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Nonparametric Estimation and Decomposition of Total Factor Productivity of Rice and Maize in Telangana State

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ABSTRACT

The present study was conducted to estimate the total factor productivity (TFP) growth of major foodgrain crops (namely rice and maize) of Telangana state. The growth of the agricultural sector in the newly formed state Telangana has reached a level of stagnation. It is of the utmost importance to find out the factors that contribute to the growth of the agricultural sector other than the primary inputs of production namely, seed, fertiliser, human labour and so on. Estimation of TFP growth will help to understand the performance of the variables other than the primary inputs. Non-parametric model was applied to estimate the TFP growth of the agricultural sector in the state during the period from 2000-01 to 2012-13. The Malmquist Index has been used to calculate the index of total factor productivity in the present study. It has been estimated that the TFP of rice has witnessed a 7.7% improvement during the period from 2000-01 to 2012-13 owing to growth in the technical change component whereas the efficiency change component has remained unchanged during the same period. In case of maize, the state witnessed 0.1% growth of the TFP which is near stagnation.

Key Words: *Total Factor Productivity, Malmquist Index, Decomposition Analysis, Non-parametric Estimation, Telangana*

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INTRODUCTION

Rice (*Oryza sativa* L.) and maize (*Zea mays* L.) are two major foodgrain crops in the Indian state of Telangana accounting for about 30 per cent and 10 per cent area of gross cropped area respectively. Being an agrarian state, productivity growth is of central importance both to economic growth and to the role of government policy in promoting growth [8]. The growth estimation of the agricultural sector in the newly formed state of Telangana will help the policy makers in prioritising the areas of importance. The green revolution of 1960s contributed significantly for increasing agricultural production mainly through the spread of modern varieties and input intensification [9]. The introduction of seed-fertilizer technology in the 1960s increased total factor productivity in Indian agriculture significantly [3]. The green revolution propelled by the introduction of high yielding varieties and improved cultivation practices played an important role in achieving self-sufficiency in foodgrain production and infrastructure creation [5, 8]. Leelavathi *et al.* [7] stated that agriculture in the state of Telangana (and Andhra Pradesh) has been exhibiting stagnation in growth and is seeking innovative policy and technology interventions. In the present context of declining (or almost stagnant) trend in area and production of agricultural crops there was a need to study the factors other than primary inputs that contribute to the agricultural production of the state and find out the corners where necessary steps should be taken. Growth in TFP contributes significantly to the acceleration of agricultural growth facilitating release of scarce resources from agriculture to other sectors in the economy [5].

MATERIALS AND METHODS

Estimation of total factor productivity for the state of Telangana was based on data of 13 years starting from 2000-01 to 2012-13. The entire state of Telangana was classified into three different sub-divisions each comprising of three districts. These three sub-divisions are as follows, northern Telangana

(Adilabad, Nizamabad and Karimnagar), central Telangana (Medak, Rangareddy and Warangal) and southern Telangana (Khammam, Mahaboobnagar and Nalgonda). The total value of output of rice and maize was derived by summing up the values of main product and the by-product in Rupees. This gross value of the output was then divided by the area under rice to get the price of the product. The selected inputs of production for the present study were family human labour (in hours), paid human labour (in hours), animal labour (in hours), machine hours, seeds (in Kg.), nitrogenous fertiliser (in Kg.), phosphorous fertilises (in Kg.), potassium fertiliser (in Kg.), farm yard manure (FYM) (in quintals), insecticide and irrigation hours. These data were collected for the period of 2000-01 to 2012-13 from the published documents of Comprehensive Scheme on Cost of Cultivation of Principal Crops in India. The district, as well the state level data were compiled from the unit level data from Cost of Cultivation Scheme.

