



## Potato production scenario and analysis of its total factor productivity in India

RAJESH K RANA<sup>1</sup> and MD. EJAZ ANWER<sup>2</sup>

ICAR-National Institute of Agricultural Economics and Policy Research, DPS Marg, Pusa, New Delhi 110 012

Received: 02 September 2017; Accepted: 04 May 2018

### ABSTRACT

India is second largest producer of potatoes in the world after China. India showed tremendous growth in potato production during last one and half decade, however, this growth is led more by the area expansion than the yield enhancement. For further analysis on nature of productivity growth in Indian potato sector the computation of Total Factor Productivity (TFP) was done with the help of Malmquist Productivity Index (MPI). Year 2005 being the inflection point in the growth in Indian agriculture was used as period break year for this study and two periods, viz. pre-period (1997 to 2004) and post period (2005 to 2013) were considered for all analysis and descriptions. Bihar, West Bengal and Uttar Pradesh states constitute about 74% of Indian potato production hence, these states were assumed to represent Indian potato scenario. Except mild decline in potato productivity growth in Uttar Pradesh, area, production and productivity growth of potato showed acceleration in post-period compared to the pre-period in all the states. TFP improved in all the three states in post period however, in West Bengal the growth was negative (-2.3) even in the post period. Except Bihar where efficiency change was positive (1%) in pre-period, and further improved in post-period (2.1%), the efficiency change stagnated in all other cases. The TFP improvement in all the cases was either solely or mainly led by the technical change.

**Key words:** Data envelopment analysis program (DEAP), India, Malmquist productivity index (MPI), Potato, Technical change, Total factor productivity (TFP)

Significance of potato crop was rightly assessed by FAO (2008) before declaring 2008 as the International Year of Potato and indicating potato as future crop for fighting hunger and poverty. Impending food and nutritional security challenges in India and related policy implications have been aptly emphasized in various studies (Acharya 2009, Bhavani *et al.* 2010, Chand and Jumrani 2013, Kesavan 2015). Role of potato as food and income security crop for the global poor in general and the residents of developing countries in particulate, was adequately documented by Thiele *et al.* (2010) and Singh and Rana (2013).

Being the second largest producer, India occupies a prominent position on global potato map (Scott and Suarez 2011, Rana 2015). India produced 45.34 million t potatoes (12.32% of world production) against 95.99 million t by China (24.17% of world production) while Russian Federation, third largest producer of potatoes, produced 30.20 million t (8.20% of world production) in 2013 (FAOSTAT 2015). Hence, nearly 45% of global potato production took place in these three largest potato

producing countries. Share of India and China both in potato area and production has increased (Scott and Suarez 2011, 2012) from the year 1997 to 2013 through the year 2005, while share of Russian Federation for both these attributes has gone down. However, the trend growth rate for potato production during initial 13 years of 21<sup>st</sup> century was the highest in India followed by China and Russian Federation (Table 1). On productivity front, although India has grown significantly, yet the growth rate is much lower than that of the area during this period of time. Higher contribution of area expansion than productivity enhancement in the potato production growth scenario in India indicates that changing Indian socio-economic scenario is generating higher demand for potato (Singh *et al.* 2014, Rana 2015).

Potato production in India is highly concentrated in Gangetic plains as three largest potato producing states, viz. Uttar Pradesh (32.38% of national production), West Bengal (26.94% of national production) and Bihar (14.56% of national production), collectively contribute about 74% to the national production (Table 2). Share of Bihar state in national potato production and area has increased from the year 1997 to 2013; however, this share has decreased in case of Uttar Pradesh and West Bengal states, over this period. Trend growth rates over the period of 2001 to 2013 depict that potato area and production has significantly grown in all these three states while the productivity grew only in

<sup>1</sup>Principal Scientist (Agricultural Economics) (e mail: rajesh.rana@icar.gov.in), ICAR-ATARI, Zone-1, PAU Campus, Ludhiana, Punjab 141 004. <sup>2</sup>Research Associate (dr.ejaz2011@gmail.com), ICAR-NIAP, DPS Marg, New Delhi, Pusa 110 012.

Table 1 Trend growth rates (%) of potato area, production and productivity from 2001 to 2013

Country	State	Area	Production	Productivity
China†		1.79*	2.64*	0.84***
Russian Federation†		-4.38*	-2.24***	2.23**
India†		4.22*	6.04*	1.74*
	Bihar#	8.73*	17.50*	8.07*
	Uttar Pradesh#	3.61*	4.30*	0.67
	West Bengal#	2.46*	4.23**	1.73
	Overall 3 states#	4.26*	5.90*	1.58**
World (Total) †		-0.10	1.40*	1.50*

†: Data source is FAOSTAT; #: Data source is Directorate of Economics and Statistics, Ministry of Agriculture, Cooperation and Farmers Welfare, Government of India. \*, \*\* and \*\*\* denote level of significance at 1, 5 and 10%, respectively.

case of Bihar state (Table 1).

This analysis depicts a definite healthy growth in potato production scenario in India and its top three potato producing states. However, there is a mixed picture on contributory factors of this growth. Apparently, it appears that potato production growth in India during about two recent decades largely area expansion led with relatively less contribution of productivity enhancement. This indication fuels a policy debate whether the potato growth in India is technology led or just induced by its higher prices. This study of three largest potato producing states in Gangetic plains, contributing about 74% of Indian potato production, envisages detailed analysis of reasons contributing to potato production in the country and further investigations into the constituents of productivity growth with the help of Malmquist Productivity Index.

