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Total Factor Productivity Growth in Indian Crop Sector

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ABSTRACT

Growth in agricultural productivity can be due to growth in intensive use of inputs or it may be technology driven. Many studies reported the recent growth on agricultural productivity especially after the year 2004-05. The key question is whether this growth in agricultural productivity will be sustainable? The paper attempts to answer this question based on analysis of total factor productivity growth of the crop sector based on country data during the last 31 years (1980-81 to 2011-12). Tornqvist index methodology has been used for estimation of TFP index for each year. Further, TFP growth has been analysed during four structural breaks. It is observed that annual TFP growth in recovery phase of agriculture, i.e., during 2004-05 to 2011-12 is as high as 5.41. An important contribution of the study is estimation of TFP indices at alternate price scenarios like market price, input price and with exclusion and inclusion of labour wage bill. Further, it is estimated that the contribution of TFP in output growth has been nearly 88 per cent at economic prices. Thus, the paper concludes that recent growth in agriculture is going to be sustainable.

Keywords: TFP, Tornqvist index, Agricultural productivity.

JEL: D24, E24, Q11, O15

I

INTRODUCTION

Agricultural intensification is most noticeable in India where population density is high because of land scarcity. The Central Statistics Office (CSO) estimated that the share of agriculture and allied sectors in gross domestic product (GDP) of the country has been declining from 52 per cent in 1950-51 to 14 per cent in 2013-14 at 2004-05 prices though it continues to be the main source of livelihood providing about 55 per cent of the total employment (Government of India, *Economic Survey 2013-14* based on 2011 Census). "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 (Saikia, 2014). Therefore, sustaining productivity growth in agriculture continues to be critical for achieving food security, poverty reduction, and broad-based economic growth (Tripathi and Prasad, 2008).

Measuring productivity is essential in order to account for economic growth. In

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simple terms, productivity is defined as the ratio of output to input (Coelli *et al*., 1998). The partial productivity measures like labour productivity and land productivity are of limited use in the presence of multiple outputs and multiple inputs as they do not indicate the overall productivity when considered in isolation. When the productivity concept is extended beyond single output and single input case, an alternative approach for aggregating output and inputs is used. TFP is ratio of aggregate output index to aggregate input index (Kannan, 2011). Total-factor productivity (TFP), also called multi-factor productivity, is a variable which accounts for effects in total output not caused by traditionally measured inputs of labour and capital. Thus, TFP can be taken as a measure of an economy's long-term technological change or technological dynamism. TFP growth indicates technical progress, which represents shifts in the production function over time. In the Indian context, technical progress measures the impact of shift in production technology on account of irrigation, high-yielding varieties (HYVs), modern agricultural equipment, fertilisers, pesticides, etc. It also captures the effect of improved labour quality, better management practice, and intensive use of resources which lead to increased crop intensity, change in cropping pattern in favour of high value-added crops, etc. Although, boosts in TFP growth can be due to good weather but the influence of short term effects on TFP growth can be moderately reduced by studying a longer period of time. TFP growth becomes an important indicator for quantifying the sustainability of a growth process if longer period of time is considered.

II

REVIEW OF LITERATURE

Based on importance of TFP estimates, many studies have been carried out in the past. These are commodity-specific, sector-specific, state-specific or time period specific. Even if they match on one of these aspects, they have used different sources of data. Surprisingly, estimates from these studies differ from each other. As per recent report of World Bank Group, 2014, both choice of data source, choice of starting and terminal years and the methodology used affect the TFP estimates (World Bank, 2014). Many studies pointed out that TFP estimates for the post 2003 period shows growth but this finding needs to be tested with additional years data to determine whether it is a recovery from the previous slow down.

A recent study by Chand *et al*. (2011), undertakes in depth analysis of contribution of technology and factors which contribute to growth in TFP. However, the study confines to growth of TFP of selected crops at country level and in major states using 1975-2005 data from CACP (Commission for Agricultural Costs and Prices, Ministry of Agriculture and Farmers Welfare, Government of India). Crop wise growth was estimated for two periods 1986-95, 1996-2005. The results of the study suggests that TFP growth increased in crops like maize, pearl millet, gram, green gram, soybean, groundnut, cotton, etc. in the latter period compared to the former one, but a deceleration was visible in crops like wheat, rice, rapeseed and mustard, jute, etc., and negative growth rates in others such as sorghum, barley, pigeon pea, black gram, sugarcane, etc. The authors reported that, it is not clear to what extent, the TFP growth in overall agriculture fared well in two periods. The basic reason for this is that the study does not include some important crops like horticulture and the aggregated crop sector.

Kannan (2011) has estimated the TFP growth using Tornqvist-Theil index of ten major crops in Karnataka using two outputs and nine inputs. The study reported that yield of the most crops in particular foodgrains has declined during the 1980-81 to 1989-90 leading to stagnation in production. However, during 1990-91 to 2007-08 there is reversal of growth in production and yield for some food and non-food crops. TFP has risen at 10.9 per cent per annum contributing about 58.67 per cent to the total output growth. The analysis of the determinants of TFP indicates that the government expenditures on research, education and extensions, canal irrigation, rainfall, and the balanced use of fertilisers are the important drivers of crop productivity in Karnataka.

Kumar *et al*. (2008) summarises the TFP growth and its contribution in production growth for South Asia over the past three decades. The study by Ananth *et al*., (2006) restricted data to eight major field crops in Karnataka state and highlighted that rate of return to agricultural research shows high rate of return in case of rice and sugarcane, moderate for finger millet, cotton and sorghum, negative in red gram, ground nut and sunflower. Thus the authors concluded that TFP was higher in the crops which attracted higher research investment.

Kumar and Jha (2005) presented a more disaggregated perspective on changes in TFP across states in India and also examined how changes in TFP will affect the possibility of generating an exportable surplus of rice. Rao (2005) estimated average annual index of TFP for crop sector as a whole during the post-reform period and found it 5 per cent less than that of pre-reform period in Andhra Pradesh. For non-foodgrains, it has been found 9 per cent less than in the pre-reform period. In the case of foodgrains, TFP index has been observed to be less than 100 during both the periods. The contribution of TFP to yield growth has been computed as 31 per cent in the pre-reform period in the crop sector of the state. An absolute decline (-37) has been noted during the post-reform period in the crop sector of the state. The study hinted that absolute decline in TFP seems to be the main reason for the distress of farmers in the state.

Ranjitha and Mruthyunjaya (2005) assessed the contribution of agricultural research in India to increase in productivity during 1964 to 1994 using TFP decomposition method. The study also estimated the contribution of various factors like research, extension, infrastructure, human capital and weather to TFP growth and concluded that an investment of one rupee in agricultural research will yield a return of Rs. 10.43 over a 17-year period. The marginal rate of return was computed to be 53 per cent.

