Productivity Improvement in Sugarcane Farming in Tamil Nadu (India): Parametric and Non-Parametric Analysis.

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ABSTRACT

Sugarcane productivity is cyclical in India and Tamil Nadu. The post-Green Revolution phase is characterized by high input-use and decelerating total factor productivity growth. Sugarcane productivity attained during the 1980s has not been sustained during the1990s and early 21st century and has posed a challenge for the researchers to shift production function upward by improving the technology index. Examination of issues related to the sugarcane productivity, particularly with reference to Tamil Nadu state which has highest yield in India. Data envelopment analysis (DEA) and stochastic frontier analysis (SFA) used to assess productivity growth of sugarcane farming. The results show consistency between the approaches and there are potentials for efficiency improvements. Second, there has been a productivity improvement in the sector, in the interval 0.7–15% in the periods studied and technical change had the greatest impact on productivity. The average TFP in after introducing variety Co 86032 was larger than that of pre- introduction of this variety. In both periods, productivity growth is sustained through technological progress. In general, policy-makers should try not to be indifferent with respect to the approach used for productivity measurement as these may give different results.

Key words: Sugarcane, TFP, Malmquist Index, variety Co 86032

INTRODUCTION

Sugarcane is the second most important industrial crop in the country is grown about 5 million hectares. The growth of sugarcane agriculture in the country had been consistent during the past seven decades. There was increase in area, production, productivity and sugar recovery. During the period from 1930-31 to 2010-11, the area under sugarcane had gone up from 1.18 million ha to 5.0 million ha, productivity from 31 tonnes to 70 tonnes per hectare and total cane produced from 37 million tonnes to 340 million tonnes. Current sugar production in the country is about 24.5 million tonnes (Co-operative sugar 2011).

Among the sugarcane growing states in India, Tamil Nadu ranks third in area (0.37 M.ha) and production (3.5 Million tonnes) and first in productivity (105 t/ha) and sugarcane productivity is 40% higher than the national productivity (69.5 t/ha). The area and production of sugarcane at Tamil Nadu is comparable as equal as Australia and USA.

One of the notable characteristics of the sugarcane agriculture in the country is its inherent instability. The cane productivity in the state is dependent on rainfall and drought spells appearing in regular intervals leading to wide fluctuations in cane productivity. Rising yields also contributed to the growth in sugarcane production. Yields rose by more than 30% from an average of 75 tonnes/ha in the early-sixties to more than 105 tonnes/ha in the mid-nineties. Following rapid increases in productivity in the seventies and early-eighties, the rate of growth slackened in the latter part of the nineties. The extension of cane area to marginal lands and the use of varieties susceptible to disease were partly responsible for the slower growth. However, an average sugarcane yield varies region to region in the state which greatly affects the cost of cane production in the state.

To improve the productivity and efficiency of the sugarcane production system, new varieties and technologies were introduced in the state to shift the productivity horizon. Never the less, the yield scenario did not change much and become cyclical and uneven up to 1999, however, new noble variety (Co 86032)was introduced in the state, then the yield was increased significantly. Hence, to identify the different factors responsible for the productivity growth, this study was undertaken with panel data to estimate technical change, efficiency change and total factor productivity of sugarcane production system of the state.

Total Factor Productivity (TFP) of Sugarcane

Productivity growth in agriculture is both a necessary and sufficient condition for its development and has remained a serious concern for intense research over the last five decades. Solow (1957) was the first to propose a growth accounting framework, which attributes the growth in TFP to that part of growth in output, which cannot be explained by growth in factor inputs like land, and capital. Development economists and agricultural economists have computed productivity and have examined productivity growth over time and differences among countries and regions. Productivity growth is essential to meet the food demands arising out of steady population and economic growth.

TFP is an important measure to evaluate the performance of any production system and sustainability of a growth process. However, a number of complex conceptual issues are not adequately captured by an analysis of the kind described earlier. First, for example, agricultural research has contributed to breaking the seasonality in crop production. Second, a great deal of stability has been introduced in crop production by providing farmers with varieties that tolerate or resist adverse environmental conditions. Finally, high sugar recovery improvements have added to

the value of production as in the case of sugarcane production. All of these and many other contributions have been subsumed under a residual TFP measure. It would be worthwhile to identify these influences explicitly, which would lead to a more realistic assessment of the productivity of sugarcane production system.