MATERIALS AND METHODS

Top three potato producing states of India, viz. Uttar Pradesh, West Bengal and Bihar collectively account for nearly 74% of Indian potato production and form a national potato production hub in Gangetic plains. These three states were therefore taken as study area for this investigation.

Performance of Indian agriculture has been characterised

Table 2 Share of potato area and production for the three largest potato producing states in India (%)

State	Area			Production		
	1997	2005	2013	1997	2005	2013
Bihar	15.06	11.38	16.48	7.94	5.79	14.56
Uttar Pradesh	34.81	33.24	29.92	39.98	41.19	32.38
West Bengal	23.14	24.82	20.41	33.15	31.04	26.94
Overall	73.00	69.43	66.81	81.07	78.02	73.87

Data source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

as ‘A Change from Slowdown to Fast-track’ during recent two decades having 2005 as the year of inflection point (Chand 2014). In fact, years 2005 and 1998 had structural breaks in the growth trajectory of Indian agriculture which moved to a higher level of 3.75% (trend growth rate) during 2005 to 2013 against a modest 1.92% per annum during 1998 to 2004 after being high at 3.15% per annum during 1989 to 1997 (Chand and Shinoj 2012). For a comparative analysis of trend and growth of potato in these states, the overall period was divided into two sub-periods, viz. before and after the year 2005. The cost of cultivation data were available from the year 1997 onwards hence the pre-period was considered from the year 1997 to 2004. On the other hand, the cost of cultivation data were available only up to the year 2013, hence the post-period was constituted by the years 2005 to 2013.

This study is based on the time series data of three major potato producing states situated in Gangetic plains of India, namely Uttar Pradesh, West Bengal and Bihar from various sources for different time periods ranging from the year 1988 to 2013. For having an overview of factors responsible for potato growth in top three potato producing countries of the world and top three states of India during 21<sup>st</sup> century so far, growth rates of potato area, production and productivity were estimated for the period of 2001 to 2013. Data on potato area, production and productivity for different countries were obtained from the FAOSTAT while these data for Indian states were taken from the Directorate of Economics and Statistics (DES), Ministry of Agriculture and Farmers Welfare, Government of India. Cost of potato cultivation data from 1997 to 2013 were also taken from DES. The time series data on potato cost of cultivation in the study area were smoothed with the help of Hodrick-Prescott (HP) filter. The HP filtered data were used for computation of MPI and other estimates based on these data. The HP filter provides a smooth nonlinear time series after eliminating short-term fluctuations from the data.

These data were used to estimate Malmquist Productivity Index (MPI) as proposed by Malmquist (1953), and standardized by Caves *et al.* (1982), Nishimizu and Page (1982) and Fare *et al.* (1989). The choice of MPI over other existing methods to measure TFP was guided mainly by the ability of the MPI to decompose TFP into technical change and efficiency change followed by its estimation feasibility in MPI approach without data on prices of inputs and outputs, and no underlying assumptions, associated to the error term in ordinary least square approach, exist in MPI approach (Fare *et al.* 1994, Suresh 2013). Data Envelopment Analysis Program (DEAP) version 2.1 (Coelli 1996), was used for carrying out the computations. Following equation expresses the computation process of TFP change and its components (technical change and efficiency change):

$$M_0(x^t, y^t, x^r, y^r) = \left[ \frac{D_0^{t2}(x^t, y^t)}{D_0^{r2}(x^r, y^r)} \right] \left[ \left( \frac{D_0^{t1}(x^t, y^t)}{D_0^{t2}(x^t, y^t)} \right) \left( \frac{D_0^{r1}(x^r, y^r)}{D_0^{r2}(x^r, y^r)} \right) \right]^{\frac{1}{2}} \tag{1}$$

Where: t1 is current and t2 is next period of time i.e. next year.

$$Efficiency\ Change = \left[ \frac{D_0^{t2}(x^{t2}, y^{t2})}{D_0^{t2}(x^{t1}, y^{t1})} \right] \quad (2)$$

$$Technical\ Change = \left[ \left( \frac{D_0^{t1}(x^{t2}, y^{t2})}{D_0^{t2}(x^{t2}, y^{t2})} \right) \left( \frac{D_0^{t1}(x^{t1}, y^{t1})}{D_0^{t2}(x^{t1}, y^{t1})} \right) \right] \quad (3)$$

In the above expressions equation-2 estimates efficiency change while the equation-3 measures technical change. The overall MPIs estimated by the equation-1 and a value higher than one depicts positive growth in TFP while any value less than one represents negative growth in the TFP.

In order to compare the quantum of growth and to assess direction of change in some important attributes related to potato production and its cost of cultivation, growth rates were computed. Two different methods of trend growth rate estimation were employed, viz. usual single value estimate for a series of data popularly known as Exponential Model and double value estimate for two sub-periods of the kinked series known as Kinked Exponential Model (Boyce 1986). Potato production and productivity attributes are highly variable over the years, hence a reference to a

single year becomes arbitrary in nature (Scott 2011). Hence, decennial moving growth rates (Scott and Suarez 2011) were estimated for the pre and post-period, i.e. years 1988-1997 to 1995-2004 for pre-period and 1996-2005 to 2004-2013 for post-period.