Non-parametric estimation of TFP

Non-parametric approach to total factor productivity (TFP) estimation uses the Malmquist index method described by Fare *et al.* [6] and Coelli, Rao, O'Donnell and Battese [4]. Data envelopment analysis (DEA) is the non-parametric mathematical programming approach to frontier estimation which uses data on the input and output quantities of a group of firms to construct a piece-wise linear surface over the data points. This frontier surface is constructed by the solution of a sequence of linear programming problems – one for each firm (here the districts and the state as a whole) in the sample. The degree of technical inefficiency of each firm (the distance between the observed data point and the frontier) is produced as a by-product of the frontier construction method.

DEA can be both input as well as output oriented. Output oriented DEA seeks to maximise the quantity of the outputs by keeping the inputs fixed. In the real world most of the farmer-producers always seek to maximise their output while less bothered about their input quantity. Keeping this in mind output oriented DEA has been applied in the present study. The assumption of CRS seems to be more appropriate when the data under considerations involves aggregation of the input and output quantities whereas VRS is appropriate for the individual firm level studies [3]. Hence, an output oriented with constant returns to scale (CRS) model has been adopted for the present study.

The Malmquist TFP Index

Malmquist TFP index has become a commonly used measure of productivity change and has gained prominence in the literature [3]. The Malmquist TFP index was first introduced by Caves *et al* [1, 2]. Distance functions are used for the calculation of the Malmquist index. These distance functions describe a multi-input, multi-output production technology without the need to specify a behavioural objective (such as cost minimisation or profit maximisation). An input distance function characterises the production technology by looking at a minimal proportional contraction of the input vector, given an output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector. Only an output distance function in detail is considered in the present study.

A production technology may be defined as,

$P(x) = \{y: x \text{ can produce } y\}$ ………………………………………………… 1

Where,

y is the vector of all outputs,

x is the vector of all inputs, and

The technology satisfies the axioms listed in Coelli, Rao and Battese [4].

The output distance function is defined on the output set, P(x), as,

$d_o(x,y) = \min\{\delta : (y/\delta)\in P(x)\}$ …………………………………………. 2

The distance function, $d_o(x,y)$, will take a value which is less than or equal to one if the output vector, y, is an element of the feasible production set, P(x). Furthermore, the distance function will take a value of unity if y is located on the outer boundary of the feasible production set, and will take a value greater than one if y is located outside the feasible production set.

The description of the Malmquist TFP index draws upon the works of Fare *et al.* [6]. The Malmquist TFP index measures the TFP change between two data points (e.g., those of a particular firm in two adjacent time periods) by calculating the ratio of the distances of each data point relative to a common technology. If the period t technology is used as the reference technology, the Malmquist (output oriented) TFP change index between period s (the base period) and period t can be written as

$$m_0^t(q_s, x_s, q_t, x_t) = \frac{d_0^t(q_t, x_t)}{d_0^t(q_s, x_s)} \quad \text{……………………………………………….3}$$

Where,

q and x are non-zero output and input vectors in the particular period.

Alternatively, if the period s reference technology is used it is defined as,

$$m_0^s(q_s, x_s, q_t, x_t) = \frac{d_0^s(q_t, x_t)}{d_0^s(q_s, x_s)} \quad \text{...4}$$

The above equations and notation $d_0^s(q_t, x_t)$ represents the distance from period t observation to the period s technology. A value of m_0 greater than 1, represents the positive TFP growth and *vice versa*.

The Malmquist TFP index is defined as the geometric mean of the above two indices and given as,

$$m_0(q_s, x_s, q_t, x_t) = \left[\frac{d_0^s(q_t, x_t)}{d_0^s(q_s, x_s)} \times \frac{d_0^t(q_t, x_t)}{d_0^t(q_s, x_s)}\right]^{1/2} \quad \text{...............................5}$$

