douglas production function namely with and without constant returns to scale (CRS) assumptions by placing the input index on 2007-08 as a base. The ratio of total output index (TOI) and total input index (TII) yielded the TFP index.

V

DESCRIPTIVE STATISTICS

In order to provide a precursor to the estimation of models and their subsequent analysis, summarising the descriptive statistics for the key and crucial variables of this study can shed some interesting insights into various aspects of the issues under consideration and accordingly the estimates are presented in the Table 1 below:

TABLE 1. DESCRIPTIVE STATISTICS

Period (1)	Statistic (2)	AGDP (3)	GCA (4)	AWF (5)	AGCF (6)	ANRNFL (7)	FSUB (8)
1991-92 to 1995-96	Mean	4267.44	186.01	202.96	372.65	1203.68	5671.20
	S.D.	246.29	2.29	12.54	30.41	72.85	819.54
	C.V.	5.77	1.23	6.18	8.16	6.05	14.45
1996-97 to 2000-01	Mean	5050.34	188.98	230.98	509.02	1145.36	11227.20
	S.D.	194.41	2.35	6.51	117.13	70.31	2542.31
	C.V.	3.85	1.24	2.82	23.01	6.14	22.64
2001-02 to 2005-06	Mean	5592.04	187.08	250.37	766.99	1123.90	14165.20
	S.D.	277.05	7.58	11.55	58.06	104.70	3453.08
	C.V.	4.95	4.05	4.61	7.57	9.32	24.38
2006-07 to 2010-11	Mean	6617.52	193.90	249.82	1181.64	1125.62	60140.40
	S.D.	354.84	3.30	4.69	183.95	102.31	26
	C.V.	5.36	1.70	1.88	15.57	9.09	977.42
							44.86
2011-12 to 2015-16	Mean	7742.39	196.98	265.28	1516.38	1074.57	72633.60
	S.D.	175.42	2.49	3.13	60.36	29.28	1823.43
	C.V.	2.27	1.27	1.18	3.98	2.72	2.51

Source: Authors' calculations.

Notes: (1) Description of the variables is as follows: AGDP – Agricultural gross domestic product at factor cost (at constant price, base year 2004-05), GCA – Gross cropped area (millions of hectares), AWF – Agricultural workforce (millions of workers) AGCF – Agricultural gross capital formation (at constant price, base year 2004-05), ARNFL – Actual annual rainfall (millimeters per year), FSUB – Fertiliser subsidy at current prices. (2) SD – Standard deviation and C.V. – Coefficient of variation.

A cursory look at the table reveals some important observations about the behaviour of agro-output and other key variables across various sub-periods. These facts can be stated as below:

On the one hand, persistent growth in both agricultural output as well as agricultural inputs, viz., land, labour and capital has been observed, and on the other, the changes in all the three inputs display a strong positive correlation with the changes in agricultural output[4]. The fact that agricultural inputs have been growing along with output, indicates a possibility that the observed output growth may have probably occurred as a movement over the existing production frontier itself instead of a shift in it, thereby requiring further investigation about the empirical importance of TFP in explaining the growth in output during the study period.

Across the sub-periods ranging from 1991-92 to 1995-96 up to 2011-12 to 2015-16, it was found that the increase in agricultural output was 81 per cent while the rise in the inputs was approximately 90 per cent, 31 per cent and 307 per cent for land, labour and capital respectively. Moreover, public investment has shown a consistent increase during the chosen period which probably points to the fact that this sharp rise might exemplify the role of the Government as a key supplier of finance for investments in agricultural activities and that it has become more pronounced with time. Probably this rise can be traced to the nature of involvement of the Government in facilitating agrarian development and its role has further dispersed across the various sub-sectors ranging from macro level efforts such as all-India irrigation and water resource development programmes to micro level efforts such as regional and crop-specific development programmes.

Even though it cannot be conclusively emphasised but *prima facie* it appears that a surge in the amount of capital supplied to agricultural sector coupled with an increase in agricultural output without substantial change in the agricultural labour force[5] may indicate that agricultural production in India is probably tending towards more capital-dependent agro goods and services. When compared to the increase in capital, none of the other inputs show such a sizeable expansion over the period under consideration. Only a very small expansion has been observed since 1991 in case of land available for agriculture, which may have been on account of a shift in the pattern of usage of total available land towards more profitable and remunerative industrial, services and household sectors. Labour supply has remained almost constant. It can be argued that the gradual shift in the labour market towards non-farm occupations might explain the limited growth in aggregate labour force, though still a large proportion of workforce is dependent on agriculture. This could be the result of variety of pull and push factors that may have been contributing to the limited growth of agro-workforce and their subsequent gradual shifting towards more remunerative industrial and service sectors.