RESULTS AND DISCUSSION

Potato production performance

Potato production in all the three selected states has considerably grown over the two reference years, i.e. triennium ending (TE) average of year 2013 over the year 2005. Both the determinants of potato production, i.e. area and yield have invariably increased, however, overall potato area increase at 41% is much higher than 24% yield enhancement over this period (Fig 1). Hence, the findings indicate contribution of both area expansion and yield enhancement in the potato production augmentation in the study area.

Analysis of growth in potato area, production and yield

After having sufficient indication of the rising pattern of potato area, production and yield of potato in the studied

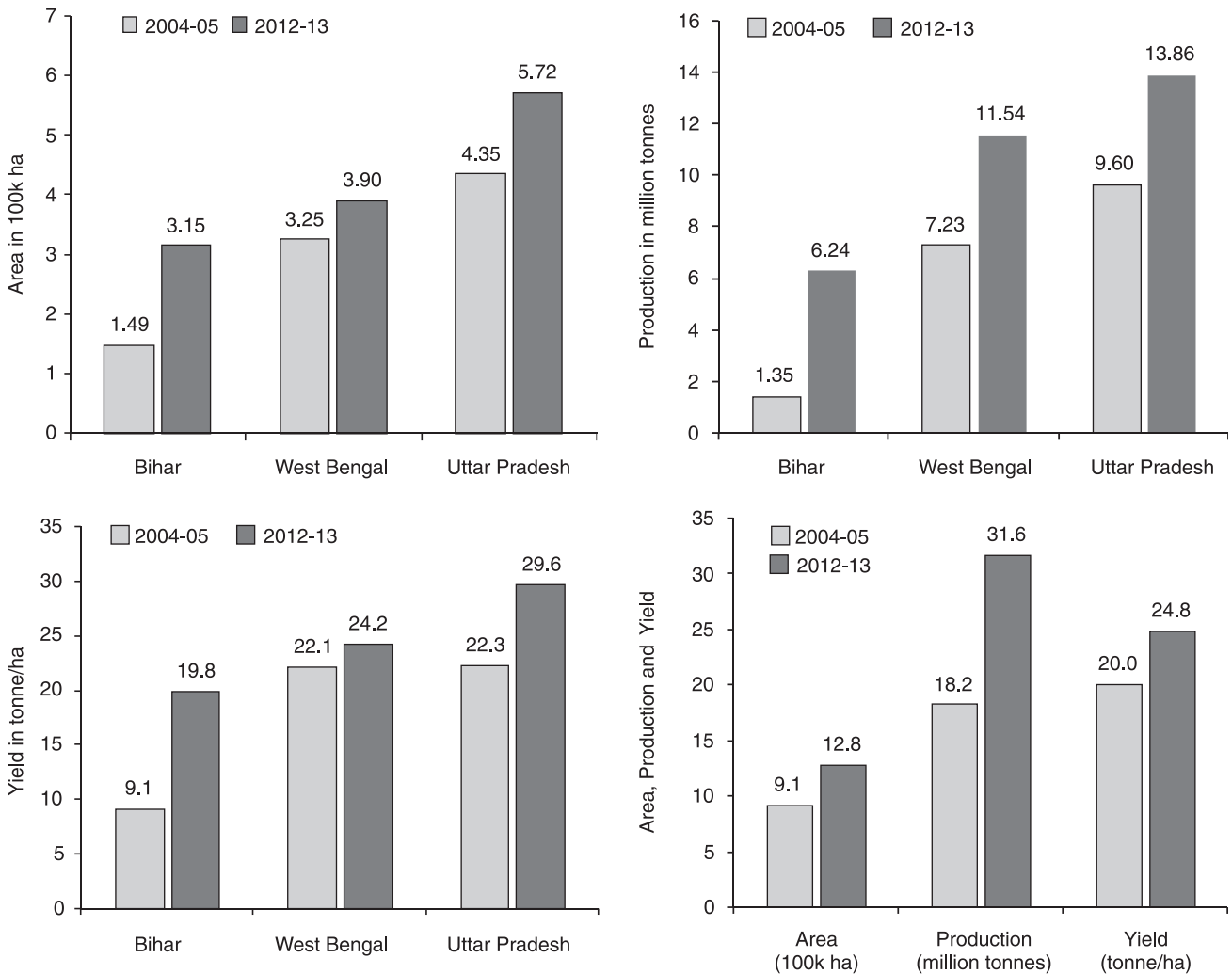


Fig 1 Area, production and yield of potato in selected Gangetic states of India (TE 2005-TE 2013)

states the score of analysis was further increased to cover and compare the two different phases of agricultural growth in India, i.e. decennial ending year (DE) 1997 to DE 2004 and DE 2005 to DE 2013 (Scott 2011, Scott and Suarez 2011). All the states under consideration, experienced falling trend in potato area DE moving growth rates during pre-period however, potato area growth rates showed a rising trend in all these states in the post period. Hence, rate of growth in potato area in the study area was negative in pre-period which started being positive in the post-period. In other words, potato area increased at decreasing rate in pre-period and at increasing rate in the post-period. Bihar and West Bengal states showed a declining trend in potato production growth rates during pre-period while Uttar Pradesh had more or less stagnant trend (Fig 2). Nevertheless, during post-period potato production DE moving growth rates trend was strongly positive.

