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Research Paper

An Analysis of Total Factor Productivity of Rice in Assam

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ABSTRACT

The present study was conducted of estimating the total factor productivity (TFP) growth of rice and its contribution to rice production in Assam and examining the determinants of TFP. The study was carried out for two decades, from 1991-92 to 2010-11, using secondary data, estimated us the Tornqvist Theil index. The input, output, and TFP indices were calculated at a constant price (for 1991-92) of the inputs and outputs to nullify the nominal price effect. Again, the indices were computed for per hectare area and total area under rice in the state to know how efficiently inputs were utilized in both situations. To evaluate the determinants of TFP in Assam, regression was carried out by using Cobb Douglas production function. The study revealed that TFP growth for rice at a constant price was found to be positive in both per hectare area and total area for the study period. Determinants like investment in agriculture and allied activities, expenditure in agricultural research and education, HYV area, rural literacy, irrigation, and cropping intensity were found to have a positive impact on TFP.

HIGHLIGHTS

- TFP growth for rice was found to be positive in both per hectare area and total area in Assam.
- Determinants like investment in agriculture and allied activities, expenditure in agricultural research and education, HYV area had a positive impact on TFP.

Keywords: Assam, rice, TFP, Tornqvist Theil index, determinants

The total factor productivity (TFP) accounts for effects in total output not caused by traditionally measured inputs (or single input-centric analysis). Therefore, growth in TFP is the residual share of output growth after accounting for changes in land, labor, and other conventional agricultural inputs). Changes in TFP can be interpreted as a measure of the collective contribution of non-conventional inputs in agriculture, such as improvements in input quality, market access, economies of scale, and technology (Alston *et al.* 1995). Total Factor Productivity is often seen as the driving force of growth within an economy andmay account for up to 60 percent of growth within economies (Easterly and Levine, 2001).

Assam is situated in the Northeast region of India with a geographical area of 78438 sq km, of which 98.40 percent area is rural. Assam occupies about 2.40 percent of country's total geographical area and provides shelter to 2.60 percent population of the country (Economic Survey of Assam, 2014-15). The economy of Assam is predominantly rural. During 2014-15, 3.16 percent of the growth rate was estimated for agriculture at the constant price of 2004-05. About 99 percent area of the total land mass of the state is rural, and almost 50 percent of the total land area is used for cultivation. The net sown area of the state is 28.11 lakh hectares (2011-12), and it shares 35.80 percent of the total geographical area. Among all crops grown in Assam, rice is the major crop that occupied 59.96 per cent of the state's total cropped area during 2013-14. Rice occupied the lion's share of 97.22 percent of total food grain.

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During the last few decades, the Assam government has made lots of agricultural investments. But whether these investments have contributed significantly towards rice production in the real sense or not is questionable. To answer this question, a study on TFP growth for rice in the state is critical. However, very few studies on rice productivity have been undertaken in Assam during the past four decades or so using TFP approach. Kumar and Mittal (2006) reported in a study that from 1971 to 1986, Assam exhibited increasing TFP by more than 1 percent for rice. While during 1986 to 2000, stagnant TFP growth of rice was reported for Assam. According to a study, for the whole period, 1970 to 1994, Assam was one of the states which exhibited negative TFP growth (Fan *et al.* 1998). Another study showed that, during the period 1999-2000 to 2005-06, 'small' TFP improvements were observed in Assam and reported little technical progress of 1.4-1.99 percent (Chaudhary, 2012). TFP growth for rice in Assam was 3.37 percent during 1971-80, -1.67 percent during 1980-91, and during 1971-91 it was 1.08 percent, according to Kumar and Jha (2005). Again During 1975-2005, TFP for rice in Assam was 0.68 percent (Chand *et al.* 2011). But these studies were not individual studies for Assam concerning the TFP growth of rice. Secondly, after 2005-06, improvements have been made in this sector of the state; therefore, it is important to know their contributions. Considering the above facts, the present study was conducted with the objectives of estimating the TFP growth of rice, its contribution to rice production, and the determinants of TFP of rice in Assam.