The productivity in each district is conditioned by various micro and macro environmental and biotic factors besides socio-economic aspects. There is a wide gap in productivity between the fertile and the marginal soil and climate regions of the state, the former averaging about 125 t/ha and the latter 90 t/ha. Wide gap exists between the potential yield and the yield levels achieved at present in all the districts/regions without exception. Bridging of the yield gap should be the primary focus for attaining the projected targets for the future.

To provide an historical perspective on sugarcane productivity, figure 1 depicts productivity over the last three decades (1981–2010). Before introduction noble variety (Co86032), productivity has been sluggish, with year to-year fluctuations. Since 1979/1980 production season, there seems to be some improvement in the productivity of sugarcane in this period (1999-2010). Largest improvement can be observed in the recent past.

While much evidence has been provided attesting the productive performance of the agricultural sector in India and factors influencing it (Kumbakar and Lovell, 2000: Kumar et al., 2003, 2006 and 2008) there is little evidence on sugarcane crop – specific and sub – regional productive performance. An assessment of crop – specific efficiency and productivity analysis should be of more interest to policy-makers implementing liberalization policy than overall aggregates.

The rationale is twofold; (a) An insight can be gained on the potential for resource savings and productivity improvements of sugarcane crops and, (b) the

producers can learn from the front-runners how best to utilize their resources efficiently. Inter alia, issues of interest in this study are: (a) is there any potential for improving the efficiency of sugarcane producers in Tamil Nadu? If so, what are the magnitudes? (b) Has there been any productivity progress in Tamil Nadu cane production since 1981? The choice of 1981 as reference point is highest yield recorded since post green revolution period in the state. (a) and (b) irrespective of the methodology applied? While questions (a) and (b) are interesting to the extent that the much needed insight on the performance the sector is gained, question (c) provides evidence on the consistency of frontier techniques within two different and most commonly used approaches.

This is of considerable interest for policy purpose. If methods do not give results that are similar or highly correlated to each other, the policy may be fragile and depends on which frontier approach is employed. While the vast majority of empirical studies on productivity growth in the agricultural sector mostly have utilized only one method to estimate their efficiencies, this study focuses on two methodological approaches for measuring efficiency as follows:

(1) The construction of a nonparametric piecewise linear frontier using linear programming method known as data envelopment analysis (DEA) (Charnes et al., 1978);

(2) The construction of a parametric production function using stochastic frontier analysis (SFA) (Aigner et. al 1977; Meeusen and van de Broeck, 1977; Battese and Coelli, 1992, Coelli, 1996).

The data

The farm-level data on sugarcane yield and the use of inputs and their prices from year 1981 to 2010 collected under the "Comprehensive scheme for the study of

cost of cultivation of principal crops," Directorate of Economics and Statistics (DES), Government of India (GOI), were used in the analysis of TFP. The out put prices were collected from various issues co-operative sugar journal of 1980 to 2011. The missing year data on inputs and their prices were collected using interpolations based on trends of the available data. The time-series data on area, yield, production, irrigated and high-yielding variety (HYV) area for the sugarcane were taken from the various published reports of the DES (GOI). The share of the hills region in sugarcane production was marginal and was therefore not included in the analysis.

The rest of this paper is organized as follows: The theoretical foundation for the stochastic and non-stochastic measurement of the TFP in section 2. Section 3, the data used is described and the parameter estimates are reported to infer which factors explain the growth of output. A final section concludes.

II. Methodology

This study utilizes two methodological approaches for measuring efficiency namely: data envelopment analysis (DEA) (Charnes et al. 1978) and production function using stochastic frontier analysis (SFA) (Coelli, 1996). For measuring productivity growth, both methods and their extensions to Malmquist index approach are used throughout the study. Each of the methods and their subsequent Malmquist indices is briefly described as follows:

$$M_o(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_0^t(x_t+1, Y_t+1)}{d_o^t(x_t, y_t)} * \frac{d_0^{t+1}(x_t+1, y_t+1)}{d_o^{t+1}(x_t, y_t)} \right]^{1/2} \text{---------- (1)}$$

Where $d_0^t \ (x_t, y_t)$ is the output distance for year t, which is defined as the ratio of observed output to the maximum output, y producible with given technology and

input vectors, x (Shapard, 1970). The superscript is the value of the output distance evaluated input-output of year *t+1* using technology of year t.