Overall at the level of all the three states under consideration the potato production increased at falling

rate during per-period and DE moving growth rates started increasing at a healthy 0.77% during post-period. The rate of growth in potato productivity is the most important indicator of potato research and development activities being carried out in the country. Potato productivity grew at increasing rate in pre-period in the states of Bihar and Uttar Pradesh, however, the rate of growth of DE growth rates in pre-period was negative in the state of West Bengal (Fig 3). The rate of potato productivity growth in Bihar during post-period was much stronger than in the pre-period. Similarly, in the state of West Bengal the rate of potato productivity growth in post-period was strongly positive. However, contrary to the pre-period the rate of potato productivity growth in Uttar Pradesh was negative during post-period.

*Malmquist Productivity Index (MPI)*

Total Factor Productivity (TFP) approach has been used in many important agricultural productivity studied in other

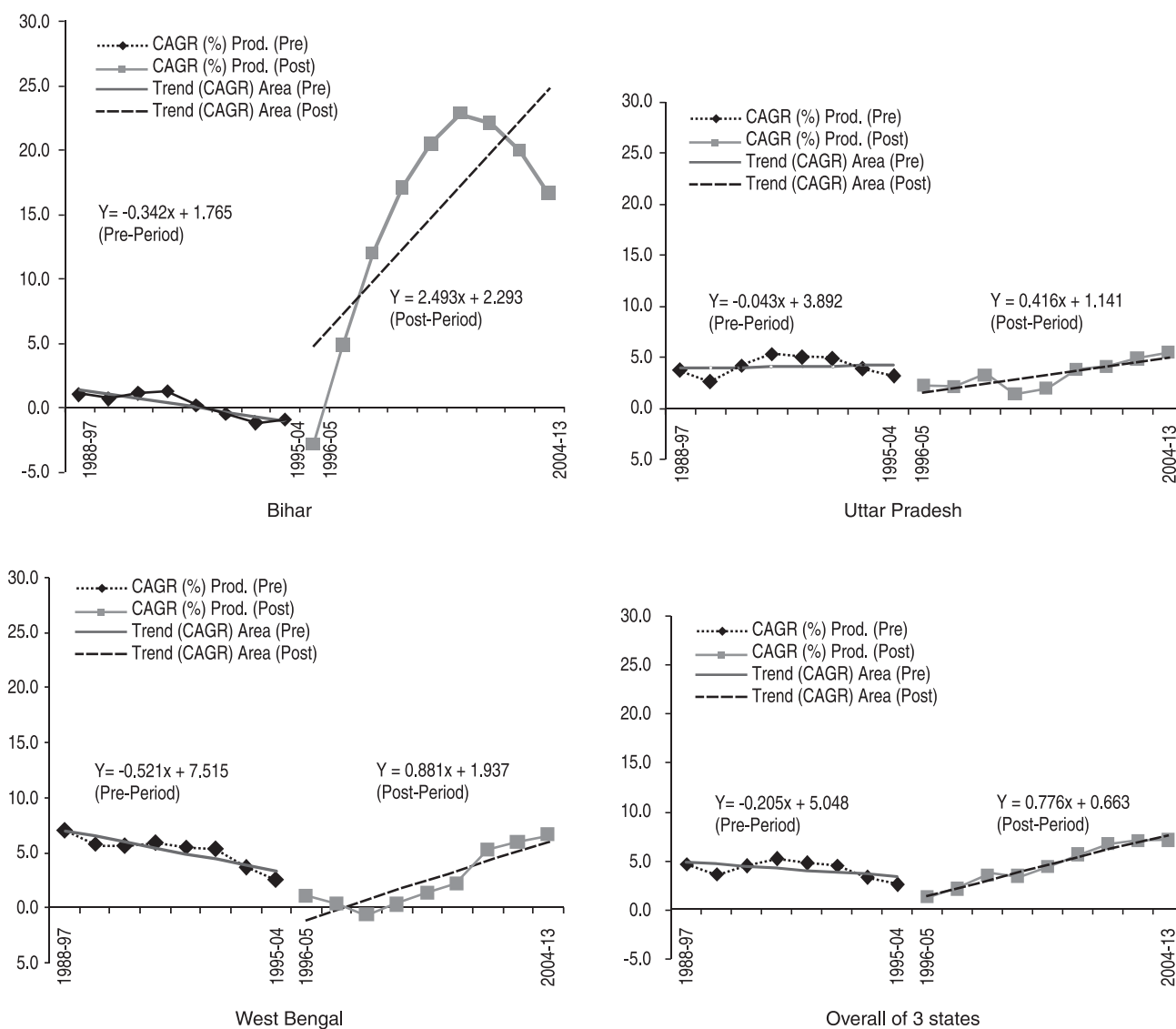


Fig 2 State-wise decennial moving trend growth rates (%) and trend lines for potato production during pre and post period. Data source: Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Govt. of India.