Research Methodology

A time period of two decades, from 1991-92 to 2010-11 was chosen by considering the secondary data availability used in the study. For analytical purposes, the entire time period was divided into two sub-periods of one decade each as: Period I- 1991-2000, Period II-2001-2010, and Overall period-1991-2010. The study was carried out in Assam with rice output and eight inputs during the study period based on secondary data. Data relating to area and production of rice were collected from the publications of Directorate of Economics and Statistics, Assam. The quantities of inputs used per hectare and their per hectare expenditure, yield and per unit/hectare price of output were collected from "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops", Directorate of Economics and Statistics (DES), MoA, GoI. The input factors included in the study were human labor, bullock labor, machine labour, seeds, farm yard manure and fertilizers, Interest on capital, rent paid for the land, depreciation on implements, and farm buildings. In this study, the Tornqvist Theil index was used for computing the total output, total input and TFP indices of rice. This Tornqvist Theil index is considered superior for calculating TFP (Rosegrant and Evenson, 1995). By expressing in logarithmic form, the Tornquist-Theil TFP index is given by the following equation-

$$ln\,(TFP_t/TFP_{t-1}) = \tfrac{1}{2}\sum_j (R_{jt} + R_{jt-1})\,ln\,(Q_{jt}/Q_{jt-1}) - \tfrac{1}{2}\sum_i (C_{it} + C_{it-1})\,ln\,(X_{it}/X_{it-1})$$

Where,

R_{jt} = Share of output '*j*' in revenues in the year '*t*'

Q_{jt} = Output '*j*' in the year '*t*'

C_{it} = share of input '*i*' in total input cost in year '*t*'

X_{it} = Input '*i*' in period '*t*'

Q_j and X_i are in monetary values

This index was computed as the ratio of an index of aggregate outputs to an index of aggregate inputs of the individual crop. Considering the index equal to 100 in a particular year (1991-92 in the present study) and accumulating the measure based on the above equation results in the TFP index. In the study, the input, output, and TFP indices were calculated in constant price (at price of 1991-92) of the inputs and outputs to nullify the price effect. Again, the indices were also computed for per hectare area and total area under rice in Assam to know how efficiently the inputs were used in both situations.

The estimation of input, output, and TFP growth rates for the specified periods was done by fitting an exponential (or semi-log) trend equation as follows

$$Y = ab^t$$

Or, $ln\,y = ln\,a + t\,lnb$

Where,

y = time series data on input, output and TFP

b = regression coefficient

t = time period in years

Compound Growth Rate (CGR) of input, output and TFP was computed by using the formula:

$$CGR = (Antilog\ b - 1) \times 100$$

To estimate the contribution of TFP in agriculture, its percent share in total output was estimated.

In order to evaluate the determinants of TFP in Assam, the TFP index was regressed by using the Cobb Douglas production function against the variables - rice area under flood (RA_FL), a number of villages electrified (VL_ELECT), rainfall (RF), the share of the irrigated area to total cropped area % (IRR), expenditure in agricultural research and education (EXP_Agril RES_EDU), investment in agriculture and allied activities(INV_AGRI_ ALLIED), share of HYV area to total rice area % (HYV), rural literacy % (RUR_LIT) and cropping intensity % (CI). Flood is one of the major problems faced by the state's farmers every year. Winter rice is mostly affected since flood occurs mainly during its growing season.

