Int. J. Cur. Tr. Res (2013) 2 (1): 236 - 244

ISSN: 2278-8042
www.injctr.com

Decomposition of Total Factor Productivity Change in Temi Tea Estate: A Malmquist Productivity Index Approach

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Received: 18 May 2013/ Accepted: 25 June 2013/ Published online 29 June 2013.

ABSTRACT

The paper is an empirical study of the decomposition of the Total Factor Productivity Change of the seventeen sections (firms) of Temi Tea industry in Sikkim, India, for Eleven years. The Data Envelopment Analysis based Malmquist Index approach was used and the result implied that the average total productivity change (1.1%) during the period is largely due to technological change. Comparing the productivity change in pre and post organic period, it was found that the productivity change is faster in the pre organic period and no change occurred in post organic period. The study suggested focus on the improvement on the managerial function through training, government investment in educating the garden people, initiatives for brand building of the product for viable and sustainable production in the long run.

Key words: Technical Efficiency Change, technological change, scale efficiency change, total factor productivity change.

Introduction

Tea is the oldest industry with a history dating back more than 150 years with a current turnover of 100 billion *Rupees*. Tea is grown mainly four states (West Bengal, Assam, Tamilnadu and Kerala) of India. Its importance is recognized in terms of direct employment of 1.5 *million* people and another 10 *million* indirectly. More than 50 percent of the women workers are employed in the tea industry. India produces 966 *million Kilograms* (*MK*) of tea in 2010 of which 76 per cent is produced in North East States of India. It consumes 837 *MK* in 2010 and brings $413 *Million Dollaras* foreign exchange per annum. Sikkim, after its statehood in 1975, started taking initiatives for the development of such small-scale industries, which are geographically look sustainable. The tea industry of Temi of South Sikkim, India, established in 1969 taken over by the Sikkim government in 1975 has a distinguished character of becoming complete organic in its process of production since 2005(unpublished record of the Temin Tea Estate. Since tea estate provides employment in large section of the population and earns foreign exchange, it is very much important to study the changes in the total factor productivity during the 2001 - 2011. The paper empirically studies the decomposition of the total factor productivity change (TFPC) into technical efficiency change (TEC) and technological change (TCC). Further TEC is decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC). Malmquist Index (MI) has been utilized to estimate all such components. MI based on Data Envelopment Analysis (DEA) is one of the prominent indexes for measuring the relative productivity change of the producing units in multiple time periods. The original idea of Malmquist Index (MI) was proposed by Malmquist (1953) who, advocated comparing the input of a given firm at two different point of time in terms of the maximum factor by which the input in one period could be decreased such that the firm could still produce

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same output level of the other time period. Finally Fare *et al.* (1992) successfully shown that MI can be calculated using non parametric DEA on assuming constant returns to scale and estimated technological change and productivity change over a period of time. Fare et al (1994) has extended its application through the use of variable returns to scale. And hence scale efficiency could be estimated. Fulginity and Perrin (1998) used a parametric meta production function and a non- parametric MI to examine the performance of the agricultural sectors in a set of 18 less developing countries and find productivity regress in many of them. Trueblood (1996) used non-parametric MI and finds negative productivity growth in a significant number of developing countries. Arnade (1998) estimated agricultural productivity indices using non-parametric MI for 70 countries during the year 1961-93. Nin *et al.* (2003) estimated TFPC for 20 countries during 1961-1994 using non-parametric MI and finds most of developing countries experience productivity growth. Coelli et al (2003) estimate TFPC for Bangladesh crop and find a decline in TFPC over the period. Alene (2009) estimated TFPC in African agriculture for the period 1970-2004 using both contemporaneous and sequential MI and it has been found that the sequential MI was found to be rising at 1.8% per annum. Kumar and Rosegrant (1994) found that TFPC has risen by 1.8% annually in southern region of India.