The distance functions in the productivity index can be rearranged in an equivalent way as,

$$m_0(q_s, x_s, q_t, x_t) = \frac{d_0^t(q_t, x_t)}{d_0^s(q_s, x_s)}\left[\frac{d_0^s(q_t, x_t)}{d_0^t(q_t, x_t)} \times \frac{d_0^s(q_s, x_s)}{d_0^t(q_s, x_s)}\right]^{1/2} \quad \text{.....................6}$$

The ratio outside the square brackets in the above equation measures the change in the output-oriented measure of Farrell technical efficiency between period s and t. Thus the efficiency change is equivalent to the ratio of the technical efficiency in period t to the technical efficiency in period s. The second part of the index in equation 6 is a measure of technical change. It is the geometric mean of the shift in technology between the two periods, evaluated at x_t and also at x_s.

Thus the two terms in the equation 6 are,

$$\text{Efficiency change} = \frac{d_0^t(q_t, x_t)}{d_0^s(q_s, x_s)} \quad \text{... 7}$$

And,

$$\text{Technical Change} = \left[\frac{d_0^s(q_t, x_t)}{d_0^t(q_t, x_t)} \times \frac{d_0^s(q_s, x_s)}{d_0^t(q_s, x_s)}\right]^{1/2} \quad \text{.............................. 8}$$

This technique constructs a grand frontier over the data on all the regions and compares each of the regions to the frontier. How close a firm is as compared to the frontier is termed as “catching up” and how much the grand frontier shifts at each firms input mix is termed as “technical change” or “innovation”. Any value of the indices so calculated, more than 1 implies an improvement in the performance and value less than 1 implies regress or deterioration in the performance.

Fare *et al.* [6] suggested that the technical efficiency change can be decomposed into scale efficiency change and “pure” efficiency change. The two components are presented as,

$$\text{Pure efficiency change} = \frac{d_{0v}^t(q_t, x_t)}{d_{0v}^s(q_s, x_s)} \quad \text{... 9}$$

Scale efficiency change=

$$\left[\frac{d_{0v}^t(q_t, x_t)/d_{0c}^t(q_t, x_t)}{d_{0v}^t(q_s, x_s)/d_{0c}^t(q_s, x_s)} \times \frac{d_{0v}^s(q_t, x_t)/d_{0c}^s(q_t, x_t)}{d_{0v}^s(q_s, x_s)/d_{0c}^s(q_s, x_s)}\right]^{1/2} \quad \text{............. 10}$$

The scale efficiency change component in the above equation is actually the geometric mean of two scale efficiency change measures, one related to the period t technology and the second one is relative to period s technology. The extra subscripts c and v refer to the CRS and VRS technologies, respectively.

RESULT

Malmquist productivity indices of rice

Malmquist indices of productivity growth of rice were calculated to study and decompose the productivity growth into various efficiency measures and the results have been presented in tables 1 and 2. Table 1 summarises the annual means of the indices for the regions and the state over the period of years and the table 2 presents the region means of the indices. All the averages so calculated in are geometric means.

A quick look into the table 1 revealed that over the study period of time on average the TFPch of rice was 7.70 per cent, which was completely due to TECHch, i.e., due to improvement in innovation. EFFch did not affect the TFPch in overall study period i.e., there was no catching up. In overall study period, the main source of productivity gain was TECHch or innovation. EFFch over the period of study mainly deteriorated in almost all the years. TFPch was highest in the year 2005-06 (66.50 per cent) followed by

2007-08 (65.90 per cent). The lowest value of the TFPch index was recorded in the year2006-07 when it deteriorated by 37.4 per cent as compared to the base year due to fall in both EFFch and TECHch followed by 2002-03 (-26.8 per cent). In most of the years TFPch was mainly explained by TECHch.
The region wise indices of productivity change of rice were presented in the table 2. The TFPch was highest in southern Telangana region (14.30 per cent) followed by central Telangana (7.40 per cent) and northern Telangana (1.70 per cent). The average value of TFPch in Telangana during the study period was 7.7 per cent. The results revealed that the productivity gains in all the regions as well in the state was completely due to improvement in innovation i.e., TECHch. EFFch did not have any effect on the productivity growth in the regions means there was no catching up. The results were in accordance of Suresh (2013) who reported that the TFP change in Andhra Pradesh for the period 1980-81 to 2009-10 was 1.051 largely contributed by technical change.