Equation (1) can be decomposed into the following two components namely efficiency change index which measures the output –oriented shift in technology between two periods and the technical change between period *t+1* and t. If the technical change is greater (or less) than one, then technological progress (or regress) exists.

Symbolically,

$$\text{EFFCHI} = \frac{d_o^{t+1} + (x_{t+1}, Y_{t+1})}{d_o^t(x_t, y_t)} \quad \text{---------- (2)}$$

and

$$\text{TECHCHI} = \left[\frac{d_0^t(x_{t+1}, Y_{t+1})}{d_o^t(x_{t+1}, y_{t+1})} * \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_o^{t+1}(x_t, y_t)} \right]^{1/2} \quad \text{---------(3)}$$

There exist several methods of estimating the distance functions which makes up the Malmquist TFP index. The most popular and widely adopted in recent time has been the DEA like linear programming (LP) methods suggested by Fare et. al (1994) and its parametric equivalent – stochastic frontier method adopted in this study.

Stochastic Frontier Method

The stochastic production function for panel data can be written as

$$\text{In } (y_{it} = f(x_{it}, t, \alpha, v_{it} - u_{it}) \text{ ---------- (4)}$$

I = 1, 2, ……N and t = 1, 2, ……T (Battese and Coelli 1992)

Where y_{it} is production of the ith firm in year t, α is the vector of parameters to be estimated. The v_{it} are the error component and are assumed to follow a normal distribution N $(0, \sigma_{it}^2)$, u_{it} are non negative random variable associated with technical

inefficiency in production which are assumed to arise from a normal distribution with mean u and variance σ_{μ}^{2} which is truncated at zero. F(.) is a suitable form (e.g translog), t is a time trend representing the technical change.

In this parametric case, according to Coelli et. Al (1998), the technical efficiency (TE) are obtained as

$TE_{it} = E(\exp)(-u_{it})/v_{it} - u_{it})$ ---------- (5)

This can be used to compute the efficiency change component by observing that

$TE_{it} = d_0^t(x_{it}, y_{it})$ and $TE_{i,}t+1 = d_0^t t+1(x_{i,t+1,}Y_{i,t+1})$ the efficiency change (EC) is

$EC = TE_{it} / TE_{i,t+1}$ ----------(6)

An index of technological change between the two adjacent periods t and *t+1* for the ith region can be directly calculated from the estimated parameters of the stochastic production frontier by simply evaluating the partial derivatives of the production function with respects to time at x_{it} and $x_{i,t+1}$ Following Coelli et al (1998), the technical change (*TC*) index is

$$TCit = \left\{\left[1 + \frac{\delta f(x_{it}, t+1, \alpha}{\delta f + 1}\right] x \left[1 + \frac{\delta f(x_{it}, t, \alpha}{\delta f}\right]\right\}^{1/2} \text{ ---------- (7)}$$

The TFP index can be obtained by simply multiplying the technical change and the technological change i.e

$TFP_{it} = EC_{it} * TC_{it}$ ---------- (8)

This is equivalent to the decomposition of the Malmquist suggested by Fare et al (1994).

Empirical Specification

This study utilized data on output and inputs of sugarcane of the Tamil Nadu to construct indices of TFP using the two methods described by equations 1 – 8. The sample data comprise annual measures of the output of each crop and 6 direct inputs

(land area, seed, fertilizer, labour, machine labour and irrigation). For the purposes of the present study, several functional forms were fitted beginning with Cobb-Douglas technology. The underlying stochastic production frontier function upon which the results and discussion of this study are based is approximated by the generalized Cobb-Douglas form (Fan 1991). The function may also be viewed as a translog specification without cross terms, i.e. a strongly separable-inputs translog production frontier function of the sugarcane is specification as:

$$\text{In } y_{it} = \alpha_o + \alpha_h \text{ In } H_{it} + \alpha_s, \text{ In } S_{it} + \alpha_f \text{ In } F_{it} + \alpha_l \text{ In } L_{it} + \text{In } K_{it} + \text{In } I_{it} + \alpha_t t + \frac{1}{2} \alpha_n t2 + \alpha_{ht}$$

$$(\text{In } H_{it})t + \alpha_{st} (\text{In } S_{it}) + \alpha_{ft} (\text{In } F_{it}) t + \alpha_{it} (\text{In } L_{it}) t + \alpha_{kt}(\text{In } K_{it})t + a_{it} (\text{In}I_{it})t + v_{it} - u_{it} \text{ ---------- (9)}$$