Chand *et al.* (2011) estimates crop level Total factor productivity change for the period 1986-2005 using Tornqvist index and concludes highest TFP growth for wheat crop. Mukharjee and Khuroda (2001) used Tornqvist-Theil methodology to construct the TFP index for Indian agriculture in fourteen states from 1973-1993 and find TFP index to be 1.73. Murgai (1999) uses Tornqvist-Theil approach to estimate TFP growth in Punjab at district level and finds 1.9% TFP average growth from 1960-1993. Rao (2005) estimated TFP across different crops and found growth rate for all crops to be 0.23% in the pre 1990 and -0.7% in the post reform period. Other studies related to TFP are Bhusan (2005), Kumar and Mittal (2006).

Materials and Methods

The discussion of efficiency measurement begins with Farrell (1957), who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of farm efficiency that could account for multiple inputs. Farrell (1957) proposed that efficiency of firm consists of two components: technical efficiency which shows the ability of a firm to obtain maximal output from a given set of inputs and allocative efficiency implies the ability of a firm to use inputs in optimal proportions, given their respective prices production technology. The Farrell input-output oriented technical efficiency measures are equivalent to the input-output functions distant functions of Shephard (1970) and Primont (1995). It is possible that a firm is both technically and allocatively efficient but the scale of operation of the firm may not be optimal. Hence, efficiency of the firms might be improved by changing their scale of operations i.e., to keep the same input mix but change the size of operation. If the production technology is globally constant returns to scale technology, then the firm is automatically scale efficient.

There have been several attempts to measure scale efficiency and its influence on productivity change over time. Some of the earlier measures of scale efficiency are Banker and Thrall (1992), Fare et al (1994). Fare et al (1998) presented a definition of scale efficiency and use it in deriving a decomposition of productivity change over time. Balk (2001) provides a formal framework to define scale efficiency and to study the role of scale efficiency in productivity change.

Measuring change in productivity

Productivity is essentially a level concept and measures of productivity can be used in comparing performance of firms at a given point of time. Productivity change refers to the movements in productivity performance of a firm or an industry over time. In the presence of multiple output and inputs, TFP may be defined as a ratio of aggregate output produced relative to aggregate input used. Aggregation of inputs and outputs gives rise to index number problem. The change of productivity by a Total Factor Productivity (TFP) or a multi -factor productivity Index, among several approaches to measure changes in TFP, the component-based approach to productivity change as advocated by Balk (2001) was used. Caves *et al.* (1982a, 1982b) first introduced the Malmquist Index (MI). The index is constructed by measuring the radial distance of the observed output and input vectors in period t+1 and t relative to a reference technology. In case of panel data DEA-like linear programming and a MI can be used to measure productivity change and to decompose the productivity change into technical change and technical efficiency change. Fare *et al.* (1994) specified an output based Malmquist productivity change Index as

$$M_I(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left(\frac{D_0^{\,t}(Y_{t+1}, X_{t+1})}{D_0^{\,t}(Y_t, X_t)} \times \frac{D_0^{\,t+1}(Y_{t+1}, X_{t+1})}{D_0^{\,t+1}(Y_t, X_t)} \right)^{1/2} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

The index represents the productivity of production point (Y_{t+1}, X_{t+1}) relative to the production point (Y_t, X_t). A value greater than one indicates positive TFP growth from period t to period t+1. This index is the Geometric Mean (GM) of two output based Malmquist TFP index. Equation (1) can be formulized as

$$M_I(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left(\frac{D_0^{\,t}(Y_{t+1}, X_{t+1})}{D_0^{\,t}(Y_t, X_t)} \right) x \left\{ \left(\frac{D_0^{\,t}(Y_{t+1}, X_{t+1})}{D_0^{\,t+1}(Y_{t+1}, X_{t+1})} \right) x \left(\frac{D_0^{\,t}(Y_t, X_t)}{D_0^{\,t+1}(Y_t, X_t)} \right) \right\}^{1/2}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The first term in the right hand side of equation (2) measures change in input based technical efficiency between period t and t+1. The change in efficiency is represented by the ratio of efficiency in period (t+1) in proportion to efficiency in period t . The GM of two terms in the bracket represents the change in technology between two periods. Hence changes in TFP and components are measured as GM of MI (Fare *et al.*, 1994). TFP exceeding one indicates an increase in TFP during the period t and t+1 where as its being less than one means the contrary (Coelli, 1996a). Given the Constant returns to Scale (CRT) technology and input based approach the LP is used in building Malmquist TFP change index is as follows (Worthington, 2000).