In 2015, the flood destroyed standing crops across an area of 180,000 hectares. Therefore, the flood has a direct impact on the productivity of crops which again reflects total factor productivity. Likewise, rice area under flood is an essential factor to be considered as a determinant of TFP in Assam since rice is the principal crop of Assam. In Assam 98.40 percent area of the total land mass is rural and around 86 percent of the total population lives in the rural area. Electricity is an essential component of agricultural productivity. So, village electrification in the state continues to be a matter of concern since here, most of the agricultural activities are predominantly done in the village area. Therefore, village electrification indirectly affects the TFP growth in Assam. Another important variable of TFP is rainfall. In Assam, crop production is mainly done under rain-fed condition. The state receives, on average 2580 mm rainfall annually (Economic survey of Assam, 2014-15). Excessive rainfall may cause flood problems, and deficit rainfall may cause draught situations both of which hamper crop production. Therefore, rainfall was selected as one of the determinants of TFP. Irrigation is an essential input of agriculture. Assam agriculture depends primarily on rainfall. But due to adverse and unpredictable weather conditions such as flood, drought *etc*, practice double/ multiple cropping and modernization of different agricultural practices in the agricultural sector to cope with the growing needs of agricultural production to feed increasing population, irrigation is highly vital in the state. For the cultivation of summer rice, autumn rice irrigation is required. Therefore, percent share of the irrigated area to gross cropped area of Assam is considered as a determinant of TFP. Agriculture research and education is an important factors of agricultural growth Increase in agriculture productivity can be induced by public investments in research, extension (Rosegrant and Evenson, 1995).

Agriculture research has contributed significantly and substantially to the agricultural productivity of India, and returns to agricultural research have been both stable and high since the 1970s (Kumar and Rosegrant, 1994; Jha and Kumar, 1988; Lau and Yotopoulos, 1972). That is why the expenditure in agriculture research and education is considered as one the vital factors of TFP in Assam. Investment in Agriculture and allied activities is also an important factor for agricultural development as well as total factor productivity. Investment in agriculture and allied activities includes (by excluding agricultural research and education) investment in crop husbandry, horticulture, soil and water conservation, animal husbandry, dairy development, fisheries, forestry, and wildlife, plantation, food, storage and warehousing, agricultural financial institution, cooperation, agricultural marketing. High Yielding Variety (HYV) is an important technological change in Assam agriculture. Introduction of HYV is one of the important steps initiated for agricultural development in the region (Majumder *et al*. 2021).

However, in Assam, these HYV's are extensively used, mainly for rice. Gradually area under high-yielding varieties for rice has been increased. So, the percent share of HYV to total rice area was considered as a determinant of TFP in the study. Literacy plays a vital role in the process of human resource development and national development. Most of the farmers live in the rural area. Literacy among farmers is to be enhanced to cope with the modern technological change in agriculture. In the

state rural literacy rate has significantly increased from 59.74 percent during 2001 census to 69.34 percent in 2011 census. Cropping intensity measures the extent of land-use for cropping purposes during a given agricultural year. Higher cropping intensity indicates higher use of land for crop production. In the state, cropping intensity also shows an increasing trend. During 2001-02 it was 144 percent whereas during 2010-11 it was increased to 148 percent. Cropping intensity also contributes to high output productivity in agriculture, which in turn affects on total factor productivity.

Regression equation fitted, which was specified as following:

$$TFP = f(RA\_FL, VL\_ELECT, RF, IRR, EXP\_Agril\ RES\_EDU, INV\_AGRI\_ALLIED, HYV, RUR\_LIT, CI)$$

It was noted that in the function, all variables are specified in logarithms, except those variables which are defined in percentage terms (Chand *et al.* 2011). The contributions of the determinants of TFP (Mittal and Kumar, 2005) were estimated by the following way:

$$\text{Per cent share in TFP growth} = \left(\frac{\text{Annual growth of determinant}}{\text{Annual growth of TFP}} \times 100\right) \times \text{elasticity of TFP}$$

Since Cobb Douglas function was used to regress TFP against its determinants, therefore, estimated regression coefficient was considered as the elasticity of TFP for the particular determinant as coefficient of a Cobb Douglas production function is its elasticity itself.