Y_{it} is the output of crop i in the year

H_{it} is the hectares of land cultivated sugarcane each year

S_{it} is the quantity of seed planted in ‘tonnes

F_{it} is the quantity of fertilizer used in ‘kgs

L_{it} is amount of labour used in mandays

K_{it} is the amount of machine labour used in man days

I_{it} is the proportion of each crop land area under irrigation

In is the natural log

α_i *s* are unknown parameters to be estimated

v_{it} *s* are iidN (0, σ,) random errors and are assumed to be independently distributed of the u_{it} s which are non negative random variables associated with TE inefficiency.

Outputs:

This is the Quantity of sugarcane production in ’000 kgs.

Inputs Fertilizer: Fertilizer use is proxyed as the total fertilizer use in kgs.

Labour: This is measured as the amount of labour in cane production proxyed as the

economically active agricultural labor force per unit of area.

Machine labour: it refers to the amount of machine and skilled machine operator used in cane production.

Land: Expressed in '000 ha, it is measured as land area under cane cultivation.

Seed: expressed in '000 metric tonnes, it covers quantity of sugarcane seed (setts) planted/ha.

Irrigation: This is the proportion of rice land area that is irrigated.

III. EMPIRICAL RESULTS AND ANALYSIS

The results of the analysis are in two steps. First we outline the results based on the SFA and DEA approaches. Then we present the efficiency and technical change results of both methods, followed by the Total Factor Productivity Analysis.

The Results of the Stochastic Frontier Model

Parametric productivity measures are based on the estimated parameters of the stochastic frontier function (9), and so a brief discussion of these estimates and their statistical properties precedes our comparative analysis of productivity indices. The estimated parameter of the stochastic quasi translog production frontier function is estimated using FRONTIER 4.1 software (Coelli, 1996). The parameter estimates of the model for the whole period (1981-2010), pre-introduction of variety Co86032 period (1981-1998) and introduction of variety Co86032 period (1999-2010) were presented in Table 1. The variance parameters, α^2 and ¥ are significantly different from zero. This provides statistical confirmation of the presumption that there are differences in technical efficiency among farmers. The mode of the truncated normal distribution μ, is significantly different from zero, providing statistical evidence that the distribution of the random variable μ, has a non-zero mean and is truncated below

zero. Thus the stochastic frontier production function is empirically justified. Further, logarithm of the likelihood function indicates a satisfactory fit for the generalized Cobb Douglas specification. The statistical significance of all of the parameters α^2 and L reinforces the view that technical efficiency affects productivity.

The Maximum Likelihood Estimates (MLE) results indicate that twelve out of fifteen variables are found to be statistically significant. Apart from fertilizer, the coefficients of all the variables have the expected positive signs over the entire analysis period. The negative coefficient of fertilizer over the entire analysis period suggests operation in stage III of the production function where there is considerable congestion in the use of fertilizer. Such congestion might be due to late availability of fertilizer to farmers in the state. Over the analysis period the coefficient of both labour and capital are positive and significant. The coefficient on the time trend indicates positive technological progress in sugarcane production between 1981 and 2010. The frontier is shifting upwards at annual rate of 8 %. The technological progress actually takes place after introduction of variety Co86032 indicated technological decline in pre-introduction of variety Co86032 in the state.

IV. Total factor productivity (TFP) and its decomposition

Malmquist productivity indices: SFA

The summary description of the average annual TFP obtained from using the stochastic frontier analysis and its decomposition into efficiency and technical changes over the entire period for each country are presented in Table 2. The evolution is made clearer in figure 2. It should be recalled that if the value of the Malmquist index or any of its components is less than one, it implies regress between two adjacent periods, whereas values greater than 1 imply progress or improvement.

The values of the indices capture productivity relative to the best performers. In this study, the Malmquist indices measure year to year changes in productivity. The evolution in Figure 2 indicates that differences exist among the years.