$$\left[D_0^{\,t}(Y_t, X_t)\right]^{-1} = \mathrm{Min}_{\theta,\lambda}\, \theta$$

Subject to

$$-y_{it} + Y_t\lambda \geq 0$$

$$\theta x_{it} - X_t\lambda \geq 0$$

$$\lambda \geq 0 \text{ -- } (3)$$

$$\left[D_0^{\,t+1}(Y_{t+1}, X_{t+1})\right]^{-1} = \mathrm{Min}_{\theta,\lambda}\, \theta$$

Subject to

$$-y_{i,t+1} + Y_{t+1}\lambda \geq 0$$

$$\theta x_{i,t+1} - X_{t+1}\lambda \geq 0$$

$$\lambda \geq 0 \text{ -- } (4)$$

$$\left[D_0^{\,t+1}(Y_t, X_t)\right]^{-1} = \mathrm{Min}_{\theta,\lambda}\, \theta$$

Subject to

$-y_{it} + Y_{t+1}\lambda \geq 0$

$\theta x_{it} - X_t \lambda \geq 0$

$\lambda \geq 0$ ....(5)

$\left[D_0^t (Y_{t+1}, X_{t+1})\right]^{-1} = \text{Min}_{\theta,\lambda}\, \theta$

Subject to

$-y_{i,t+1} + Y_t \lambda \geq 0$

$\theta x_{i,t+1} - X_t \lambda \geq 0$

$\lambda \geq 0$ ....(6)

The equation (3) and (4) are evaluated by using the efficient limit of the given period as a base. Model (5) compares the data of period t with efficient limit of period (t+1) while model (6) compares the datum of period (t+1) with period t's efficient limit. For given number of period (T) and number of observation (N) N(3T-2) LP problems should be solved.

Nature and Source of Data

The data used in this study have collected from the records of the Temi Tea estate [1].The entire tea estate is divided into 17 sections and data on each section has been collected. These 17 sections are considered as the individual producing unit with specific allocation of inputs such as labour. The data on total production of green tea leaves in *Kgs*, made tea in *Kgs*, amount of labour used in *days*, are in *hectares*, pruning style, fertilizer as well as bio fertilizers (N+P+K) in *Kgs* and rainfall in *Millimeters* have been collected for use. The information on all the 17 units for eleven years (2001-2011) have been used in estimating the TFP change. Since the government of Sikkim is going for a total organic culture in the entire state, the Temi tea estate also became completely organic from 2005 onwards. The TFP change is estimated for the entire 11 years together and separately by dividing it into two periods i.e., pre organic (2001-2004) and post organic period (2005-2011).

Results and Discussion

The results of MI of Total factor productivity change (TFPC) year-wise and firm wise for the entire period is presented in the table-1 and table-2 and same during the period 2001-2004 are reported in table-3 and table-4. Table-5 and table-6 presents the MI TFPC for the post organic period (2005-2011). The Malmquist TFP change indices are computed using the DEA models of equation (3) to (6). The indices measure the TFPC for the sample firms in the adjacent year 200/2001 and 2010/2011. Its decomposition into Technical Efficiency Change (TEC) and Technological Change (TCC) and further TEC into Pure Technical Efficiency Change (PTEC) and Scale Efficiency Change (SEC) are derived using the DEAP 2.1 (Coelli, 1996). Since the option of Variable Returns to Scale (VRS) or Constant Returns to Scale has no influence on the MI because both are used to calculate the various distances used to construct the MI index.