Avila and Evenson (2010) have utilised FAO published data on crop land, pasture land, human labour, fertilisers, seeds, tractors and combine harvesters and animal stocks for measuring the changes in TFP for crop production, livestock production and aggregate agricultural production in India for two periods i.e. 1961-1980 and 1980-2001. But due to limitation of data on factor shares TFP growth (between 1.5 and 3.0) was on a higher side. These studies have focussed largely on the estimation of effect of technological change on agriculture as a whole or total crop production. Due to non-availability of input allocation data for individual crops, they may over or under estimate the TFP for crop sector.

Birthal *et al.,* (1999) have analysed the trend in TFP growth for the livestock sector in India and estimated TFP growth of 0.8 per cent during 1951-96. Evenson *et al*., (1999) have analysed the trends and sources of TFP growth in the crop sector of India. TFP annual growth estimated as 1.1-1.4 per cent since 1956, have contributed about half of the output growth.

There are very few estimates available of TFP changes at state-level. A notable study in this regard is Fan *et al*. (1998) at state-level using Tornqvist-Theil index for the period 1970-1994. The study finds that total factor productivity for India grew at an average annual rate of 0.69 per cent between 1970 and 1995. In the 1970s, total factor productivity improved rapidly, growing at 1.44 per cent per annum, grew faster in the 1980s at 1.99 per cent per annum. But since 1990, total factor productivity growth in Indian agriculture has declined to 0.59 per cent per annum. The study also reports state-level estimates for the whole period 1970 to 1994, the states with TFP growth rate in the range 0-1 per cent per annum are Andhra Pradesh, Karnataka, Uttar Pradesh, Himachal Pradesh and Kerala; with TFP growth rate greater than 1 are Punjab, Bihar, Orissa, Maharashtra, West Bengal and J&K. The states with negative TFP growth are Haryana, Madhya Pradesh, Gujarat, Assam and Rajasthan.

Kumar and Rosegrant (1994) estimated TFP growth for rice and found that the TFP index has risen by around 1.85 per cent annually in the southern region, 0.76 per cent in the northern and 0.36 per cent in the eastern region. In the western region, due to wide fluctuations in weather wide variation in the TFP index was observed and the estimated annual growth was negative (-0.98), but insignificant.

The present study estimates an annual output index, input index and TFP index for the agriculture sector excluding allied activities. Instead of computing TFP at different points of time, the study estimated TFP on annual basis and analysed the TFP trends during last thirty one years. The specific objectives of the study are to find out the movements of the index of TFP in the crop sector, to measure the contribution of the TFP in the output index growth during the period 1980-81 to 2011-12. The study analyses whether the recent growth in agriculture sector is capital driven or technology driven. The study is different from other studies in many aspects like (i) use of all inputs including labour cost and man-days (ii) data of subsidy on agricultural inputs (iii) comprehensive inclusion of all crops including horticulture and (iv) estimates of TFP growth based on annual TFP estimates rather than terminal years.

III

DATA AND METHODOLOGY

The present study is based on the secondary data during the period 1980 to 2012. Different inputs like seed, fertilisers, manure, pesticides, electricity consumption, human labour, animal labour, number of tractors, diesel consumption, public expenditure on irrigation and subsidy are considered for computing input index for each year. Values of most inputs were collected from *National Accounts Statistics* (NAS) except fertilisers, seeds, bullock labour and human labour. Value of fertilisers was estimated by taking individual prices and quantity of N, P, and K from *Fertiliser Statistics*. Further, value of bullock and human labour were estimated from CACP and *Agricultural Wages in India* respectively. Seed quantity data has been estimated by aggregating crop wise seed quantity requirement for each state where the crop has been grown and the data is available in CACP report of the corresponding year. 'Weighted average of seed quantity' so obtained was used for estimating the country seed quantity based on the area under the crop in the country. Total quantity of seeds for the country has been estimated by adding quantity of all the crops.

Data regarding annual quantity of manure was estimated from input survey data. Input survey is done after every 5 years, so in-between values were interpolated. Input survey data was not available after 2006-07 so the quantity was estimated based on previous growth. Pesticide quantity data was made available by Directorate of Plant Protection, Quarantine and Storage, Ministry of Agriculture, DAC on request. Electricity consumption in agriculture has been taken from *Agricultural Statistics at a Glance* from 1980-81 to 2011-2012. Electricity consumption has been used as a proxy for motor based irrigation. Human labour is an important input for agriculture. Man-days in agriculture were used as a quantity of human labour which was estimated in a separate study done based on NSSO survey reports. Bullock numbers (male cattle aged 2.5 year or more from rural area) were taken from various Livestock Census available for the period under study and missing data were interpolated. Number of tractors in agriculture has been collected from Livestock Census and missing data is interpolated. Expenditure on repair and maintenance on agricultural machinery have been compiled from *National Accounts Statistics* (NAS). Diesel is used as a fuel for agricultural machinery. Diesel value is collected from NAS. Quantity of diesel consumed has been estimated from the total value of diesel divided by average current diesel prices per litre. Subsidy which is provided by government to agricultural sector and irrigation expenditure by government on canals is also included as input to estimate TFP at economic prices.

In output side, production data of cereals, pulses, oilseeds, fibres, sugarcane, 'drugs and narcotics', 'condiments and spices' and rubber were collected from DES

(The Directorate of Economics and Statistics (DES), Department of Agriculture, Cooperation and Farmers Welfare, Government of India). Production data of fruits and vegetables were collected from FAOSTAT (Food and Agriculture Organization of the United Nations website). Value of all above said crops is taken from National Account Statistics. Data regarding other and miscellaneous crops, kitchen-garden, other sugarcane, indigo and dye, other drugs narcotics, other condiments and spices and by-product values were taken from National Accounts Statistics and their constant price values are used in place of quantity for estimating output index.

There are three main approaches for estimating TFP, namely the production function approach, Growth accounting approach and the non-parametric approach. The production function approach models the state of technology by including a time trend in production or cost functions and partial differentiation with respect to time to get estimates of technological changes. In this approach, TFP growth indicates technical progress. However, different economists pointed out that there are various problems associated with the production function approach like multi-collinearity, auto correlation and degrees of freedom (Trivedi *et al*., 2000).