A comparison of the productivity in the pre-introduction of variety Co86032 period with after introduction of variety Co86032 period (Table 2) shown that more technological progress and hence more improvement in productivity was recorded after introduction of variety Co86032 than pre-introduction of variety Co86032 period. The mean technical change after introduction of variety Co86032 and pre introduction of variety Co86032 periods were 1.234 and 1.140 respectively. The annual TFP growth over the whole period is 7.6%. The improvement was more due to technological progress rather than improvement in efficiency. A major contributor to sugarcane TFP growth in the recent decades has been the technical change. The TFP changes indicate more progress after introduction of variety Co86032 than pre-introduction of variety Co86032. Two things could be responsible for this phenomenon. First, the impressive research of sugarcane breeding institute (SBI) and extension department of the sugar factories which led to adoption of improved Co 86032 variety of sugarcane at Tamil Nadu. The second is the competitive State Advised Price (SAP) for sugarcane which tend to boost farmers' income in the recent time period in the state.

DEA Result

The same sample data were used to calculate the set of indices using DEA-like method described in equations 1 to 3. The calculations were done using a DEAP version 2.1 Computer programme and the evolution is shown in Figure 3. The overall TFP growth rate was 4.3% and it is driven mainly by technical change as was the case with the stochastic approach. In general however, the two approaches agree that over

the analysis period, there have been a productivity progress in the sugarcane production system of Tamil Nadu. Like the SFA approach, the DEA approach show on the average that efficiency change indices are smaller than the technical change components. Also, it can be observed that the TFP of SFA are higher than DEA's perhaps because the efficiency scores of SFA tends to be higher than DEA's. Quite similar conclusion was reached by Kwon and Lee 2004 when considering the TFP of Korean rice using both DEA and SFA methods. The finding is however contrary to Odeck 2007 who discovered that the DEA's efficiency scores and TFPs tend to be higher than SFA in Norwegian grain farming.

Over the entire analysis period, the efficiency change is about 0.994 which is by far lower than 1.048 obtained in case of stochastic approach. However, an even greater difference is observed in the technical change component. Though both methods indicate TFP progress, the SFA indicates more productivity progress than the DEA method over the analysis period. Table 3 shows a summary description of the average performance of the entire time period of 1981 – 2010; pre-introduction of Co86032 (1981-1998) and after introduction of Co86032 (1999 – 2010). Taking a look at the result, the entire period (1981 – 2010) productivity increased on the average 8%. However TFP decline on the average in pre- introduction of Co86032 period whereas the average change in the total factor productivity index was 4.5%. The growth in was due mainly to innovation rather than improvement in efficiency. The result of this study differ significantly from few examples of rice – specific TFP studies such as Cassman and Pingali (1995) and Pardey et al. (1992). While they discover decline in rice TFP in Asia, the result of this study indicates increase. Another major difference is that the major source of rice productivity growth in Asia is efficiency change while in sugarcane it is due mainly to technical change. The use

of inputs efficiently in Asia contributes more to TFP growth than net gains from technological change. Hence, the sugarcane policy content of Tamil Nadu could be re-defined to accommodate productivity increasing policies inherent in ASEAN green revolution.

V. CONCLUSION AND POLICY RECOMMENDATION

The present research applied non-parametric and parametric models to a sample of panel data of sugarcane production for the period of 1981–2010. The productivity growth was estimated using the Malmquist index obtained through both parametric and non-parametric approaches. The productivity measures are decomposed into two sources of growth namely efficiency change and technical change. The results show evidence of phenomenal growth in the TFP after introduction of Co86032. In both periods, productivity is sustained through technological progress. Several inferences may now be drawn from the comparative analysis of DEA and SFA efficiency and productivity models examined. First, the non-parametric results tend to fluctuate widely. This is clearly the consequence of the assumption on the stochastic component, something which may be intensified for agricultural data. The second is that inefficiency and productivity growth exists over the decadal period. The magnitude of inefficiency and the extent of productivity growth that has taken place vary between the approaches applied. Third, examining the components relating to the shift in the frontier (TC) and efficiency change (EC), technical change turned out to be a more important source of growth in both parametric and non-parametric models.

A promising finding there upon is that the two approaches applied are, on average, in conformity to each other although the magnitudes are different. In terms of efficiency measurements, the differences between the methodologies are very sensitive on levels of segmentations. In this respect, the somehow conform to

previous findings in the literature e.g., Wadud and White (2000). In terms of productivity measurement, even though both approaches track total productivity similarly, they do not map each well at the decomposition level. The deviations between DEA and SFA could have been anticipated because the SFA incorporates stochastic factor while DEA does not. The differences between the techniques applied here suggests that policy-makers as well as researchers should not be indifferent as to the choice of technique for assessing efficiency and productivity, at least with respect to the magnitudes of potential for efficiency improvements and productivity growth.