Table 3 Malmquist productivity index (MPI) of potato cultivation in selected Gangetic states of India during pre and post periods

MPI	Bihar		Uttar Pradesh		West Bengal		Overall	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Efficiency change	101.0	102.1	100.0	100.0	100.0	100.0	100.1	100.2
Technical change	100.5	103.5	98.2	105.7	95.3	97.7	97.2	101.7
TFP change	101.5	105.7	98.2	105.7	95.3	97.7	97.3	102.0
Growth in MPI								
Growth in EC	1.09		0.00		0.00		0.13	
Growth in TC	2.99		7.64		2.52		4.67	
Growth in TFPC	4.11		7.64		2.52		4.81	

developing countries (Kawagoe *et al.* 1985, Nkamleu *et al.* 2003, Li *et al.* 2011) and in India (Kumar and Mruthyunjaya 1992, Rosegrant *et al.* 1995, Kalirajan and Shand 1997, Kumar and Mittal 2006, Chandel 2007, Chand *et al.* 2011 and Suresh *et al.* 2013) showing divergent results in relation to different regions, periods and crops. MPI is a powerful and convenient tool of computing decomposed TFP into technical change and efficiency change (Coelli *et al.* 2005, Suresh *et al.* 2013). TFP, technical change and efficiency change during pre-period and post period in potato cultivation in three Gangetic states of India have been given in Table 3.

Invariably the TFP has showed improvement during post period in all the states under consideration. For all the three states the TFP improved by 4.81% during post-period and it was largely affected by the technological adoption rather than the efficiency improvement. Terms of trade became favourable for agriculture during early 1990s and gradually improved till 1998-99. Afterwards, having moderate deceleration upto the year 2004-05 the terms of trade in favour of agriculture showed sharp improvement in the post-period of the study (Birthal *et al.* 2013). This development resulted in improvement in farmers' income, including the potato farmers, and with the result the technological adoption has improved in the post period. For potato specific evidence of improved profitability, growth rates of total value of output, paid-out costs and total profit were estimated in pre and post periods. A faster growth of potato profits during post-period has been confirmed in this analysis (Table 4). Healthy profit growth in potato cultivation in the state of Bihar was found even in the pre-period, and the same has been reflected even in the technical change during pre-period.

In the state of West Bengal, technological adoption on relatively smaller potato farms has been less than the ideal even in the post-period (Table 3) due to nullification of positive growth rate for total value of output and prices during post-period by the fast escalation of paid-out costs (Table 4). These growth rates efficiently reflect change from negative TFP growth for Uttar Pradesh in pre-period to the considerably positive TFP growth for the state in the post period. Bihar was the only state where potato cultivation was done more efficiently even in pre-period which further improved considerably in the post-period. Implementation

of massive development initiatives including the agricultural sector in Bihar during post period has resulted in the improvement of potato cultivation efficiency in the state. However, in order to further improve growth of TFP change in the study area new technologies specific to farmers' preferences and needs (Rana *et al.* 2011, 2013) should be developed and efficiently delivered to resource poor and relatively unaware small and medium potato farmers.

Agricultural sector in Bihar grew by 6.24% growth rate in post-period (national estimate at 3.81%) compared to the 2.34% in pre-period (national estimate 1.85%). However, this growth was associated by 10.69% growth rate in state GDP in post-period (national GDP at 7.48%) against 4.74% state GDP growth rate in pre-period (national GDP growth rate at 5.82%). The corresponding trend growth rate of real cost of potato cultivation in Bihar during post-period has fallen compared to pre-period mainly on account of lower cost of human and bullock labour and total fixed cost (Table 5). However, the cost of potato cultivation has grown at higher growth rate in Uttar Pradesh and West Bengal affecting overall scenario in the same direction.

In Uttar Pradesh and West Bengal potato cultivation efficiency remained static over both the periods indicating an urgent need of general rural development programmes

Table 4 Trend growth rates (%) of factors of profitability in potato cultivation in the study area during pre and post period

State	Periods	Total value of output (₹)	Paid-out costs (₹)	Profit (₹)
Bihar	Pre	8.03*	7.70*	10.55***
	Post	8.68*	6.71*	11.58*
Uttar Pradesh	Pre	-0.86	0.46	-3.62
	Post	5.14*	3.75*	6.32**
West Bengal	Pre	5.79**	2.89	7.77
	Post	6.33*	5.36*	6.62
Over-all	Pre	4.25**	3.38***	4.93
	Post	6.67*	5.23*	8.51**

Data source: Ministry of Agriculture and Farmers Welfare, Government of India. Pre-period: 1996-97 to 2003-04; and Post-period: 2004-05 to 2012-13; \*, \*\*, \*\*\* represent the level of significance at 1, 5 and 10%, respectively.