RESULTS AND DISCUSSION

Estimation of TFP growth of rice in Assam

Growth of Input, output, and TFP indices of rice per ha and for their total area in Assam were estimated at constant prices of 1991-92 shown in Table 1. Output of rice per hectare increased by 1.80 percent during the period of 1991-2000 and later that declined to the rate of 1.07 percent during the period of 2001-2010. During 1991-2010, the output index of rice per hectare grew at a highly significant rate of 1.61 percent per year. The input index also had risen at a rate of 0.51 percent per annum during the 1st period, which had fallen to a negative rate of -0.70 percent during the 2nd period. Over the period of 1991-2010, input witnessed only 0.03 percent per annum. TFP growth was estimated to be as high as 1.28 percent contributing 71.14 percent to output growth during the 1st period. During the 2nd period, TFP growth improved to a significant rate of 1.78 percent contributing 166.13 percent towards the total output growth of rice per hectare. Due to the negative growth of input, input contributed negatively to the output. Therefore, the contribution of TFP exceeded 100 percent. Rice experienced a highly significant TFP growth of 1.57 percent contributing 97.82 percent to output per hectare during the entire period of 1991-2010 at a constant price**.**

From Table 1 it was observed that, during the 1st period, total rice witnessed to have the positive output-input growth comprising 1.83 and 0.98 percent. Rice experienced significantly positive TFP contributing 46.04 percent in output growth. During the 2nd period, rice was reported to have 2.12 percent of output growth and -0.80 percent of input growth. In the case of TFP, rice exhibited a growth rate of 2.95 percent with 138.87 percent contribution toward the output. For the entire period, rice exhibited significantly positive output growth (1.23 per cent) as well as TFP growth (1.43 percent) per annum. While in the case of input, negative growth was reported.

While comparing the input, output and TFP of crops per hectare with the total rice (as shown in Fig. 1) it was observed that, indices were higher in total area than per hectare area. But overall growth of the output, input and TFP was higher in per hectare area during the entire period. It indicated that per hectare input utilization was more efficient resulting better output and TFP as compared to their total area implying lower allocative efficiency of the inputs in total area.

Examining the determinants of TFP

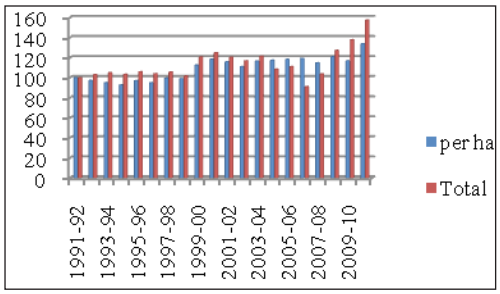
The growth rate in TFP was further analyzed for the whole study period to estimate the determinants and their contribution to TFP growth. It was noted that the estimation was done for total rice produced in Assam, since the selected factors were available

Table 1: TFP growth and its contribution to rice production in Assam

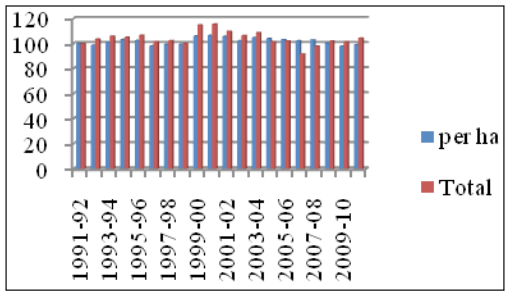
Periods	Output		Input		TFP		Share of TFP in output	
	Per ha	Total	Per ha	Total	Per ha	Total	Per ha	Total
1991-2000	1.80*	1.83*	0.51	0.98*	1.28*	0.84**	71.14	46.04
2001-2010	1.07*	2.12	-0.70**	-0.8	1.78**	2.95*	166.13	138.87
1991-2010	1.61***	1.23**	0.03	-0.19	1.57***	1.43***	97.82	115.64