Table 1: Malmquist Index Summary of Annual Means of Rice in Telangana from 2000-01 to 2012-13

Year	EFFch	TECHch	PEch	SEch	TFPch
2000-01	1.000	1.000	1.000	1.000	1.000
2001-02	1.000	0.963	1.000	1.000	0.963
2002-03	1.000	0.732	1.000	1.000	0.732
2003-04	1.000	1.368	1.000	1.000	1.368
2004-05	0.998	0.800	1.000	0.998	0.798
2005-06	1.002	1.662	1.000	1.002	1.665
2006-07	0.914	0.685	0.950	0.962	0.626
2007-08	1.094	1.517	1.053	1.039	1.659
2008-09	1.000	1.507	1.000	1.000	1.507
2009-10	1.000	0.911	1.000	1.000	0.911
2010-11	0.991	1.134	1.000	0.991	1.124
2011-12	1.009	1.168	1.000	1.009	1.178
2012-13	1.000	1.004	1.000	1.000	1.004
Mean	1.000	1.077	1.000	1.000	1.077

**Note: Malmquist index averages are geometric means

Table 2: Malmquist Index Summary of Region wise Means of Rice from 2000-01 to 2012-13

Region	EFFch	TECHch	PEch	SEch	TFPch
Northern Telangana	1.000	1.017	1.000	1.000	1.017
Central Telangana	1.000	1.074	1.000	1.000	1.074
Southern Telangana	1.000	1.143	1.000	1.000	1.143
Telangana Average	1.000	1.077	1.000	1.000	1.077

**Note: Malmquist index averages are geometric means

Malmquist productivity indices of Maize

Decomposition of the productivity of maize into various efficiency measures was done using the Malmquist decomposition procedure and the results were presented in the tables 3 and 4. It was revealed from table 3 that the geometric average of annual means of the TFPch of all the regions was 1.001 i.e., average change of Malmquist total factor productivity index of maize over the period of years was 0.1 per cent. This implied that the over period of years on a geometric average basis the performance of maize in the state was almost stable in the state. On an overall basis efficiency change (EFFch) did not have any implication in the TFPch of maize. The year wise performance of the means of the productivity indexes revealed that the TFPch was positive in almost all the years except 2002-03 (-58.1 per cent), 2004-05 (-24.6 per cent), 2006-07 (-52.60 per cent) and 2012-13 (-9.1 per cent). All the deterioration in the performance of the productivity of maize in the state could be due to lack of innovation in production except in the year 2006-07 when efficiency change largely influenced the negative performance. The efficiency change (EFFch) in 2006-07 was -24.20 per cent, of which was mainly due to deterioration in the scale efficiency (SEch). The highest improvement in the performance was observed in the year 2007-08 where the TFPch was 164.6 per cent when TECHch was 100.5 per cent and EFFch was 32.0 per cent. This implied that there was significant improvement in both the “catching up” and “innovation” in this year. Decomposition of the EFFch in 2007-08 revealed that improvement in the efficiency was mainly due to scale efficiency and also due to improvement in the “managerial efficiency”. In some other years when significant improvement in the TFPch was observed are 2005-06 (34.90 per cent), 2009-10 (35.9 per cent) and 2001-02 (35.7 per cent). In all the cases where there was an improvement in the performance, most of them were realised due to improvement in the innovation of TECHch. “Catching up” or EFFch was almost nil in all the years.