While there has been a clear rise in inputs as well as agro output, the changes in the average values of these variables during the sample period have not been stable. The variability observed through the coefficient of variation was very high for capital and rainfall while that of other variables namely agricultural workforce, agro-output and gross capital formation has remained fairly stable but subjected to smaller variation. Moreover, the correlation between departure of actual rainfall from normal level and agricultural output was found to be negative.[6] Owing to less variation observed on departure of actual rainfall from its normal level, probably the risk in agricultural production and fluctuation in the income of farmers to some extent might have been reduced. This observation becomes all the more important when it is analysed along with the fact that agricultural production in India still exhibits strong rain-dependency. It probably appears that the efforts of the Government to reduce rain-dependency of farmers and promote proper water management systems and, the subsequent policy-induced shift towards more efficient irrigation systems might have been gradual.[7] Such an insight possibly becomes more significant given the fact that a large part of irrigated land is concentrated among a small group of large farmers and small and marginal farmers are still rain-dependent. However, some contribution to output must have come from irrigation-driven cultivation.

VI

MODELS AND ESTIMATION

This study has estimated production elasticities for three inputs by using Cobb Douglas production function; a standard production function model for empirical analysis with assumptions that are obviously known including that it is homogenous. It is utilised to measure residual factor productivity as per the framework developed by Solow (1957) who used the growth accounting method to decompose change in aggregate output into change in inputs and change in the technical parameter which measured technological progress. The technical change parameter was the residual change in output not explained by changes in conventional inputs. An attempt has also been made to measure TFP by relaxing the constant returns to scale assumption and by taking explicitly land, labour and capital as independent factors of production to give scope to clearly explain the underlying factors of production as can be revealed by the data generating process. The logic of relaxing CSR lies in the fact that the production process differs depending on whether the area under cultivation follows some degree of variability such as high yielding varieties vs. non high yielding varieties, irrigated vs. un-irrigated and low quality soil vs. high quality soil. Accordingly, the scope is given to reflect whether average information available in the data generating process could produce increasing return or diminishing returns to scale and also to account for good amount of heterogeneity that exists in the agricultural production process. Our estimation of TFP is certainly based on the assumptions of both CRS and without CRS on the Cobb-Douglas production function and this could reveal some of the interesting facts related to the very dimensions of TFP.

A typical standard empirical Cobb-Douglas production function can be stated as follows:

$$\log Q = \log A + \alpha \log LAN + \beta \log LAB + \gamma \log CAP + \varepsilon \qquad \ldots(1)$$

where; $\alpha + \beta + \gamma = 1$ in the case of CRS restriction, and logQ = Log of Gross Domestic Product of Indian agricultural sector, logA = Log of Technical change parameter, logLAN = Log of Gross Cropped Area, α = Output elasticity of Land, logLAB = Log of Agricultural Work Force, β = Output elasticity of Labour, logCAP = Log of Gross Capital Formation[8] and γ = Output elasticity of Capital and ε = error term.

The estimated model in double-logarithmic form without Constant Returns to Scale is presented as below:

$$\log Q = -2.96 + 0.417 \log LAB + 1.436 \log LAN + 0.269 \log CAP \quad \ldots(2)$$

(-2.016)* (3.244)*** (5.079)*** (10.80)***

F: 388.41 R^2: 0.981 D.W.: 1.409

Notes: (1) Dependent variable is Q – Log of Gross Domestic Product. (2) Figures in the bracket indicate t-values, three stars, two stars and one star represent that parameters are significant at 1, 5 and 10 per cent respectively.

The model seems to be fitting the data very well and without the restrictions of constant returns to scale, the output elasticity of Land was found to be higher, thus suggesting its significant contribution to agricultural output. The same model has been estimated subjecting it to CRS and is presented below:

$$\log Q = 2.888 + 0.275 \log LAB + 0.396 \log LAN + 0.329 \log CAP \quad \ldots(3)$$

(118.3)*** (1.737)* (2.846)*** (12.88)***

F: 15.87 $R^2 = 0.684$ D.W.: 1.50

Notes: (1) Dependent variable is Q – Log of Gross Domestic Product. (2) Figures in the bracket indicate t-values, three stars, two stars and one star represent parameters that are significant at 1, 5 and 10 per cent respectively.