** Data considered at constant price w.r.t. 1991-92 (in percentage).*

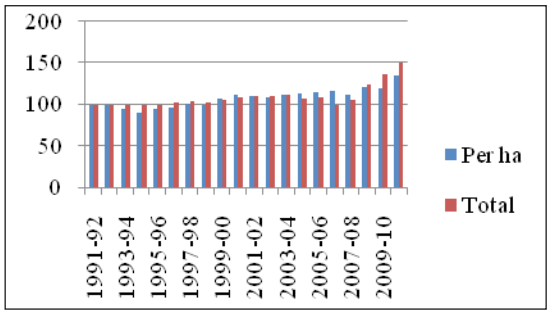
Significant at 10 per cent significance level **Significant at 5 per cent significance level, * Significant at 1 per cent significance level.*



(a) Output index



(b) Input Index



(c) TFP index

Fig. 1: Comparison of input, output and total factor productivity indices of rice per ha with rice total in Assam (at constant price)

for the total area, not for per hectare area. For estimating the factors affecting TFP growth, TFP indices at the constant price were used to avoid the nominal price effect.

The determinants and their contribution to the total factor productivity of rice in the study area were estimated and presented Table in Table 2. Except rice areas under flood, a number of village electrified, and rainfall, all other variables contributed positively towards TFP enhancement. Among them, investment in agriculture and allied activities (0.116) in the state was found to be the most significant determinant of TFP in rice. Public investment in the agriculture sector, as well as allied sector, is increasing day by day by implementing different new schemes. During the study period, with the implementation of lots of new schemes like National food security mission (NFSM), the Horticulture mission, and bringing green revolution to Eastern India (BGREI) *etc*, investment in this sector had been increased with a significant growth rate of 3.84 percent per annum. Another important variable was rural literacy (0.009), having a significant effect on TFP growth. Literacy had an indirect effect on TFP as reported by Mittal and Kumar (2005). Literacy brings more knowledge, more improved skills, more new technologies, and many more. Mittal and Kumar (2000) have concluded that literacy had a positive and significant relationship with farm modernization and agricultural productivity. During the study period, rural literacy had increased with a highly significant growth rate of 1.73 percent. With this growth, it is quite possible to introduce new technological innovations in agriculture by

Table 2: Determinants of TFP and their contribution to TFP growth of total rice in Assam

Variables	Regression coefficient	Annual growth (%)	Elasticity of TFP	Per cent share to TFP growth
Rice area under flood	-0.002	-11.25	—	—
No. of villages electrified	-0.218	-0.92*	—	—
Annual Rainfall	-0.353	-0.28**	—	—
% share of irrigated rice area to total cropped area	0.018	3.31*	0.018	4.17
Expenditure in Agricultural research and education	0.029	6.95***	0.029	14.09
Investment in Agriculture and allied activities	0.116*	3.84*	0.116	31.15
Percent share of HYV rice area to total rice area	0.0002	2.74***	0.0002	0.04
Rural literacy	0.009*	1.73***	0.009	1.09
Cropping intensity	0.003	0.01	0.003	0.002

**Data period considered from 1991-92 to 2010-11.*

Significant at 10 per cent significance level, **Significant at 5 per cent significance level, * Significant at 1 per cent significance level, $R^2 = 0.97$.*