Solow (1957) was the first to propose a growth accounting framework and then Denison (1962) refined the approach. In this approach TFP is measured as a residual factor, which attributed to that part of the growth in output that is not accounted for by the growth in basic factor inputs. This approach approximates the technological change by the computation of factor productivity indices. Basically there are three main indices used in the growth accounting framework: (i) Kendrick Index (KI), (ii) Solow Index (SI), and (iii) Translog Index (TLI). Kendrick index and Solow Index suffer from some limitation. But 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 (Saikia, 2014). It is based on Translog Production function characterised by constant returns to scale. It allows for variable elasticity of substitution and does not require any assumption of Hicksian-neutrality.

The most recent approach is the non-parametric approach which identifies a group of implied linear inequalities that profit maximising firm must satisfy and estimate 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 piecewise linear production frontier for each year over the data points. This approach can be used when we have sufficiently enough units to construct the frontier (Coelli and Rao, 2005).

All the three approaches have their respective advantages and disadvantages. However, the growth accounting approach is the most popular one in the empirical research because it is easy to calculate, requires no econometric estimation and data requirement is minimal. Growth accounting approach based on Tornqvist Index is used in this study and discussed further.

Tornqvist index of TFP is the most popular method for computing aggregate output index and aggregate input index (Coelli *et al*., 1998). The Tornqvist index is a weighted geometric average of relative price, with weights given by the simple average of the value share in time periods. Let there be m outputs and n inputs for the agricultural sector. Q_{jt} and V_{jt} are the quantity and value of j-th product in t-th year. X_{it} and C_{it} are the quantity and total value of i-th input in t-th year. Let R_{jt} be the share of value of the j-th product in t-th year in relation to the total value of the products in t-th year. Similarly, let S_{jt} be the share of value of the j-th input in t-th year in relation to the total value of the inputs in t-th year. Tornqvist Index formula computes total output index and total input index using the equation (1) to (4) given below.

$$TOI_t = \prod_{j=1}^{m} \left(\frac{Q_{jt}}{Q_{jt-1}}\right)^{\frac{1}{2}(R_{jt}+R_{jt-1})} \qquad ....(1)$$

$$TII_t = \prod_{i=1}^{n} \left(\frac{X_{it}}{X_{it-1}}\right)^{\frac{1}{2}(S_{it}+S_{it-1})} \qquad ....(2)$$

$$R_{jt} = \frac{V_{jt}}{\sum_{j=1}^{m} V_{jt}} \qquad ....(3)$$

$$S_{it} = \frac{C_{it}}{\sum_{i=1}^{n} C_{it}} \qquad ....(4)$$

For the productivity measurement over a long period of time output, input and TFP indices are computed on the basis of chain index (Coelli *et al*., 1998). With chain-linking, an index is calculated for two successive periods t and t-1 over the whole period t varying from 0 to T, (sample from t=0 to t=T) and the separate indexes are then multiplied together. Equation (5) to equation (7) provide the index of total output (TOIt*), total input (TIIt*) and TFPIt Index, respectively for year ‘t’.

TOIt* (t) = TOI (1). TOI (2)………………TOI (t-1) ...(5)

TIIt* (t) = TII (1). TII (2)………………TII (t-1) ....(6)

TFPIt (t)=TOIt* / TIIt* ....(7)

For analysis of the TFP index during various years, many approaches are prevalent. Some studies use compound annual growth rates computed for two points of time for interpretation of TFP index. The limitation of CAGR is that the results are highly dependent on terminal years ignoring the intermediate data. To overcome this limitation, trend growth rates are preferred when data is available for all the years during the period of study. This study uses trend growth rates to analyse temporal changes in TFP.

TII and TFP have been computed separately at market price, economic price and also excluding the cost of labour for both the prices to understand the effect of subsidy and cost of labour on TFP estimates.

To estimate TFP growth rates, it is necessary to consider large time periods. Therefore the study uses 31 years of data. We attempt an analysis based on moving decadal average annual growth rates to capture the effects of major changes in technologies and policies on the agriculture sector and understand the broad trends in growth.TFP trends were analysed of the years 1980-81 to 1988-89, 1988-89 to 1995-96, 1995-96 to 2004-05, and 2004-05 to 2011-12.

IV

RESULTS AND DISCUSSION

Chand and Shinoj (2012) identified six phases of growth based on GDP agriculture series from 1960-61 to 2010-2011. Using the identified phases of Chand and Shinoj and the data series available for the present study, we attempted the analysis of data in 4 phases: (i) Phase I: Period of wider technology dissemination 1980-81 to 1988-89 (WTD), (ii) Phase II: Period of diversification (DIV)-1988-89 to 1995-96, (iii) Phase III: Post-reform period (PR)-1995-96 to 2004-05 and (iv) Phase IV: Period of recovery (REC)- 2004-05 to 2010-11. We aim to analyse whether the recent growth in agriculture in recovery phase is technology-driven or input-driven.

Input Trends

It is important to understand the input patterns for any study on TFP. Table 1 presents the share of different inputs in agriculture at different points of time mainly in the beginning of each phase. Shares of each input in the table are presented at different prices. It is observed that share of labour plays a dominant role among all inputs at market price as well as at economic price. It varies from 53 to 66 per cent at economic price and 56-78 per cent at market price. During the year 2004-05 labour share shows declining trend due to (i) implementation of MGNREGS, (ii) spread of education and more employment opportunities in service sector and (iii) increased use of machinery. Continuous rising share of machinery in agriculture sector with annual growth rotating around 7.14 per cent, has resulted in decreasing share of bullock labour from 18 per cent to 3 per cent. It is observed that share of inputs like seeds, fertilisers, manures and pesticides have been declining since 1980-81. It is worth mentioning that decline in shares of seeds and fertilisers are not due to decrease in the corresponding physical use as growth in quantities of seeds and fertilisers has been positive during these years (Table 2). The decreasing share of seeds and fertiliser is due to increasing value of other inputs like imported diesel, machinery cost and subsidies. Decline in share of manure is due to negative growth in quantity use of manure which is further compensated by chemical fertiliser quantity

TABLE 1. SHARE OF DIFFERENT INPUTS IN TOTAL AGRICULTURAL INPUT AT DIFFERENT POINTS OF TIME

(*per cent*)