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[1] The garden was established in 1969 during the period of 12[th] *Chogyal*(king) Palden Thondup Namgyal and the factory was inaugurated by Kazi lendup Dorjee the 1[st] chief minister of Sikkim on 21[st] December 1975. According to government of Sikkim, 2011 there are 177.64 hectares of plantation area under that there are 17 sections. The most unique character of the Temi Tea garden is organic and is certified by Institute for Marketecology (IMO) of Switzerland. It is learnt from the interaction of the staffs that in 1acre of land there are 6000 - 6500 of tea plants are planted. In Temi tea garden there are two varieties of tea one is China variety and another one is clone variety. Clone variety is recent phenomena; earlier means in beginning time only the China variety was there. Temi tea export to several countries but it is famous in Germany and France.

Table-1 Malmquist index summary of annual means

YEAR	TEC	TCC	PTEC	SEC	TFPC
2	1.001	0.971	1.007	0.994	0.972
3	0.997	1.106	0.998	0.998	1.102
4	1.003	0.984	0.999	1.003	0.986
5	1.008	1.051	1.002	1.007	1.060
6	0.984	1.016	0.994	0.990	1.000
7	0.968	0.987	0.994	0.973	0.955
8	1.049	0.978	1.008	1.041	1.026
9	0.993	1.014	1.004	0.989	1.007
10	1.000	1.014	0.998	1.002	1.014
11	1.004	0.994	0.999	1.005	0.998
Mean	1.001	1.011	1.000	1.000	1.011

Table-2 Malmquist index summary of firm mean

Firm	TEC	TCC	PTEC	SEC	TFPC
1	1.004	1.005	1.001	1.002	1.008
2	1.003	0.989	1.002	1.001	0.992
3	1.002	1.007	1.003	1.000	1.009
4	0.998	1.002	1.000	0.998	1.000
5	0.999	0.979	1.000	0.999	0.978
6	1.005	0.995	1.004	1.000	1.000
7	0.995	0.997	1.002	0.994	0.992
8	0.998	0.999	1.001	0.997	0.997
9	0.999	1.002	1.000	1.000	1.001
10	1.002	1.027	1.002	1.000	1.030
11	1.000	1.040	1.000	1.000	1.040
12	0.995	0.981	0.996	0.999	0.977
13	1.000	1.015	1.000	1.000	1.015
14	1.004	1.063	1.000	1.004	1.066
15	0.998	1.046	0.999	0.999	1.044
16	1.002	1.024	0.998	1.004	1.026
17	1.005	1.017	1.000	1.005	1.022
Mean	1.001	1.011	1.000	1.000	1.011

Table-3 Malmquist index summary of annual means

Year	TEC	TCC	PTEC	SEC	TFPC
2	1.005	1.033	1.002	1.002	1.038
3	0.993	1.034	0.992	1.001	1.026
4	1.012	0.991	1.013	0.999	1.003
Mean	1.003	1.019	1.002	1.001	1.022

Table-4 Malmquist index summary of firm means

Firm	TEC	TCC	PTEC	SEC	TFPC
1	1.021	1.038	1.021	1.000	1.059
2	0.997	1.115	1.001	0.996	1.111
3	0.994	1.011	1.011	0.983	1.005
4	0.989	1.003	0.993	0.996	0.992
5	1.017	1.001	1.005	1.012	1.019
6	1.017	1.038	1.008	1.009	1.056
7	0.993	1.000	0.994	1.000	0.993
8	1.000	0.999	1.000	1.000	0.999
9	1.020	1.001	1.000	1.020	1.022
10	1.017	1.027	1.000	1.017	1.045
11	1.000	0.999	1.000	1.000	0.999
12	0.989	1.057	0.989	1.000	1.046
13	1.020	1.001	1.019	1.001	1.021
14	0.997	1.000	1.000	0.997	0.998
15	0.994	1.009	1.009	0.985	1.002
16	0.989	1.022	0.992	0.997	1.011
17	1.000	1.011	1.000	1.000	1.011
Mean	1.003	1.019	1.002	1.001	1.022