Equation (2) shows the estimates of production elasticities for labour, land and capital without CRS while Equation (3) is for estimates with CRS. From the standpoint of data fitting the model and inferential statistics, estimated models turn out to be excellent. Although, R^2 is less for Eq. (3) compared to that of Eq. (2), all estimated coefficients are statistically efficient. It is important to note that these estimates are specifically meant to be used for aggregation of inputs rather than making any generalisations. The output growth, production pattern and growth dynamics are far deeper issues from the point of view of econometric analysis than what one would detect from simple production elasticity estimates. As far as this paper is concerned, our objective is achieved by producing statistically efficient estimates from Cobb-Douglas production function and using them for the purpose of weighting to calculate Total Input Index (TII).

The calculated Total Output Index (TOI), TII and TFPI without and with CRS, are presented in Table 2 below:

TABLE 2. TOI, TII AND TFP INDEXES WITHOUT AND WITH CRS

Year (1)	TOI (2)	TII (3)	TFPI (4)	TIICRS (5)	TFPICRS (7)
1991-92	59.57	63.95	93.14	46.99	126.77
1992-93	63.53	68.74	92.41	53.47	118.80
1993-94	65.64	68.12	96.36	51.71	126.94
1994-95	68.73	68.17	100.83	51.13	134.42
1995-96	68.26	68.60	99.50	51.75	131.89
1996-97	75.03	70.63	106.23	54.31	138.15
1997-98	73.11	72.37	101.03	56.80	128.71
1998-99	77.73	73.27	106.09	57.59	134.97
1999-00	79.81	81.94	97.40	72.59	109.95
2000-01	79.80	78.69	101.41	68.15	117.10
2001-02	84.59	85.26	99.22	78.37	107.95
2002-03	79.01	82.07	96.27	76.52	103.25
2003-04	86.16	85.23	101.09	76.97	111.94
2004-05	86.31	87.92	98.17	80.58	107.11
2005-06	90.75	92.26	98.37	87.49	103.72
2006-07	94.52	94.13	100.41	90.88	104.01
2007-08	100.00	100.00	100.00	100.00	100.00
2008-09	100.09	108.38	92.36	114.03	87.78
2009-10	100.90	109.21	92.40	117.32	86.00
2010-11	109.58	111.49	98.29	118.28	92.64
2011-12	115.07	121.53	94.69	134.95	85.27
2012-13	116.70	116.81	99.91	127.22	91.74
2013-14	122.21	123.17	99.22	136.30	89.66
2014-15	118.00	117.81	100.16	128.36	91.92
2015-16	118.97	119.26	99.75	130.63	91.08
2016-17	119.72	120.08	99.70	131.76	90.86

Source: Authors' estimation.

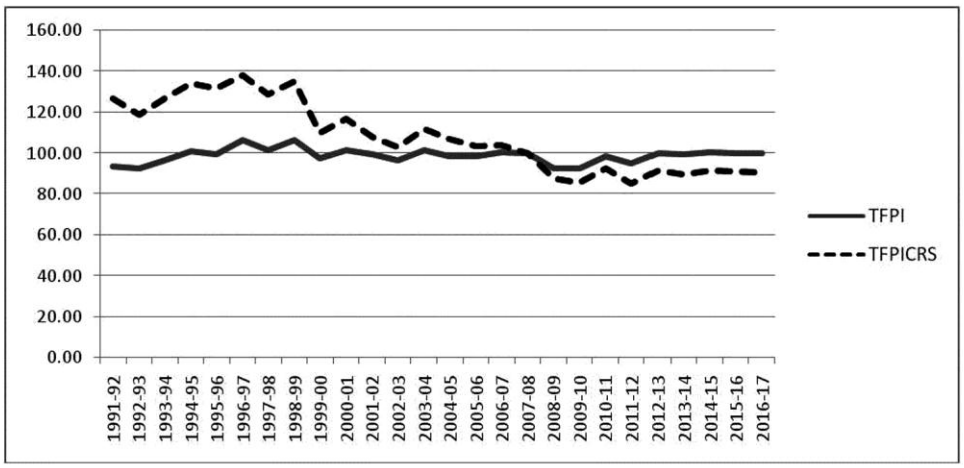
Notes: (1) TOI - Total output index, (2) TII - Total input index without CRS, (3) TFPI – Total factor productivity index without CRS, (4) TIICRS - Total input index with CRS, (5) TFPICRS - Total factor productivity index with CRS.