(1)	Sseeds (2)	SN (3)	SP (4)	SK (5)	Smanure (6)	Spesticide (7)	SElectricity consumption (8)	Sagworker (9)	Sbullock labour (10)	STractor (11)	Sdiesel (12)	SIrrigation (13)	SSubsidies (14)
Shares in per cent at economic prices													
1980-81	6.4	6.1	2.3	0.4	2.5	0.5	1.0	53.0	17.2	0.6	0.8	2.7	6.5
1988-89	5.0	5.0	2.2	0.3	2.7	0.5	1.0	58.5	11.6	0.7	0.8	4.0	7.7
1995-96	4.2	3.6	2.5	0.4	2.4	0.4	1.0	66.2	5.8	0.8	0.9	3.6	8.3
2004-05	3.2	3.1	2.5	0.4	2.4	0.2	1.5	61.0	6.9	0.8	2.6	3.5	12.0
2011-12	2.6	1.9	1.5	0.4	1.8	0.2	0.8	66.0	2.7	0.7	2.5	3.5	15.4
Shares in per cent at economic prices excluding labour cost													
1980-81	13.7	13.1	4.9	0.9	5.4	1.1	2.1	–	36.5	1.2	1.6	5.7	13.7
1988–89	12.1	12.0	5.2	0.8	6.5	1.2	2.3	–	28.1	1.7	1.9	9.7	18.6
1995-96	12.4	10.7	7.4	1.1	7.1	1.1	2.9	–	17.1	2.3	2.7	10.6	24.5
2004-05	8.1	7.9	6.4	0.9	6.2	0.6	3.9	–	17.6	2.1	6.7	9.0	30.7
2011-12	7.6	5.5	4.4	1.1	5.4	0.5	2.4	–	8.0	2.2	7.4	10.1	45.4
Shares in per cent at market prices													
1980-81	6.9	6.6	2.5	0.5	2.7	0.5	1.1	56.7	18.3	0.6	0.8	2.9	–
1988-89	5.4	5.4	2.3	0.3	2.9	0.6	1.1	63.4	12.6	0.8	0.9	4.4	–
1995-96	4.6	4.0	2.7	0.4	2.6	0.4	1.1	72.2	6.3	0.8	1.0	3.9	–
2004-05	3.6	3.5	2.8	0.4	2.8	0.3	1.7	69.3	7.8	0.9	3.0	4.0	–
2011-12	3.1	2.2	1.8	0.4	2.2	0.2	1.0	78.0	3.2	0.9	3.0	4.1	–
Shares in per cent at market prices excluding labour cost													
1980-81	15.8	15.1	5.7	1.1	6.3	1.2	2.5	–	42.4	1.4	1.9	6.7	–
1988-89	14.8	14.7	6.4	0.9	8.0	1.5	2.9	–	34.5	2.1	2.4	11.9	–
1995-96	16.4	14.2	9.8	1.5	9.5	1.4	3.9	–	22.7	3.0	3.6	14.1	–
2004-05	11.6	11.4	9.2	1.4	9.0	0.9	5.6	–	25.4	3.0	9.7	13.0	–
2011-12	13.9	10.1	8.0	2.0	9.9	0.9	4.3	–	14.7	4.0	13.6	18.6	–

Notes: '–' is not applicable, the prefix 'S' denotes 'share of'.

growth (Table 2). Declining share of pesticide is due to decrease in quantity of pesticide (Table 2) which may be further due to prevalence of improved seeds like BT-cotton which reduced the requirement of pesticides. The value share of electricity and irrigation at market price have been stagnant and rotating at around 1 per cent and 0.4 per cent respectively in spite of increase in electricity consumption with annual growth of more than 7 per cent during the period 1980-2012 (Table 1 and Table 2). The stagnancy in value share of electricity and irrigation charges at market price is explained by increasing subsidies from 6.46 per cent to 15.4 per cent (Table 2).

TABLE 2. ANNUAL GROWTH OF PHYSICAL INPUTS AND CORRESPONDING VALUE SHARE IN INDIAN AGRICULTURE

	Growth of physical inputs quantities (Q)				Annual growth in Q	Annual growth in per cent value share
	1980-81 to 1988-89 Phase I	1988-89 to 1995-96 Phase II	1995-96 to 2004-05 Phase III	2004-05 to 2011-12 Phase IV	1980-81 to 2011-12 All	1980-81 to 2011-12 All
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Seeds	- 0.66	2.22	1.45	- 1.04	1.66	- 3.41
N	7.64	4.52	1.11	5.46	4.50	- 3.64
P	9.84	- 0.50	4.13	8.59	5.38	- 0.79
K	5.65	- 1.43	6.03	6.13	5.17	- 0.61
Manure	3.41	- 0.77	- 2.33	- 8.82	- 1.89	- 0.99
Pesticide	2.99	- 3.28	- 3.84	4.28	- 1.61	- 4.53
Electricity consumption	13.75	12.07	- 0.26	7.13	6.97	- 0.45
Agworker	0.09	4.15	0.18	- 2.17	0.82	0.62
Bullock labour	- 0.40	- 0.29	- 2.30	- 3.70	- 1.39	- 4.63
Tractor	8.55	7.94	6.17	5.78	7.14	0.53
Diesel	9.63	6.27	3.05	6.68	5.68	4.00
Irrigation*	9.14	1.98	3.61	4.80	4.89	0.06
Subsidy*	7.64	4.62	8.68	11.22	7.76	15.31

*Indicates growth at constant price of 2004-05.

Divergent growth of different inputs is observed during different phases (Table 2). It is observed that during the last 31 years all physical inputs have followed positive annual growth except manure, pesticide and bullock labour. During first phase period of wider technology dissemination, all inputs showed positive growth except seeds and bullock labour. During Phase II, i.e., period of diversification, annual growth of consumption of seeds increased to 2.22 but manure, pesticide, fertilisers P and K showed negative growth rate. In Phase III, i.e., post-reform period, all technological inputs showed positive growth. Negative growth is observed for inputs like bullock labour, manure, pesticides and electricity consumption. During Phase IV, consumption of seeds has shown negative annual growth due to lesser seed rate for BT varieties. Negative annual growth of human labour in this phase is due to diversion of labour to MGNREGS. In terms of growth in value share (at market price), there has been negative growth of value share of most of the inputs except human wage bill, tractors and irrigation expenses. Negative growth in value share is due to increasing share of subsidy for fertilisers and electricity; decrease of physical use of seeds, manure and bullock labour.

In order to understand the trends of all inputs together, Total Input Index (TII) is estimated using Tornqvist Index. Table 3 presents annual growth of TII during the four phases as well as overall period of 31 years. Trends are based on TII at economic prices (TIIEP), TII at economic prices excluding labour cost (TIIEP-L), TII at market prices subsidised cost (TIIMP), TII at market prices excluding labour (TIIMP-L). It is observed that during the recovery phase (phase IV), overall input growth has been minimum at economic prices (TIIEP) and market prices (TIIMP) but without labour cost both are maximum during phase IV. Thus, it is inferred that labour is an important input and annual growth of total inputs is affected by inclusion and exclusion of this factor in estimation of TFP. Very less or negative growth of TIIEP and TIIMP during this phase suggests higher TFP values during the phase IV and also hints towards sustainability as the growth is not input driven.