Table 5 Trend growth rates (%) of attributes for potato cultivation in selected Gangetic states of India during pre and post period

Particular	Bihar		Uttar Pradesh		West Bengal		Overall	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Human labour	10.15*	7.30*	6.93*	6.11*	2.48	4.47*	5.53**	5.59*
Bullock labour	-14.61	-22.28*	6.52	3.48	9.65**	5.37*	8.43**	3.05**
Machine labour	14.66	15.65	7.56***	7.48*	5.38**	7.82*	7.66**	8.88*
Irrigation charges	8.65**	11.42*	17.97*	13.57*	2.33	3.27**	6.63**	7.29*
Total fixed costs	7.22***	4.72*	5.27*	7.57*	5.71***	6.61*	6.00**	6.57*
Total variable costs	8.45*	8.66*	1.98	4.49*	3.31***	5.29*	4.23**	5.42*
Total costs (C2)	8.20*	6.24*	2.68	5.23*	3.99***	5.65*	4.66**	5.69*

Data source: Ministry of Agriculture and Farmers Welfare, Government of India. Pre-period: 1996-97 to 2003-04; and Post-period: 2004-05 to 2012-13; \*, \*\*, \*\*\* represent the level of significance at 1, 5 and 10%, respectively.

to enable supporting infrastructure augmentation in these two states. Except for some efficiency growth in post-period over the pre-period in the state of Bihar, TFP growth in the study area during post-period over pre-period has been by and large achieved on the bases of positive technical change. In spite of 2.52% growth in TFP in West Bengal potato cultivation during post-period over the pre-period,

the actual TFP change in potato cultivation was considerably negative even in the post-period which is a real cause of concern both at policy as well as research and development level. Availability of processing grade potato varieties (Rana *et al.* 2010, Pandit *et al.* 2015) in India and their adoption in the study area (Pandit *et al.* 2015) has not only led to development of potato processing sector in India (Rana *et*

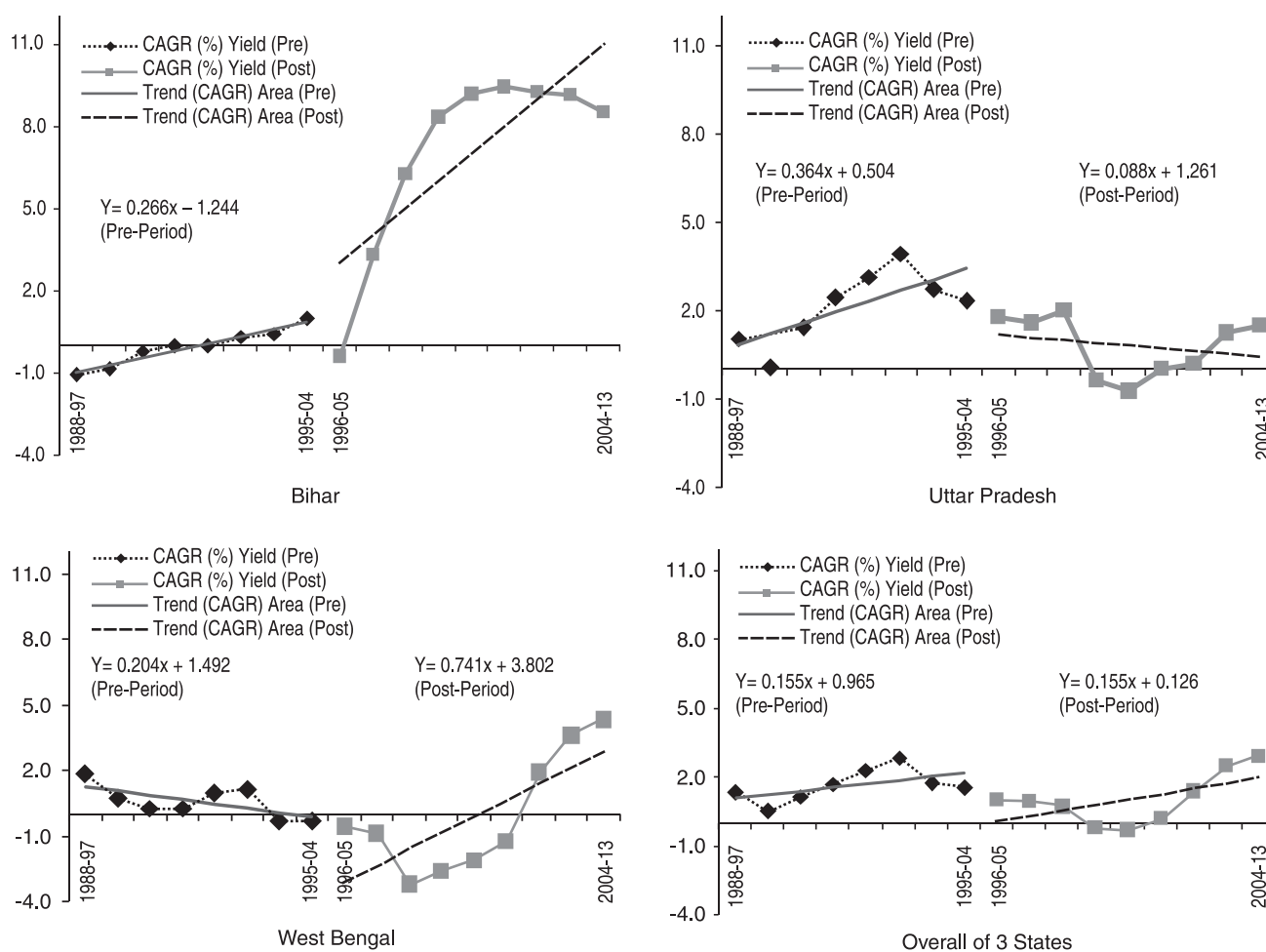


Fig 3 State-wise decennial moving trend growth rates (%) and trend lines for potato productivity during pre and post period. Data source: Department of Agriculture and Cooperation and Farmers Welfare, Ministry of Agriculture, Govt. of India.

al. 2010, Rana 2011, Rana *et al.* 2017) during post-period but it has also contributed in augmentation (Table 4) and stability (Pandit *et al.* 2015) of potato cultivation profitability in the country.