The estimated measure of TFP index with CRS shows that residual total productivity is falling throughout the sample period. Purely on empirical grounds, estimation is also made by relaxing the CRS assumption to suit the context and data properly. It is also interesting to note that restricting the relationship of inputs with agricultural output to constant returns to scale has behavioural implications for TFP in terms of its movement, growth, volatility and existence of a conclusive linear trend in the series. The estimates of TFP without CRS clearly indicate that there is no secular pattern observed and on the contrary is randomly fluctuating while clearly having no indication of non-stationarity.[9]

VII

DETERMINANTS OF TFP

The relationship between TFP and the variations in the underlying determinants of the same undergo considerable change in the final estimation of the model for analysing the sources of TFP depending upon the assumption that we have made



Notes: (1) TFPI - Total factor productivity index without CRS, (2) TFPICRS - Total factor productivity index with CRS.

Figure 1. Time Series Plot of TFP Indexes without and with CRS.

regarding the nature of the production function. This study attempts to estimate the determinants of TFP for both the assumptions of the Cobb-Douglas production function while analysing the implications of estimating TFP in the presence of disguised unemployment, wide heterogeneity that exists in agricultural production and local variations in agro-climatic conditions.

The estimated residual factor productivity can throw good amount of light on the extent to which the changes in output have been induced by technological, socio-economic, institutional and policy-related factors that bring out the multi-dimensional nature of TFP. Available literature reveals a large number of possible determinants of TFP. A very cautious and deliberate attempt has been made to properly identify the underlying aggregate determinants of TFP while considering the inherent dynamics of Indian agricultural production and productivity across time and regions. The selection of variables for analysis is partly guided by the availability of data and its continuity. Without getting much into data mining, the theoretical determinants of TFP in the Indian context can be stated as:

$$\log TFPI = \alpha + \beta_1 GPIN + \beta_2 \log RNST_{t-1} + \beta_3 \log RLIT + \beta_4 \log FERT/GIA + \beta_5 D_1 + \beta_6 \log TFPI_{t-1} + \varepsilon \quad \ldots.(4)$$

where; $\log TFPI$ = log of TFP Index, GPIN = change in annual growth rate in Public Investment, $\log RNST_{t-1}$ = log of lagged value of Rainfall Instability, logRLIT = log of Rural Literacy rate, logFERT/GIA = log of Ratio of Fertiliser Consumption to Gross Irrigated Area, D_1 = Dummy variable for weather and $\log TFPI_{t-1}$ = log of lagged value of TFP Index and ε = error term.

We strongly expect that the variation in rainfall and agro-climatic conditions play a critical role and therefore instability measure for rainfall is calculated by using coefficient of variation of monthly rainfall for each year and a dummy has been utilised to capture adverse years where the drought and, bad and unfavourable production conditions are considered. It is also expected that rural literacy, which could have exposed farmers on skill-based training for proper utilisation of resources and adopting new information for cultivation process, should have a strong positive impact on productivity. Private investment, which plays a complimentary role to public investment, may also have enhanced TFP along with gross irrigated area and distribution of fertiliser consumption per unit of gross irrigated area. Non-availability of data on certain variables for some specific period imposed several constraints and continuous time series is prepared by adjusting the data for wherever gaps were found by using moving average and interpolation techniques. Accordingly, the following model has been estimated in double-logarithmic form:

$$\begin{aligned} \log TFPI = & -0.53 + 0.026\, GPIN - 1.334\, \log RINST_{t-1} + 0.24\, \log RLIT \\ & (1.78)^{*} \quad (3.76)^{**} \quad (2.73)^{**} \quad (5.44)^{***} \\ & -0.021\, \log FERT/GIA + 0.084\, D_1 + 0.07\, \log TFPI_{t-1} \qquad \ldots(5) \\ & (2.67)^{*} \quad (1.18)^{\#} \quad (3.032)^{***} \\ & F: 5.80 \quad R^2: 0.657 \quad D.W.: 1.85 \end{aligned}$$

Notes: (1) Dependent variable is TFPI – TFP Index. (2) Figures in the parentheses indicate t-values and ***, **, and * represent that the estimated parameters are significant at 1, 5 and 10 per cent respectively. (3) # signifies 13 per cent of level of significance. (4) All the variables are expressed in logarithmic form.