The region wise analysis of the indices from the table 4 revealed that the Telangana average of TFPch had remained stable over the period when its value was 0.10 per cent. There was an improvement in the TFPch of maize in northern and central Telangana where changes in TFP were 7.0 per cent and 0.5 per cent over the years. Southern Telangana registered deterioration in the productivity performance. All the changes in the indexes were due to TECHch and there was no “catching up” effect.

Table 3: Malmquist Index Summary of Annual Means of Maize in Telangana from 2000-01 to 2012-13

Year	EFFch	TECHch	PEch	SEch	TFPch
2000-01	1.000	1.000	1.000	1.000	1.000
2001-02	1.000	1.357	1.000	1.000	1.357
2002-03	1.000	0.419	1.000	1.000	0.419
2003-04	1.000	1.194	1.000	1.000	1.194
2004-05	0.998	0.756	1.000	0.998	0.754
2005-06	1.002	1.346	1.000	1.002	1.349
2006-07	0.758	0.626	0.921	0.823	0.474
2007-08	1.320	2.005	1.086	1.215	2.646
2008-09	1.000	0.763	1.000	1.000	0.763
2009-10	0.995	1.366	0.999	0.996	1.359
2010-11	1.005	1.192	1.001	1.004	1.198
2011-12	1.000	1.040	1.000	1.000	1.040
2012-13	1.000	0.906	1.000	1.000	0.906
Mean	1.000	1.001	1.000	1.000	1.001

**Note: Malmquist index averages are geometric means

Table 4: Malmquist Index Summary of Region Wise Means of Maize from 2000-01 to 2012-13

Region	EFFch	TECHch	PEch	SEch	TFPch
Northern Telangana	1.000	1.070	1.000	1.000	1.070
Central Telangana	1.000	1.005	1.000	1.000	1.005
Southern Telangana	1.000	0.939	1.000	1.000	0.939
Telangana average	1.000	1.001	1.000	1.000	1.001

**Note: Malmquist index averages are geometric means

DISCUSSION

The present study was conducted to assess the performance of rice and maize with respect to total factor productivity (TFP) in the state of Telangana. Since Telangana state is of recent origin, it lacks empirical evidence about the TFP performance of agricultural sector. TFP growth of a sector is the index of its long term growth, hence it is important to estimate and analyse the TFP index of every sector. It has been found despite positive TFP for both rice and maize; the indices have witnessed a great deal of fluctuation throughout the study period. The indices of TFP of both rice and maize have registered significant rise and fall during the study period. This fluctuation in the performance of TFP could mainly be due to severe fluctuation in annual rainfall in the state. During the study period the state of Telangana has witnessed the years of both excess rainfall and severe drought. The index of TFP depicted improvement during the years of good rainfall and *vice versa.* The erratic and uneven distribution of kharif rainfall in the state could have been the main reason behind the variation among three regions of Telangana.

CONCLUSIONS

The Malmquist summary index of firm means of rice revealed that Telangana state and its regions witnessed an improvement in the TFP performance over the years as indicated by the TFPch index more than 1. The average TFPch index in Telangana was 1.077 implying a 7.7 per cent improvement in the TFP during the study period. The highest performance was noticed in southern Telangana region with TFPch index 1.143. In the state as well as all three regions the change in TFP was described by TECHch i.e., improvement in "innovation". The average of the Malmquist indices of maize during the study period revealed that Telangana state witnessed stable productivity performance as indicated by TFPch index of 1.001. Northern Telangana and central Telangana registered improvement in the TFP by 7.0 per cent and 0.5 per cent respectively during the study period. In southern Telangana region the TFPch index had deteriorated by 6.1 per cent over the years. All the changes in TFP in all the regions and state were explained by TECHch. The fluctuating performance of the TFP for both rice and maize in the state could be due the heavy yearly fluctuations in the kharif rainfall. Improvement in the irrigation status in the state will improve the performance of the agriculture sector. This can be achieved through adoption of rain water harvesting technologies to store the excess rainfall in the surplus rainy years, providing less water using agricultural technologies to the farmers and so on.

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