TABLE 3. ANNUAL GROWTH OF TOTAL INPUT INDEX AT DIFFERENT FACTOR COSTS DURING DIFFERENT PHASES

Periods (1)	TIIEP (2)	TIIEP-L (3)	TIIMP (4)	TIIMP-L (5)
1980-81 to 1988-89	1.93	4.10	1.43	3.42
1988-89 to 1995-96	3.37	2.14	3.27	1.53
1995-96 to 2004-05	1.14	3.10	0.39	1.05
2004-05 to 2009-10	0.48	5.07	- 1.19	1.72
2004-05 to 2011-12	1.87	3.64	1.22	2.13

Output Trends

Table 4 presents the growth of physical output of different commodity groups. All crop groups have shown the positive growth of physical output during the last 31 years as shown in the last column of Table 4. It is observed that in phase IV (i.e., recovery phase) annual growth in physical output has improved in cereals, pulses, oilseeds, sugarcane, fibre crops, drugs and narcotics, horticulture and by products. Further it is observed that different crop groups show divergent growth rates.

Total Output Index (TOI) is estimated and the growth rates of different phases are estimated (Table 5). It is observed that annual growth of TOI in phase IV is 4.15 as compared to Phase III 1.86 which is lowest in the four phases of the Indian agriculture in last 31 years.

TFP Trends

Table 6 presents Total input index (TII), Total output index (TOI), and TFP index for the country over a period of 1980-81 to 2011-12. The TII trend is similar at market price as well as economic price. Further, TII is more than 1 for the entire

TABLE 4. ANNUAL GROWTH RATES OF PHYSICAL QUANTITIES OF DIFFERENT COMMODITIES GROUPS DURING FOUR PHASES

Commodities (1)	1980-81 to 1988-89 (2)	1988-89 to 1995-96 (3)	1995-96 to 2004-05 (4)	2004-05 to 2011-12 (5)	1980-81 to 2011-12 (6)
Cereals	2.6	1.7	0.6	2.9	2.1
Pulses	1.5	- 0.6	- 0.2	4.1	0.9
Oilseeds	4.8	3.8	- 0.8	2.4	3.3
Sugarcane	2.0	3.7	- 1.5	3.4	2.2
Other sugar	- 3.2	- 6.4	45.8	5.1	11.9
Fiber	0.0	2.3	0.5	7.3	2.9
Indigo dye	7.0	2.6	17.2	- 20.6	6.0
Drugs narcotics	0.9	1.4	0.6	3.6	1.8
Other drugs	5.9	7.3	16.4	9.6	12.6
Condiments spices	4.0	3.3	4.1	0.8	3.6
Other condiments	5.4	2.8	4.8	10.1	3.4
Fruits vegetables	3.1	3.8	3.0	7.2	3.7
Rubber	7.1	9.4	4.5	1.5	6.6
Guar and miscellaneous	- 1.8	0.5	8.4	1.2	2.8
By products	0.0	- 1.2	- 0.1	1.9	0.9
Kitchen garden	1.1	-0.4	1.3	- 0.4	0.2

TABLE 5. ANNUAL GROWTH RATES OF TOTAL OUTPUT INDEX DURING DIFFERENT PHASES

Phases (1)	TOI (2)
1980-81 to 1988-89	2.39
1988-89 to 1995-96	2.10
1995-96 to 2004-05	1.86
2004-05 to 2009-10	3.75
2004-05 to 2011-12	4.15
1980-81 to 2011-12	2.78

period of the study during 1980-81 to 2011-12 at market price as well as economic price. TII indicates there has been continuous increase in inputs with reference to the base year 1980-81.The value of TOI is observed to be greater than 1 which indicates improvement in total output with reference to base year. TOI value of 1 will indicate stagnant agricultural production with reference to the year 1980 as the base year.

TFP index shows varying trends at different costs of factor inputs. Many past studies have reported different TFP values during the same time period. This is due to the different input factors considered for the TFP computation. The estimated TFP at market price (TFPMP) is greater than or equal to 1 throughout the period of study except the year 1982-83 (Table 6). TFPMP during the year 2011-12 is estimated at 1.84 with reference to the base year 1980-81. On the other hand TFP at economic price (TFPEP) is fluctuating between greater than 1 and less than 1 till 1988-89. After that, TFPEP is fluctuating in alternate years but has been observed as greater than 1. TFPEP during the year 2011-12 is estimated at 1.51 with reference to the base year 1980-81. If labour is excluded for estimating TFP, TFPMP-L estimates are less than 1 in 12 years out of 31 years data. On the contrary, TFPEP-L estimates are less than 1 in all years except 2 years namely 1981-82 and 1983-84. Based on shares of different inputs in total inputs value, it is inferred that labour is an important input for agriculture which has been stagnant in terms of quantity but its value share has been increasing due to increased wage rate. Thus it is envisaged that TFP estimates and the share of TFP in output and further analysis of TFP needs to be discussed including labour data.