Table-5 Malmquist index summary of annual means

Year	TEC	TCC	PEC	SEC	TFPC
2	0.984	1.016	0.994	0.990	1.000
3	0.968	0.987	0.994	0.973	0.955
4	1.049	0.978	1.008	1.041	1.026
5	0.993	1.014	1.004	0.989	1.007
6	1.000	1.014	0.998	1.002	1.014
7	1.004	0.994	0.999	1.005	0.998
Mean	0.999	1.000	1.000	1.000	1.000

Table-6 Malmquist index summary of firm means

Firm	TEC	TCC	PEC	SEC	TFPC
1	0.995	0.995	0.995	1.000	0.990
2	1.000	0.994	1.000	1.000	0.993
3	0.999	1.006	0.999	1.000	1.005
4	1.004	1.003	1.000	1.004	1.006
5	1.001	1.001	1.000	1.001	1.002
6	1.001	0.986	1.000	1.001	0.987
7	0.993	0.996	1.000	0.993	0.989
8	0.999	0.997	0.999	0.999	0.996
9	0.996	0.998	0.996	0.999	0.994
10	1.000	0.994	1.000	1.000	0.994
11	1.007	1.005	1.003	1.003	1.012
12	0.997	0.999	0.999	0.999	0.996
13	0.999	1.001	0.999	1.000	1.000
14	1.000	1.002	1.000	1.000	1.002
15	1.003	1.017	1.005	0.998	1.020
16	0.996	1.009	0.996	1.000	1.005
17	1.000	1.006	1.000	1.000	1.006
Mean	0.999	1.000	1.000	1.000	1.000

Table-7 Production and Total value

Year	Production (Kgs)	Price per Kg	Total Value (in `)
2006-07	85,000	118.76	10095000
2007-08	87,000	241.37	210,00,000
2008-09	82,000	286.58	235,00,000
2009-10	59,000	425.42	251,00,000
2010-2011	84,000	345.23	290,00,000
2011-2012	59,000	438.93	258,97,000

The mean TFPC reaches 1.1% growth. The firms have achieved on an average of 1.1 per cent growth in productivity. This is contributed entirely due to the TCC . Since the mean value of PTEC SEC and TEC does not show any positive change, the technological change made it possible to have higher productivity growth during the period 2001-2011. It can be inferred from the results that there is no improvement as far as managerial function and scale efficiency are concerned. The Year-wise MI TFPC result shows that during the entire 11 years, the 3rd year has achieved highest TFPC (10.2%) with reference to the 2nd year followed by 5th year (6%) in comparison to the 4th year. In the 3rd year the TFPC is entirely due to a large shift in the frontier ascribed to the adoption of more modern technology. However the positive growth in the 5th period is due to all TEC and TCC. But the highest contribution is fro TCC. The breaking up of the entire 11-year into pre organic and post organic period suggests that the TFPC in the pre organic period is 2.2%, which is due to both technological innovation and better managerial operation. The contribution of TCC is very large (1.9%). But the TFPC in the post organic period remains constant. This has a larger implication of trade off between growth in productivity and Sustainable development. The productivity can be improved through better management operations not only through better training in respect of the application of modern techniques implements etc, better educational facilities, ensuring better health facilities and through the provision of better incentives for innovative work culture.

The farm-wise Malmquist TFPC results suggested that during the entire 11 years the TFPC has registered a positive growth of 1.1, which is due entirely to the promotion of technological innovation in the process of production. Except, five units all other units (firms) have positive TFPC. But the breaking of the periods into two clearly suggests that there is faster productivity growth during the pre organic period (TFPC is 2.2%). But the corresponding post organic period does not show any productivity growth. The positive TFPC in Temi tea also supports the study by Nin et al (2003), Rahman (2004), Alene (2009). The study made by Fan et al (1998) also reported an average annual growth rate of 0.69% between 1970 and 1995. Since the productivity in the post Organic period is not increasing, the tea estate has to focus more the quality of the product, the proper marketing strategy for brand building of the product so that it can fetch more value and can sustain in the long run. Since the product has more export value, the estate should focus equally on international markets. Higher brand value will create more domestic as well as international demand and the earnings will increase.