Finally, studies have not been able to detect why and how the different approaches are so different with respect to the decomposed productivity measures. In this respect necessary caution should be observed against widespread application of either SFA or DEA until such time that the field of efficiency and productivity measurement understand how and why these approaches portray efficiency and productivity the way they do. To this end, there is a need for continuous research in understanding the differences observed, which in this study concerns the magnitudes rather than conflicts. Further limitation of the study is that the data used as shown in the yield curves tend to fluctuate considerably. This mean that yield of sugarcane was influenced by climate and soil parameters. Given the caution in interpreting the results, the following policy recommendations are suggested from the findings:

1. The government of Tamil Nadu should invest more in functional agricultural extension services to enhance efficient use of available productivity increasing inputs.
2. Given differences in the contribution of efficiency change and technological progress to the TFP of the sugarcane, the research institute focus to develop input responsive sugarcane varieties to improve efficiency of the crop.

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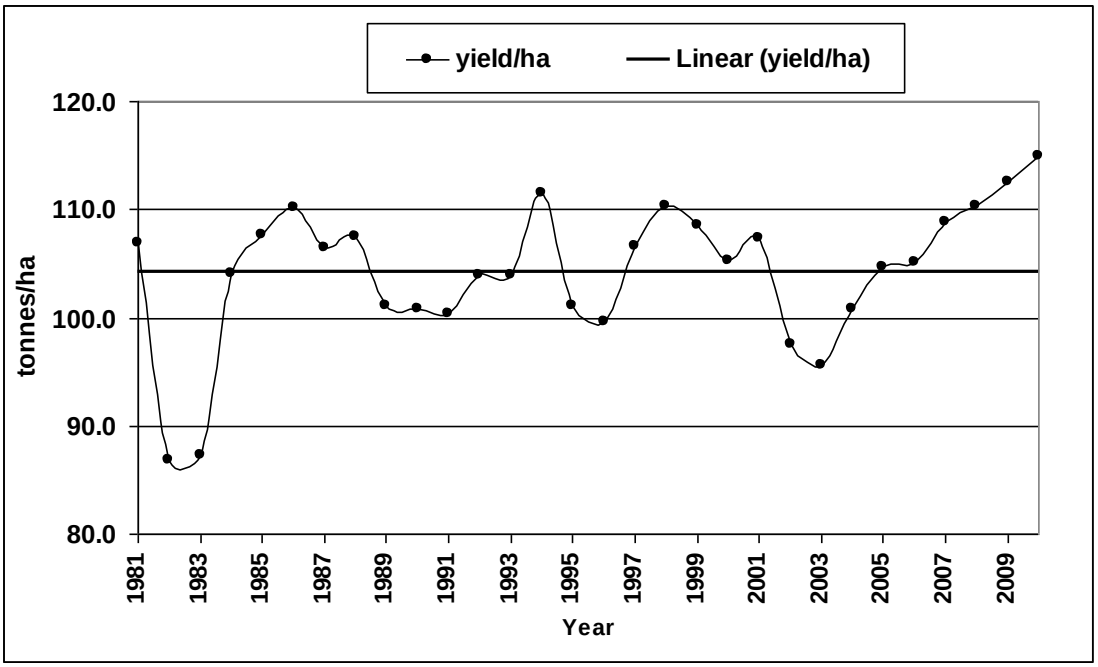

Fig.1 Yield pattern of sugarcane in Tamil Nadu (1981-2010)