enhancing the awareness among the rural people especially among the farmers. Even, many rural educated unemployed youths have chosen the agriculture as their occupation and are successfully performing it by introducing new technologies in their fields. Despite having significantly positive annual growth rates, percent share of HYV rice area to total rice area (0.0002) and expenditure in Agricultural research and education (0.029) affected TFP growth positively but not significantly. Therefore, even though investment in agricultural research and education as well as the area under HYV of rice is increasing gradually, it seeks more attention to make these more significant towards rice cultivation. Irrigation was also found to be a determinant of TFP enhancement. In Assam, rice is mainly cultivated under rainfed conditions. However, in some parts of the state, irrigation is used for rice, especially for summer rice production to some extent. In the state area irrigation is increasing, but still it is very low. So observing its positive impact (0.018) towards TFP enhancement, it is necessary to increase the irrigation facility in the state. As expected, the flood had a negative effect on TFP growth of rice. On the other hand, rainfall also was reported to contribute negatively to TFP development. During the study period, rainfall significantly declined by 0.28 percent. Since rice cultivation depends mainly on rainfall in the state. Therefore, declined rainfall directly affects adversely on the productivity of rice. Due to the state's inadequate rainfall during the study period, increased rainfall may have a positive impact on agricultural productivity (Majumder *et al*., 2021). Number of villages electrified during the study period also was found to be decreased, resulting in a negative effect on TFP growth of rice. Again, during the study period, the growth of cropping intensity was almost static (0.01%).Therefore, though cropping intensity was found to have a positive effect on TFP of rice, it was non-significant, contributing negligible share to TFP growth.

The contribution of the positive factors to TFP growth was computed by using the elasticities of TFP concerning those positive factors and their growth rates. It was observed that investment in agriculture and its allied activities accounted for the highest share of TFP growth (31.15 percent) among the all considered factors, followed by expenditure in agricultural research and education (14.09 percent) and percent share of the irrigated area to total cropped area (4.17 percent). It was observed that, although the two variables, *viz.*, expenditure in agricultural research and education and percent share of the irrigated area to the total cropped area, showed no significant impact on TFP, they constituted a reasonable share in TFP of rice.

CONCLUSIONS AND POLICY IMPLICATIONS

The present study revealed that TFP at a constant price was estimated to be positive both per hectare and total area for the same period. One policy implication was suggested by the study to give more focus to improving input-use efficiency in total area as well as per hectare area under rice in the state for more crop production. Expenditure in agricultural research and education, rural literacy, irrigation, and cropping intensity were found to have a positive impact on the TFP of rice. Therefore, additional fund allocation for agricultural research, rural education, irrigation, *etc* is required. Rice had an average yield of 20.87 q/ha in Assam, which was below the national average (24 q/ ha) during 2015-16 (Directorate of Economics and Statistics). Research investment has a direct and positive bearing on TFP. There is a need to develop new varieties through research that can break the current low yield. Enhancing rural education might also help farmers to improve technical efficiency and productivity in agricultural production, as reported by Mao and Koo (1997). Role of education in improving farm efficiency and technology adoption has been well established (Lockheed *et al.* 1980; Feder *et al.* 1985; Phillips, 1994). Therefore, encouraging education among rural farmers is one of the crucial steps toward TFP growth. As the rainfall showed a significantly reducing trend in the state, it is very important to increase area under irrigation to ensure prolonged and continuous crop production in the state. Public investment in irrigation is one of the dominant sources of TFP growth, as reported by Chand *et al.* (2011).

However, a tinysmall portion of the area is under irrigation in the state seeking more attention from the Government. Emphasis on the use of short-duration high, yielding paddy varieties to escape from monsoon floods is also suggested by the present study, as it was found to be a crucial source of TFP growth. Indian agriculture has made substantial gains in productivity with the introduction of high-yielding varieties, as measured by indexes of TFP (Rosegrant and Evenson, 1992; Dholakia and Dholakia, 1993; Evenson *et al.* 1999; Fan *et al.* 1999; Majumder *et al*. 2021). Therefore, the increasing area under HYV of rice having resistance to diseases and pests in the state is highly recommended. Cropping intensity was also found to have a positive impact on TFP. But due to its meager growth rate its effect on TFP was very negligible. Besides this, the cropping intensity of Assam is much lower than another advanced state like Punjab, Haryana *etc*. Therefore, it is highly recommended to improve the cropping intensity to improve the current level of food production to the desired level. It will help the state attain sustainable growth in its rice cultivation.

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