The concerns over inadequate growth in efficiency change in Indian agriculture have also been raised by Chand *et al.* (2011) and Suresh (2013). Diminishing returns to inputs have been cited as the principal reason for this stagnation or even the deceleration in the efficiency growth in Indian agriculture (Chand *et al.* 2011). Although, there is a meagre growth in potato cultivation efficiency change in India during post-period as compared to the pre-period, yet, it is better than the national scenario in other crops like rice (Suresh 2013) and rapeseed and mustard (Kumar and Anwer 2015).

#### Conclusions and recommendations

India is second largest producer of potatoes in the world. During recent past the indices for potato production and harvested area have shown tremendous growth. However, there is relatively milder growth in potato productivity statistics. Detailed analysis of potato production scenario in India during previous seventeen years was carried out in two different periods, i.e. pre-period (1997 to 2004) and post-period (2015 to 2013). Decennial moving growth rates confirmed that all potato production attributes, viz. area, production and productivity considerably improved at overall level during post-period compared to the pre-period. However, at individual level, except potato productivity in Uttar Pradesh all the three attributes showed improvement in all the states during post-period.

Malmquist Productivity Index (MPI) of potato cultivation in the study area showed considerable growth in Total Factor Productivity (TFP) change at individual states level as well as at overall level. However, growth in TFP change was mainly contributed by growth in technology change while the contribution of growth efficiency change was unremarkable. State of Bihar on account of large scale rural and infrastructure development initiatives showed some growth in efficiency change during post-period compared to the pre-period. Even after a positive growth of 2.52% in potato cultivation TFP change during post period compared to the pre-period in the state of West Bengal the overall TFP change is 2.3% in negative territory.

Supporting general rural infrastructure directly or indirectly influences growth of agriculture including the potato cultivation. In order to make potato cultivation and general agriculture more efficient and profitable, rural development initiatives of the current union government in India needs to be proficiently implemented in all states in the study area. Future of Indian agriculture or potato cultivation depends, to a very large extent, on general development programs like irrigation infrastructure, assured supply of quality electricity, quality and magnitude of rail and road transport etc. Concerted efforts of agencies involved in potato research and development in India are required to develop and deliver more potent potato technologies.

The technologies should be developed specific to the farmers' needs and preferences. Such technologies need to be efficiently delivered as large proportion of small and medium potato farmers in the country generally don't adopt improved technologies at their own.

#### REFERENCES

- Acharya S S. 2009. Food security and Indian agriculture: Policies, production performance and environment. *Agricultural Economics Research Review* 22: 1–19.
- Bhavani V B, Anuradha G, Gopinath R and Velan A S. 2010. Report of the State of the Food Insecurity in Rural India. M S Swaminathan Research Foundation and World Food Programme, FAO, MSSRF Report-27, pp 39–42.
- Birthal P S, Joshi P K, Negi D S and Agarwal S. 2013. Changing sources of growth in Indian agriculture: Implications for regional priorities for accelerating agricultural growth. IFPRI Discussion Paper, New Delhi, pp 21–2.
- Boyce James K. 1986. Practitioners' Corner- Kinked Exponential models for growth rate estimation. *Oxford Bulletin of Economics and Statistics* 48(4): 385–91.
- Caves D W, Christensen L R and Diewert W E. 1982. The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica* 50(6): 1393–414.
- Chand R, Kumar P and Kumar S. 2011. Total factor productivity and contribution to research investment to agricultural growth in India. Policy Paper-25, National Centre for Agricultural Economics and Policy Research, New Delhi.
- Chand R and Shinoj P. 2012. Temporal and spatial variations in agricultural growth and its determinants. *Economic and Political Weekly XLVII* (26-27, 30 June 2012): 55–64.
- Chand R and Jumrani J. 2013. Food security and undernourishment in India: Assessment of alternative norms and the income effect. *Indian Journal of Agricultural Economics* 68(1): 39–53.
- Chand R. 2014. From slowdown to fast track: Indian agriculture since 1995. Working Paper, ICAR-National Centre for Agricultural Economics and Policy Research, 26 p.
- Chandel B S. 2007. How sustainable is the total factor productivity of oilseeds in India? *Indian Journal of Agricultural Economics* 62(2): 244–58.
- Coelli T J. 1996. A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer Program), Centre for Efficiency and Productivity Analysis, University of New England, Australia.
- Coelli T J, Rao D S P, O'Donnell C J and Battese G E. 2005. *An Introduction to Efficiency and Productivity Analysis*. Springer, New York, USA.
- FAO. 2008. New Light on a Hidden Treasure. An End-of-Year Review (International Year of the Potato-2008). Food and Agriculture Organization of the United Nations, Rome, 148 p.
- FAOSTAT. 2015. FAO, statistical databases. <http://faostat3.fao.org/download/Q/QC/E>
- Fare R, Grosskopf S, Lindgren B and Roos P. 1989. Productivity developments in Swedish hospitals: A Malmquist output index approach. (In) *Data Envelopment Analysis: Theory, Methodology and Applications*. Charnes A, Cooper WW, Lewin A Y and Seiford L M (Eds). Kluwer Academic Publishers, Boston.
- Fare R, Grosskopf S, Norris M and Zhang Z. 1994. Productivity growth, technical progress, and efficiency change in industrialised countries. *American Economic Review*: 66–83.
- Kalirajan K P and Shand R T. 1997. Sources of output growth in