TABLE 6. ANNUAL TOTAL OUTPUT INDEX, TOTAL INPUT INDEX AND TFP INDEX OF CROP SECTOR IN INDIA DURING 1980-81 TO 2011-12

	TFPEP			TFPEP-L		TFPMP		TFPMP-L	
Year	TOI	TII	TFP	TII	TFP	TII	TFP	TII	TFP
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1980-81	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1981-82	1.03	1.02	1.02	1.02	1.02	1.02	1.01	1.03	1.00
1982-83	1.01	1.04	0.98	1.04	0.97	1.04	0.98	1.05	0.97
1983-84	1.12	1.05	1.06	1.07	1.05	1.05	1.06	1.06	1.05
1984-85	1.11	1.13	0.98	1.25	0.88	1.10	1.00	1.21	0.92
1985-86	1.15	1.10	1.04	1.20	0.96	1.07	1.08	1.13	1.02
1986-87	1.10	1.12	0.98	1.25	0.87	1.08	1.01	1.19	0.92
1987-88	1.10	1.12	0.98	1.26	0.87	1.10	1.00	1.24	0.88
1988-89	1.30	1.18	1.10	1.38	0.94	1.14	1.13	1.33	0.97
1989-90	1.32	1.22	1.08	1.45	0.91	1.17	1.13	1.35	0.97
1990-91	1.36	1.23	1.10	1.44	0.95	1.20	1.14	1.38	0.99
1991-92	1.33	1.30	1.02	1.48	0.90	1.26	1.05	1.39	0.95
1992-93	1.42	1.38	1.03	1.51	0.94	1.33	1.07	1.40	1.02
1993-94	1.45	1.44	1.01	1.57	0.93	1.37	1.06	1.40	1.04
1994-95	1.48	1.45	1.02	1.56	0.95	1.40	1.06	1.45	1.02
1995-96	1.47	1.44	1.02	1.62	0.91	1.38	1.06	1.51	0.98
1996-97	1.60	1.47	1.09	1.68	0.95	1.40	1.14	1.51	1.06
1997-98	1.58	1.51	1.04	1.77	0.89	1.42	1.11	1.54	1.02
1998-99	1.67	1.52	1.10	1.91	0.87	1.42	1.17	1.68	0.99
1999-00	1.76	1.54	1.14	2.06	0.85	1.43	1.23	1.77	0.99
2000-01	1.70	1.53	1.11	2.08	0.82	1.39	1.22	1.71	1.00
2001-02	1.80	1.60	1.13	2.17	0.83	1.45	1.25	1.72	1.05
2002-03	1.59	1.59	1.00	2.20	0.72	1.42	1.12	1.73	0.92
2003-04	1.85	1.59	1.16	2.01	0.92	1.45	1.28	1.59	1.17
2004-05	1.79	1.59	1.12	2.10	0.85	1.44	1.24	1.64	1.09
2005-06	1.93	1.63	1.18	2.36	0.82	1.45	1.33	1.85	1.04
2006-07	2.00	1.66	1.21	2.46	0.81	1.47	1.36	1.88	1.06
2007-08	2.13	1.71	1.25	2.64	0.81	1.46	1.46	1.82	1.16
2008-09	2.17	1.82	1.19	3.29	0.66	1.42	1.52	1.84	1.17
2009-10	2.13	1.70	1.25	2.95	0.72	1.38	1.54	1.85	1.14
2010-11	2.35	1.66	1.42	2.89	0.82	1.36	1.72	1.92	1.22
2011-12	2.46	1.64	1.51	2.95	0.84	1.34	1.84	1.95	1.25

Notes: TFPEP: TFP at Economic Prices includes adjustment for subsidy; TFPMP: TFP at Market Prices, TFPMP-L: TFP excluding the labour cost, TFPEP-L: TFP at Economic Price after excluding the labour cost.

Table 7 presents the annual growth rate of TFP at different prices. It is observed that annual growth in TFPEP is less than TFPMP in all the phases during the study period. Overall during the entire study period annual growth in TFPMP and TFPEP is 1.55 and 0.89 respectively. Annual growth in TFP during the phase II (1989-89 to 1995-96) has been negative for TFPEP, TFPEP-L and TFPMP but positive for

TFPMP-L (0.56 per cent). The positive growth of TFPMP-L is due to its negative annual growth during phase I. However, annual growth in phase IV has been highest at 3.66 and 5.41 for TFPEP and TFPMP respectively. This higher annual growth coincides with higher GDP agriculture growth during the same period (Chand and Shinoj, 2012) giving indication of sustainability of agricultural production. When cost of labour is excluded then annual growth in TIIEP-L is higher as compared to TIIMP-L which results in negative annual growth of TFPEP-L.

TABLE 7. ANNUAL GROWTH RATE (PER CENT) OF TOI, TII AND TFP DURING DIFFERENT PHASES OF INDIAN AGRICULTURE AT ECONOMIC PRICE AND MARKET PRICE

Period (1)	TOI (2)	TII-EP (3)	TFP-EP (4)	TII-EP-L (5)	TFP-EP-L (6)	TII-MP (7)	TFP-MP (8)	TII-MP-L (9)	TFP-MP-L (10)
1980-81 to 1988-89	2.39	1.93	0.45	4.10	-1.64	1.43	0.95	3.42	-0.99
1988-89 to 1995-96	2.10	3.37	-1.24	2.14	-0.04	3.27	-1.14	1.53	0.56
1995-96 to 2004-05	1.86	1.14	0.71	3.10	-1.20	0.39	1.46	1.05	0.79
2004-05 to 2009-10	3.75	1.99	1.73	8.25	-4.16	-0.69	4.48	1.72	2.00
2004-05 to 2011-12	4.15	0.48	3.66	5.07	-0.87	-1.19	5.41	1.72	2.39
1980-81 to 2011-12	2.78	1.87	0.89	3.64	-0.83	1.22	1.55	2.13	0.64

Notes: TFPEP: TFP at Economic Prices includes adjustment for subsidy; TFPMP: TFP at Market Prices, TFPMP-L: TFP excluding the labour cost, TFPEP-L: TFP at Economic Price after excluding the labour cost.

Moving Decadal Analysis

Annual indices of TOI, TII and TFP exhibit frequent fluctuations due to weather shocks and rainfall pattern and thus make it difficult to understand the pattern of productivity. To overcome this, moving decadal average annual trend growth rates of TOI, TII and TFP are estimated (Table 8). An interesting observation is that the growth of TFPEP is 0.67 during 1980-81 to 1989-90, but it jumps to 0.94 during 1981-82 to 1990-91 (Table 8). Also negative growth of TFP has been observed in many cases. The negative contribution of TFP has not been reported much in the country. However a recent study by Rao, 2005 for Andhra Pradesh has shown negative TFP growth during post-reform period during 1990s. Further, more than one per cent TFP growth was recorded during the decade ending 2000-01, 2001-02, and 2006-07 continued up to 2011-12. Some observations made from the decadal analysis (Table 8) are as follows:

(1) Negative growth rates of TFP are observed when growth rate of TII is more than growth rates of TOI.
(2) Growth rates TFPMP and TFEP follow the same pattern however annual growth rate of TFPMP has always been higher than TFPEP (Figure 1).
(3) Average annual growth rates have been lowest (negative) in the decade ending 1997-98 for both TFPMP and TFPEP.
(4) Subsequently there was revival of TFP growth till decade ending 2001-02. This revival was faster at market price than economic price (Figure 1).