It is important to note that the model is specified in a dynamic framework by taking partial equilibrium adjustment in the dependent variable. Though we have not deliberately and strictly followed data mining process, this model is an outcome of experiment with various specifications for cleanly and clearly capturing the underlying theoretical specification. Plausibly moderate goodness of fit of the estimated model along with significant F statistic imply that the variation in TFP is articulated reasonably by the variables included in the model for the sample period. The probability of significance seems to be very high for dummy variable and other variables such as public investment, rural literacy, ratio of fertiliser consumption to gross irrigated area, rainfall instability and lagged value of the dependent variable seem to be predominantly explaining TFP. The estimates suggest that some new idea has been unearthed on the data generating process pertaining to the sample period selected as compared to the previous estimates of several studies in terms of the sources of TFP. The positive impact of rural literacy suggests that the skill formation of farmers, training, etc. help produce more output with given inputs. Better trained and well-informed farmers are aware about latest farm management and production techniques. They are more conversant in using modern inputs and technology while properly availing the government support.

A serious effort was also made to estimate the sources and factors determining TFP with CRS by using various specifications and forms but the model has not come out good purely on the estimation ground. The estimated model reveals that only rainfall instability significantly explains the variation in TFP with CRS and other factors are not significant. Probably, assuming CRS is not in line with the underlying agricultural production process for empirical analysis and therefore the study has not reported the estimated equation.

VIII

LIMITATIONS AND CONCLUDING OBSERVATIONS

This study attempts to bring out different implications for both productivity measurement and factors determining productivity with broader limitations governed by not venturing deeper into the various alternative measurements of variables vis-a-vis non-availability of data which can be proxied. The room also remains for a comparative analysis of the behaviour of aggregate production function for Indian agriculture using varying functional forms. A disaggregated study on productivity, which has not been attempted in this paper, can throw alternative implications on policy perspectives which can be either complementary or overlapping to what has been investigated in the empirical analysis carried out in this study.

On summing up, this study attempted to provide a detailed but not exhaustive analysis of the nature, measurement and sources of TFP and analytically the issue is examined to provide an insight that is useful for policy framework with special reference to growth and development of agricultural sector. There are alternative methodologies such as Divisia-Tornquist Index, Stochastic Frontier approaches, etc. that are available for estimating TFP. Although the Divisia-Tornquist is popularly used in the Indian context as evident from many of the studies reviewed in this paper**,** here, an attempt is made to estimate TFP by using the Cobb-Douglas production function method as the study wanted to address the larger question of the very behaviour and determinants of TFP in the context of production function approach. Therefore, the use of other methodologies including that of the Divisia-Tornquist index has not been considered due to the scope and context of the present study and it is possible that the behaviour of TFP may vary depending on the manner in which it is estimated.

In terms of the determinants of movements in TFP, instability in rainfall and variation in agricultural work force play significant role in explaining the changes in productivity. One can critically look at the negative coefficient of fertiliser per GIA, though the size of the coefficient is very small, as imperative inter-dynamics that may play in fertiliser distribution, pricing policy and the end users of fertilisers. This simultaneity can be addressed in a large size econometric model while catering for a specific study on fertiliser consumption and pricing policy. The importance of rainfall instability draws a clear attention on the water-management system for agricultural use across states and preservation of rainwater to maintain the water table levels. Though there are policies in place in this direction, federal governments have not been able to match the rainfall variations to be compensated by stable ground water levels through appropriate ground water management policies. It is hoped that the long term implications of proper water management systems in general and policies that are adopted for ground water management in particular can be properly shaped through social infrastructure and agricultural investment and this will enhance productivity and long term stability of Indian agriculture.

Received December 2017. *Revision accepted November 2018.*

NOTES

1) Agriculture sector contributed more than 50 per cent to national income during initial planning periods. Off-late, its share in gross value added (GVA) at current prices has been 17.4 per cent (2016-17, provisional estimates, *Economic Survey 2017-18*). But as per the *Statistical Year Book of India 2017* the share of agricultural sector in aggregate employment is still above 50 per cent, thus providing considerable scope for inducing economic development through appropriate policy efforts.

2) The sources of data on all the variables that have been employed in this study are as follows: (i) the data on agricultural output as measured by gross domestic product in billions of rupees at constant prices with base year 2004-05 has been collected from the *Handbooks of Statistics* 2012-13 up to 2016-17 and also from *Agricultural Statistics at Glance* 2009 up to 2016; (ii) data on land as measured by gross cropped area in millions of hectares, labour as measured by agricultural workforce in terms of millions of workers, capital defined as gross capital formation in terms of millions of rupees at constant prices with base year 2004-05, public and private investments in billions of crores of rupees at constant market prices with base year 2004-05, consumption of fertilisers with units in lakhs of tonnes, consumption of pesticides with units in lakhs of tonnes, amount of fertiliser subsidies at current prices in crores of rupees and gross irrigated area measured in millions of hectares, have been collected from *Agricultural Statistics at Glance* 2007 up to 2016; (iii) information on rural literacy rate measured as percentage of rural population that is literate and some data on the amount of fertiliser subsidies at current prices in crores of rupees have been obtained from various *Economic Surveys* ranging from 1991-92 up to 2015-16; (iv) major data on the amount of fertiliser subsidies at current prices in crores of rupees has been obtained from the database and reports of The Fertiliser Association of India; lastly, (v) data on the levels of annual and normal rainfalls, measured in millimeters per year, has been collected from the web resource and database of the Indian Meteorological Department.