TABLE 1: MLE Estimates OF THE Stochastic Frontier Model for Sugarcane

Coefficient	*1981-2010*		*1981-1998*		*1999-2010*	
	estimate	t-ratio	estimate	t-ratio	estimate	t-ratio
α_0	-1.44	-3.42	2.00	5.54	1.10	5.44
α_h	0.61	6.81	0.73	4.96	0.56	16.13
α_f	-0.052	-3.67	0.056	2.86	-0.0097	-0.74
α_l	0.41	9.94	-0.020	-0.28	0.26	8.49
α_s	0.33	6.25	0.098	1.71	0.021	0.76
α_i	0.029	1.28	0.13	1.39	0.43	12.75
α_k	0.012	0.85	-0.12	-7.36	0.058	4.91
α_t	0.12	9.81	-0.066	-0.92	0.082	6.20
$\alpha\ 0.5_{tt}$	0.0011	5.64	-0.0067	-6.74	0.0011	5.12
α_{ht}	0.0044	1.39	0.025	9.09	0.012	4.59
α_{ft}	0.0020	3.02	-0.0053	-2.06	0.00032	0.34
α_{lt}	-0.012	-7.36	-0.00064	-0.11	-0.015	-7.66
α_{st}	-0.013	-6.31	-0.013	-1.11	-0.0053	-2.23
α_{it}	0.0065	5.79	0.00042	0.23	-0.013	-6.76
α_{kt}	0.0020	3.28	0.0051	6.84	0.00088	0.90
α^2	0.054	8.54	0.048	6.31	0.041	10.86
¥	0.99	3.04	1.00	5.66	1.00	6.12
L	173.33		78.51		183.79	

Coefficients are found significant at 1, 5, and 10 %.

Table 2: TFP and its Decomposition

Year	*Stochastic frontier analysis (SFA)*			*Data Envelopment Analysis (DEA*		
	Efficiency change	Technical change	Total Factor productivity	Efficiency change	Technical change	Total Factor Productivity
1981	1	1	1	1	1	1
1982	0.806	0.976	0.787	0.832	1.077	0.896
1983	0.888	0.97	0.861	0.845	1.072	0.906
1984	1.023	1.017	1.04	0.967	1.073	1.038
1985	1.039	1.097	1.14	1.0123	1.921	1.945
1986	1.002	1.691	1.694	1.141	1.071	1.222
1987	1.002	1.356	1.359	1.063	1.078	1.146
1988	1.002	1.456	1.459	1.061	1.079	1.145
1989	0.965	0.949	0.916	0.92	1.08	0.994
1990	0.665	1.045	0.695	0.895	1.081	0.967
1991	0.797	1.014	0.808	0.871	1.083	0.943
1992	1.067	0.953	1.017	0.861	1.079	0.929
1993	1.071	0.963	1.031	0.859	1.079	0.927
1994	1.715	1.075	1.844	1.314	1.087	1.428
1995	0.962	0.977	0.94	0.962	1.001	0.963
1996	0.892	1.025	0.914	0.852	1.09	0.929
1997	0.935	0.925	0.865	0.922	1.025	0.945
1998	0.915	0.91	0.833	0.911	1.096	0.998
1999	1.095	1.197	1.311	1.125	1.092	1.229
2000	1.078	1.025	1.105	0.935	1.092	1.021
2001	0.91	1.452	1.321	1.174	1.094	1.284
2002	0.963	1.256	1.21	0.988	1.09	1.077
2003	0.965	1.352	1.305	1.137	1.091	1.240
2004	0.895	0.996	0.891	0.964	1.085	1.046
2005	0.834	1.251	1.043	0.935	1.097	1.026
2006	0.929	1.174	1.091	0.947	1.098	1.040
2007	1.156	1.008	1.165	1.073	1.099	1.179
2008	1.162	1.128	1.311	1.066	1.099	1.172
2009	1.192	1.456	1.736	1.119	1.1	1.231
2010	1.185	1.523	1.805	1.089	1.132	1.233