TABLE 8. MOVING DECADAL AVERAGE ANNUAL GROWTH RATES OF TOI, TII, TFP IN INDIA AT DIFFERENT PRICES

Decade ending (1)	TOI (2)	TII-EP (3)	TFP-EP (40	TII-EP-L (5)	TFP-EP-L (6)	TII-MP (7)	TFP-MP (8)	TII-MP-L (9)	TFPMP-L (10)
1990	2.74	2.06	0.67	4.23	-1.44	1.54	1.18	3.46	-0.69
1991	3.06	2.10	0.94	4.18	-1.07	1.62	1.42	3.47	-0.40
1992	3.10	2.29	0.79	3.94	-0.81	1.91	1.17	3.37	-0.26
1993	3.07	2.64	0.41	3.54	-0.45	2.37	0.68	3.03	0.04
1994	3.41	2.96	0.44	3.02	0.38	2.77	0.63	2.44	0.95
1995	3.47	3.45	0.02	3.11	0.35	3.29	0.17	2.55	0.90
1996	3.40	3.39	0.00	2.83	0.55	3.23	0.16	2.20	1.17
1997	3.15	3.24	-0.09	2.69	0.44	3.01	0.14	1.86	1.27
1998	2.37	2.88	-0.49	2.51	-0.13	2.64	-0.26	1.64	0.72
1999	2.59	2.53	0.07	2.95	-0.35	2.23	0.36	2.09	0.49
2000	2.89	2.19	0.68	3.73	-0.82	1.72	1.15	2.63	0.25
2001	2.87	1.59	1.26	4.10	-1.18	0.99	1.86	2.80	0.07
2002	2.73	1.37	1.35	4.42	-1.62	0.64	2.08	2.81	-0.07
2003	1.98	1.25	0.73	4.51	-2.42	0.41	1.57	2.61	-0.61
2004	2.10	1.21	0.88	3.83	-1.67	0.38	1.71	1.70	0.39
2005	1.86	1.14	0.71	3.10	-1.20	0.39	1.46	1.05	0.79
2006	1.75	1.02	0.72	2.91	-1.13	0.34	1.40	1.18	0.56
2007	2.08	0.99	1.08	2.73	-0.63	0.36	1.72	1.17	0.90
2008	2.38	1.15	1.22	2.82	-0.43	0.40	1.98	0.86	1.50
2009	2.79	1.54	1.24	4.20	-1.35	0.27	2.52	0.97	1.80
2010	3.14	1.46	1.66	4.79	-1.58	0.02	3.12	1.34	1.77
2011	3.56	1.04	2.50	4.87	-1.25	-0.44	4.02	1.63	1.90
2012	4.26	0.76	3.48	4.93	-0.64	-0.73	5.03	1.90	2.31

Notes: EP: Economic Prices includes adjustment for subsidy, MP: Market Prices, MP-L: Market Prices excluding the labour cost, EP-L: Economic Price after excluding the labour cost.

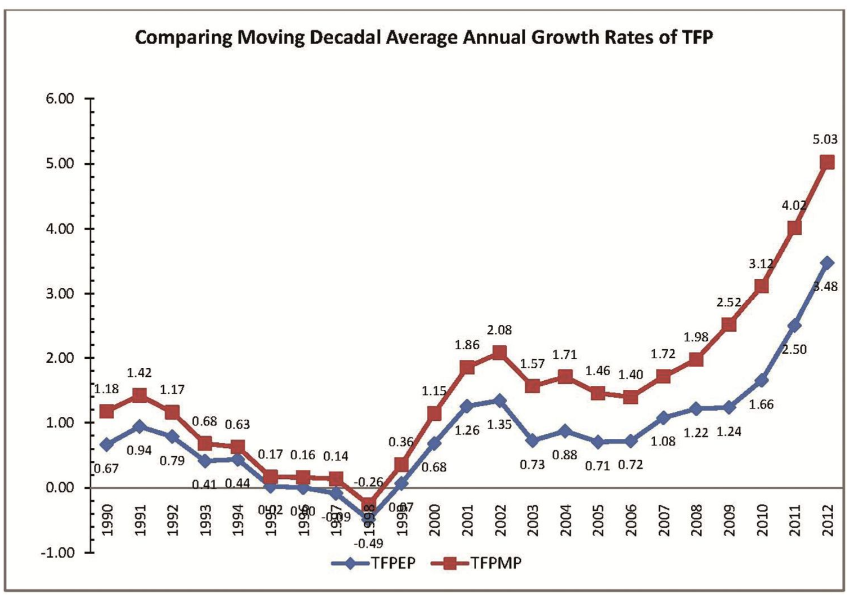

Figure 1. TFP Trends based on Moving Decadal Annual Trend Growth Rates.

(5) During the decade ending 2002-03 there was decline in the TFP annual growth rate which was due to a severe draught in the terminal year 2002-03 with less than 30 per cent normal rainfall throughout the country except some north eastern states (http://www.cccindia.co/corecentre/Database/Docs/docFiles/drought_india.pdf).
(6) Severe drought in the country are normally followed by recession, therefore TFP growth remain static till the decade ending 2005-06.
(7) Trends of improvement in annual growth rates are observed since decade ending 2005-06 both at market price as well as economic price.
(8) Growth rate in TFP (being a measure of agricultural productivity due to technological improvement) suggest that recent growth in agriculture is sustainable.
(9) Analysis in Table 8 further strengthens the fact that there has been increase in input growth rates in decade 1980-89 and decade 1990-2000. However, the growth in inputs slowed down to 1.65 during the decade 2000-01 to 2011-12 as compared to more than two in the previous two decades.

Contribution of TFP in Agriculture Growth

The contribution of growth of inputs and advancement of technology on agricultural productivity can be decomposed by using the estimated TFP index during the different phases (Table 9). The share of TFP in output is defined as the ratio of the TFP growth rate over the growth rate of output. It is observed from Table 9 that the contribution of TFP growth in output growth follows upward trend indicating the sustainability of agricultural productivity in India. These trends are similar at economic and market price both and thus refutes the theory of technology fatigue in Indian agriculture. At economic prices, overall, TFP growth rate contributed nearly 32 per cent in last 31 years while it was 88 per cent in the last phase.

TABLE 9. CONTRIBUTION OF INPUT GROWTH IN TFP GROWTH AND CONTRIBUTION OF TFP IN OUTPUT GROWTH (PER CENT)

Phases (1)	Share of TFP growth in output growth at economic prices (2)	Share of TFP growth in output growth at market prices (3)
1980-81 to 1988-89	19.0	39.6
1988-89 to 1995-96	-58.9	- 54.3
1995-96 to 2004-05	38.0	78.6
2004-05 to 2009-10	46.0	119.0
2004-05 to 2011-12	88.0	130.1
1980-81 to 2011-12	32.1	55.6

Comparison with Other Studies

TFP growth rates in agriculture sector as reported by other studies (Table 10) do not match completely with the present study mainly because of the three reasons (i)

The studies used CAGR approach for computing TFP growth rates. This approach is highly dependent on base year and the terminal year ignoring the intermediate years. Frequent fluctuations in output index and annual TFP index are observed, so to estimate TFP growth rates over different periods, trend growth rates are preferred over CAGR (Table 7, Table 8). (ii) Inputs, outputs and crops that are considered for TFP computation are different in each study. (iii) Time period is overlapping or different in the studies.