- Indian Agriculture. *Indian Journal of Agricultural Economics* **52**(4): 693–706.
- Kawagoe T, Hayami Y and Ruttan V. 1985. The intercountry agricultural production function and productivity differences among countries. *Journal of Development Economics* **19**: 113–32.
- Kesavan P C. 2015. Shaping science as the prime mover of sustainable agriculture for food and nutrition security in an era of environmental degradation and climate change. *Current Science* **109**(3): 488–501.
- Kumar P and Mittal S. 2006. Agricultural productivity trends in India: sustainability issues. *Agricultural Economics Research Review* **19**(Conference No.): 71–88.
- Kumar P and Mruthyunjaya. 1992. Measurement and analysis of total factor productivity growth in wheat. *Indian Journal of Agricultural Economics* **47**(7): 451–8.
- Kumar S and Anwer Md E. 2015. Estimation of productivity and efficiency of rapeseed and mustard production in India. *Economic Affairs* **60**(4): 809–20.
- Li G, You L and Feng Z. 2011. The sources of total factor productivity growth in Chinese agriculture: Technological progress or efficiency gain. *Journal of Chinese Economic and Business Studies* **9**(2): 181–203.
- Malmquist S. 1953. Index numbers and indifference surfaces. *Trabajos de Estadística* **4**: 209–42.
- Nishimizu M and Page J M Jr. 1982. Total factor productivity growth, technological progress and technical efficiency change: Dimensions of productivity change in Yugoslavia, 1965–78. *Economic Journal* **92**(368): 920–36.
- Nkamleu G B, Gokowski J and Kazianga H. 2003. Explaining the failure of agricultural production in sub-Saharan Africa. *Proceedings of the 25th International Conference of Agricultural Economists*, Durban, South Africa, 16–22 August.
- Pandit A, Lal B and Rana Rajesh K. 2015. An assessment of potato contract farming in West Bengal state, India. *Potato Research* **58**: 1–14.
- Rana Rajesh K, Pandit A and Pandey N K. 2010. Demand for processed potato products and processing quality potato tubers in India. *Potato Research* **53**: 181–97.
- Rana Rajesh K. 2011. The Indian potato processing industry-global comparison and business prospects. *Outlook on Agriculture* **40**: 237–43.
- Rana Rajesh K, Sharma N, Kadian M S, Girish B H, Arya S, Campilan D, Pandey S K, Carli C, Patel N H and Singh B P. 2011. Perception of Gujarat farmers on heat-tolerant potato varieties. *Potato Journal* **38**: 121–9.
- Rana Rajesh K, Sharma N, Arya S, Singh B P, Kadian M S, Chaturvedi R and Pandey S K. 2013. Tackling moisture stress with drought-tolerant potato (*Solanum tuberosum*) varieties: perception of Karnataka farmers. *Indian Journal of Agricultural Sciences* **83**(2): 216–22.
- Rana Rajesh K. 2015. Future challenges and opportunities in Indian potato marketing. World Potato Congress-2015, 29 July 2015, Yanqing-Beijing, China.
- Rana Rajesh K, Martolia Renu and Singh V. 2017. Trends in global potato processing industry- Evidence from patents' analysis with special reference to Chinese experience. *Potato Journal* **44**(1): 37–44.
- Rosegrant Mark W and Robert E Evenson. 1995. *Total Factor Productivity and Sources of Long-Term Growth in Indian Agriculture*, EPTD Discussion Paper No. 7, Environment and Production Technology Division, International Food Policy Research Institute, Washington, DC, USA.
- Scott G. 2011. Growth rates for potatoes in Latin America in comparative perspective: 1961–07. *American Journal of Potato Research* **88**: 143–52.
- Scott G J and Suarez V. 2011. Growth rates for potato in India and their implications for industry. *Potato Journal* **38**: 100–12.
- Scott G J and Suarez V. 2012. Limits to growth or growth to the limits? Trends and projections for potatoes in China and their implications for industry. *Potato Research* **55**(2): 135–56.
- Singh B P and Rana Rajesh K. 2013. Potato for food and nutritional security in India. *Indian Farming* **63**(7): 37–43.
- Singh B P, Rana Rajesh K Govindakrishnan P M. 2014. Vision 2050. Central Potato Research Institute, Shimla, 26 p.
- Suresh A. 2013. Technical change and efficiency of rice production in India: a Malmquist total factor productivity approach. *Agricultural Economics Research Review* **26**(Conference Number): 109–18.
- Thiele G, Theisen K, Bonierbale M and Walker T. 2010. Targeting the poor and hungry with potato science. *Potato Journal* **37**(3–4): 75–86.