Source: author's work

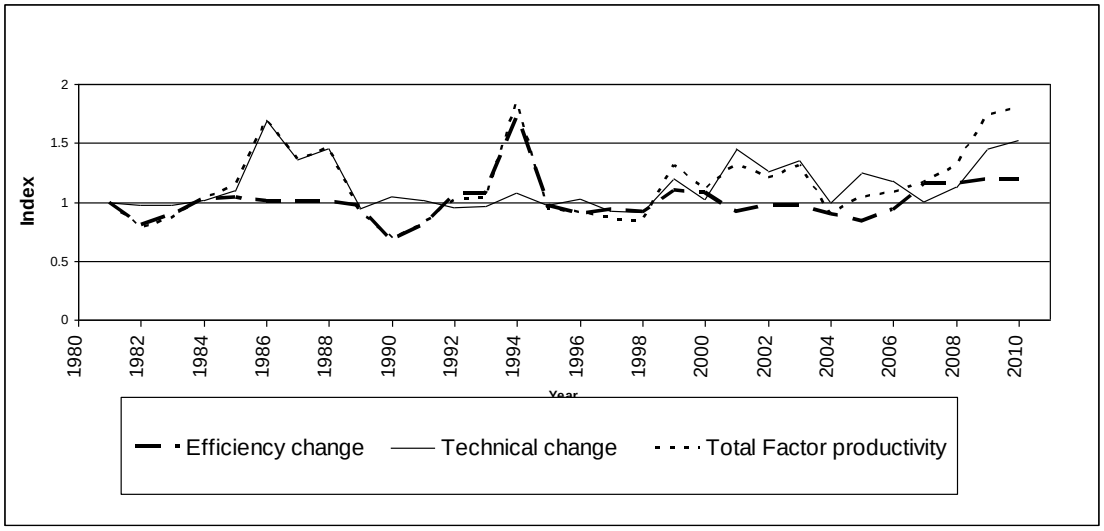

Figure 2. TFP and its decomposition by Year- SFA (1981-2010)

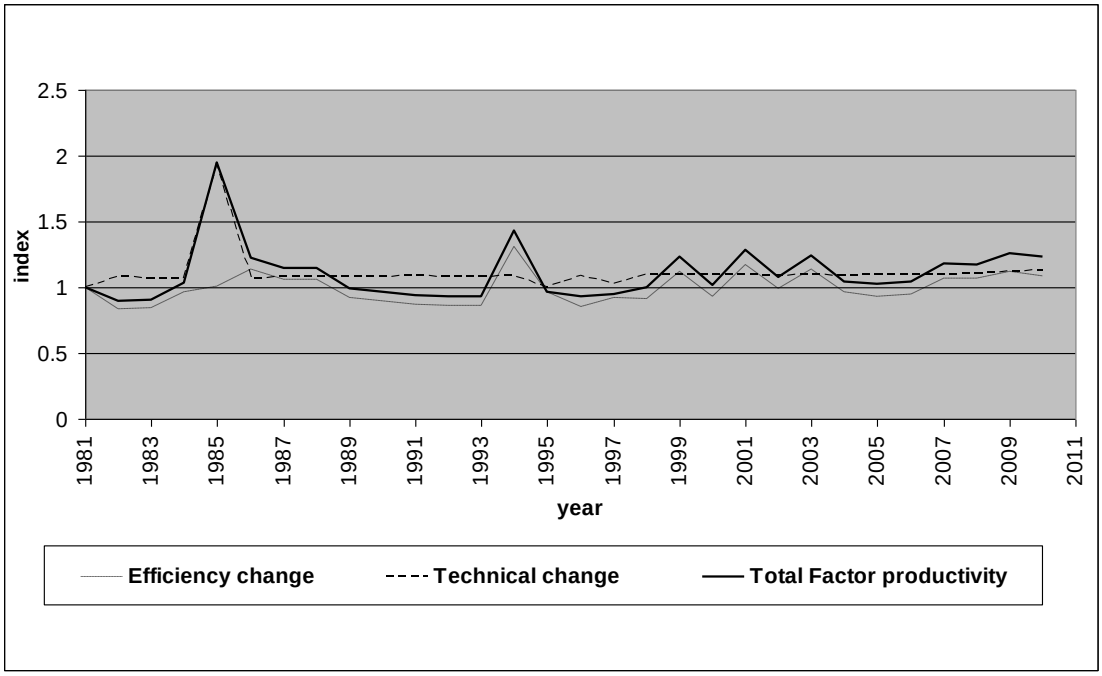

Figure 3. TFP and its decomposition by Year- DEA (1981-2010)

Table 3: Efficiency change (EC), technical change (TC) and Total Factor productivity (TFP) of pre and post introduction of Variety Co 86032 in Tamil Nadu

Year	1981 – 2010			1981-1998			1999 – 2010		
	EFFCH	TECH	TFP	EFFCH	TECH	TFP	EFFCH	TECH	TFP
Stochastic Frontier Analysis (SFA)	1.048	1.14	1.126	1.076	1.14	1.112	1.005	1.234	1.147
Data Envelopment Analysis (DEA)	0.994	1.108	1.043	0.976	1.118	1.094	1.022	1.092	1.117