TABLE 10. PEARSON CORRELATION BETWEEN TFP AND OTHER VARIABLES

Variable (1)	Description (2)	Correlation co-efficient (3)
RoadKm	Road length (km)	.926**
Nmarket	No of Regulated Market	.749**
Con_Res	National Expenditure on Research and Development (2004-05 prices, Million Rs.)	.961**
Labourno	Agricultural labour cultivators (millions)	.855**
ActualRain	Actual Rainfall in millimeters (1 June to 30 May)	-0.248
HYVPercA	Percentage area under high yielding varieties (1June to 30 September)	.789**
LHS	Average size land holding (hectare)	-.823**
roadDens	Road density	.528**
Con_RoadEXP	Rural road expenditure (2004-05 prices, Lakhs Rs.)	.926**
PtoNRatio	P_2O_5 to N ratio	.672**
RlitPercent	Rural Literacy Percent	.873**
GIA	Gross irrigated area (000 Ha)	0.814**
Con_Credit	Credit to farmers (2004-05 prices, Rs. crore)	0.830**
CI	Cropping Intensity (per cent)	0.803**

Note: ** Correlation is significant at 1 per cent level (2-tailed).

Determinants of TFP

In order to analyse the determinants of TFP of the crop sector in India, correlation analysis was carried out. The variables taken in the study and their explanation is presented in Table 10. It is observed that all variables except actual rainfall have significant and positive correlation with TFP of agriculture. However, many of the independent variables which were used in correlation analysis are removed from the model using step wise regression method due to multi-collinearity. Finally, six variables viz., National Expenditure on Research and Development (Con_res), Rural road expenditure (con_road), Credit to farmers (Con_credit), Gross irrigated area(GIA), actual rain and P_2O_5 to N ratio (PtoN ratio) were retained for determining the factors influencing the total factor productivity with the following functional forms (Equation 8 and 9) where TFP index at market price has been taken as a dependent variable.

lnTFPmp=f (lnCon_res, con_roadexp, PtoNratio, lnactualrain) ....(8)

TFPmp=f(GIA, Con_credit, PtoNratio, actualrain) ....(9)

Factors influencing the total factor productivity in agriculture sector in India is presented in Table 11 which are obtained using Ordinary Least Square Regression. In model 1, natural logarithm of TFP index at market price is taken as dependent variable and natural log of expenditure on research and development and natural log of actual rain are taken as explanatory variables while in model 2, all the variables are in level forms and the independent variables are GIA and Con_credit. Two variables such as P to N ratio and actual rain are common in both the models. Durbin-Watson statistics (1.87 in model 1 and 1.96 which are close to 2) suggest the suitability of both the models. The signs of all the coefficients in both the models are as expected and in terms with previous related studies (Kannan, 2011). Model 1 accounts for 92 per cent of variation in TFP and is quite a good fit. Public expenditure in agricultural research and development has a positive impact on the total factor productivity and statistically significant at 1 per cent level of confidence. Its coefficient suggests that 1 per cent increase in research expenditure would lead to 8.9 per cent increase in productivity. Similar findings were observed by Hassan *et al*., 2014 and Ranjitha and Mruthyunjaya, 2005. Investment on rural road also has a positive impact on TFP significant at 5 per cent level but the magnitude of the coefficient is almost negligible. In model 2, R squared value is 0.94 and f-statistic is 93.35 which indicates a good fit of the model. From this model, it can be seen that credit expenditure on farmers and gross irrigated area have positive impact on TFP and highly significant at 1 per cent level but the magnitude of the coefficients are substantially low. Other

TABLE 11. DETERMINANTS OF TOTAL FACTOR PRODUCTIVITY IN INDIAN AGRICULTURE FROM 1980 TO 2009 USING OLS REGRESSION

Model 1: Dependent Variable: LNTFPMP			Model 2: Dependent Variable: TFPMP		
Regressors (1)	Coefficient (Std. Error) (2)	t-Stat (30	Regressors (4)	Coefficient (Std. Error) (5)	t-Stat (6)
LNCON_RES	0.0897*** (0.0236)	3.797	CON_CREDIT	1.29E-06*** (1.99E-07)	6.455
CON_ROADEXP	2.39E-07*** (5.84E-08)	4.085	GIA	3.79E-06*** (1.05E-06)	3.609
LNACTUALRAIN	0.2450** (0.0986)	2.483	ACTUALRAIN	0.000180* (9.53E-05)	1.888
PTONRATIO	0.3806* (0.2222)	1.712	PTONRATIO	0.626957** (0.236546)	2.650
Intercept	-2.8436*** (0.7366)	- 3.860	Intercept	0.361686** (0.150174)	2.408
R-squared	0.9212		R-squared	0.937	
Adjusted R-squared	0.9086		Adjusted R-squared	0.927	
S.E. of regression	0.0382		S.E. of regression	0.0417	
F-statistic	73.11***		F-statistic	93.35***	
Durbin-Watson stat	1.87		Durbin-Watson stat	1.96	

Notes: *,** and ***significant at 10, 5 and 1 per cent level, respectively. LNTFPMP=natural log of TFP at market price, LNCON_RES=natural log of research expenditure at constant price, CON_ROADEXP= Expenditures on rural road at constant price, LNACTUALRAIN= natural log of actual rain, PTONRATIO= P_2O_5 to N ratio, TFPMP = Total factor productivity index at market price, CON_CREDIT= Credit to farmers (2004-05 prices, Rs crore), GIA= Gross irrigated area in 000 ha.

variables such as rainfall and nutrients also have a positive and significant impact on total factor productivity.

V

CONCLUSIONS AND POLICY IMPLICATIONS

Average annual growth rate of TFP index is found to be improving since 2004-05 to 2011-12 both at economic price as well as market price. TFP growth at economic price is lower than the TFP at market prices. Increasing relative share of labour cost in total input for agriculture has emphasised the necessity of inclusion of correct estimates of wage bill for estimation of TFP. TFP index without labour cost has shown TFP index falling mostly below one at economic prices. Thus it is necessary to include labour cost in TFP studies. The contribution of TFP in output from crop sector has been rising. Thus hypothesis that recent growth in agricultural productivity is sustainable is verified and assures that there is no technical fatigue in the Indian agriculture. Our analysis has shown that expenditure on research, area under irrigation, balanced use of fertilisers, rural infrastructure and normal rainfall are important determinants of TFP growth. The specific studies in the past have shown that expenditure on agricultural research, expenditure on road, balance use of fertilisers, natural factors like rainfall, credit disbursement to farmers and per cent area under irrigation are some of the factors to further boost the TFP of the crop sector. Thus to further sustain the growth of TFP, expenditure on agricultural research, rural infrastructure, education and credit availability need to be continued.

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