3) One of the key problems facing a researcher who wishes to employ methods other than growth accounting is primarily in terms of lack of suitable data for aggregation of inputs via factor-weights other than production elasticities and consistent and reliable information are difficult to obtain on aggregate-level factor prices, factor incomes and factor costs.

4) The correlation coefficient of output with respect to capital is 0.98, with respect to land is 0.79 and with respect to labour is 0.88.

5) Even though aggregate labour force in agriculture sector shows a small increase when compared to the growth in other inputs, it must be noted that good amount of debate has surrounded the issues such as the nature of agricultural employment, the growth of agro-labour force when compared to non-farm employment and the role of rural non-farm sector in accommodating the growing shift of workforce from farm-sector to non-farm sectors. Such considerations are presently outside the scope of this study.

6) Correlation between the departure of annual rainfall from its normal level and agro output was -0.38.

7) Micro irrigation, fertigation, drip irrigation, etc. are some of the policy initiatives in recent times.

8) Gross Capital Formation was used as a proxy for capital input in this study. Among the various reasons, insufficient information on the methodology for calculating depreciation by the concerned data collection authority, better availability of data, etc. primarily directed this choice.

9) The estimates for both TFP measures were analysed for non-stationarity and trend. TFP with CRS was found to be non-stationary while TFP without CRS was found to be stationary with no clear linear trend.

REFERENCES

Bhalla and Alagh (1983), "Labour Productivity in Indian Agriculture", *Economic and Political Weekly*, Vol. 18, No. 19/21 May.

Desai, B.M. and N.V. Namboodiri (1997), "Determinants of Total Factor Productivity in Indian Agriculture", *Economic and Political Weekly*, Vol.32, No.52, 27 December, pp.165-171.

Dev, M.S. (2012), *Policies for Raising Agricultural Growth and Productivity in India,* IGIDR Proceedings/Projects Series.

Dholakia, R.H. and B.H. Dholakia (1993), "Growth of Total Factor Productivity in Indian Agriculture", *Indian Economic Review*, Vol.28, No.1.

Kalirajan, K. and R. Shand (1997), "Sources of Output Growth in Indian Agriculture", *Indian Journal of Agricultural Economics,* Vol.52, No.4, October-December, pp.693-706.

Krishna, K.L., A.A. Erumban, D.K. Das, S. Aggarwal and P.C. Das (2017), "Industry Origins of Economic Growth and Structural Change in India", Delhi School of Economics, Working Paper No. 273, Centre for Development Economics.

Kannan, E. (2011), *Total Factor Productivity Growth and Its Determinants in Karnataka Agriculture*, ISEC Working Paper No. 265, Institute for Social and Economic Change, Bangalore.

Kumar, P. and S. Mittal (2006), "Agricultural Productivity Trends in India: Sustainability Issues", *Agricultural Economics Research Review*, Vol.19, pp.71-88.

Reddy, A.A. (2012), "Sources of Agricultural Productivity Growth in Orissa: A District Level Analysis", *The Journal of Income and Wealth*, Vol.34, No.2.

Rosegrant, M.W. and R.E. Evenson (1992), "Agricultural Productivity and Sources of Growth in South Asia", *American Journal of Agricultural Economics*, Vol.74, No.3, pp.757-761.

Rosegrant, M.W. and R.E. Evenson (1995), "Total Factor Productivity and Sources of Long Term Growth in Indian Agriculture", *Environment and Production Technology Division*, Discussion Paper No. 7, International Food Policy Research Institute.

Solow, R.M. (1957), "Technical Change and the Aggregate Production Function", *The Review of Economics and Statistics,* Vol.39, No.3, pp.312-320.

Tripathi, A. (2008, January), "Total Factor Productivity Growth in Indian Agriculture", *http://works.bepress.com/amarnath_tripathi/2 (Unpublished)*, India.