Conclusion

This paper aimed at estimating the total factor productivity change and its decomposition into technical efficiency change and technological change of 17 firm units of Temi tea industry of Sikkim during the period of 2001-2011. The Malmquist Index based result suggested that the overall average TFPC during the 11 year period is about 1.1 % which was essentially due to growth in the Technological Change. Farm wise TFPC change shown that the mean TFPC was 2.2 percent of which the contribution of TCC is larger in comparison to the PTEC and SEC component. However, the pre-organic period registered a faster TFPC in comparison to the post Organic period. Hence, the study suggested for improvement in the managerial skill not only at the managerial level but also at the workers level through proper training, better educational facilities and acquisition production related information, better coordination between administration and the working class, better work incentives. In addition to this, the industry should focus more on the brand building of the product both at domestic and international market to increase its revenue earnings and remain sustainable in the long run. Government should investment in improving the human resource development so that the industry will remain viable in the long run.

Acknowledgement

Our sincere thanks to the Tea Board, India for financial support. We also thank to the Human Resource Development Department, Govt. of Sikkim, Department of Commerce and Industry, Govt. of Sikkim, Temi Tea Garden, Sikkim for providing facilities to carry out the research activities.

References

Alene A. D. (2009). Productivity Growth and the Effects of Research and Development in African Agriculture. Contributed Paper Prepared for the Representation at the International Association of Agricultural Economists Conference, Beijing, China, August: 16-22.

Arnade C. (1998). Using A Programming Approach to Measure International Agricultural Efficiency and Productivity. *J. Agri. Eco.* 49: 67-84.

Balk B. M. (2001). Scale Efficiency and Productivity Change. *J Produc Anal.* 15: 159-183.

Banker, R. D. and R. M. Thrall (1992). Estimation of Returns to Scale Using Data Envelopment Analysis, Euro J Op Res: 62: 74-84.

Bhusan, S. (2005). Total Factor Productivity Growth of Wheat in India: A Malmquist Approach. Ind J Agri Econ: 60: 1: 2005.

Chand, R., P. Kumar, and Kumar Sant (2011). Total Factor Productivity and Contribution of Research Investment to Agricultural Growth in India. National Council for Agricultural Economic and Policy Research. Policy Paper 25, March.

Caves D.W., L.R. Christensen and Diewert W.E. (1982a). Multilateral Comparisons of Output, Input and Productivity Using Superlative Index Numbers. *Econ J.* 92: 73-86.

Caves D.W., L.R. Christensen and W.E. Diewert (1982b).The Economic Theory of Index Numbers and the Measurement of Input Output and Productivity. *Economet.* 50: 1393-1414.

Coelli, T. (1996a). A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. Centre for Efficiency and Productivity Analysis Working Paper 96/08.

Coelli, T. (1996). Measurement of Total Factor Productivity and Biases in Technological Change in Western Australian Agriculture. *J. App. Econ.* 11: 77-91.

Coelli T., S. Rahman and Thirtle Colin (2003). A Stochastic Frontier Approach to Total Factor Productivity Measurement in Bangladesh Crop Agriculture. *J. Int. Develop.* 15: 321-333.

Debreu, G. (1951). The Coefficient of Resource Utilization. *Economet.* 19: 273–292.

Primont, D. (1995) Multi-Output Production and Duality: Theory and Applications, Boston: Kluwer Academic Publishers.

Fan, S., Hazell Peter and Thorat Sukhade. (1998). Government Spending, Growth and Poverty: An Analysis of Interlinkages in Rural India. EPTD Discussion Paper No. 33, Environment and Production Technology Division, International Food Policy Research Institute, USA.

Fare, R., S. Grosskopf, B. Lindgren and P. Roose (1992). Productivity Change in Swedish Analysis, Pharmacies1980–1989: A Non Parametric Malmquist Approach. *J Prod*: 3: 85–102.

Fare R. Grosskopf S. Norris M. and Zhang A. (1994). Productivity Growth, Technical Progress, and Efficiency Changes in Industrial Country. *Ame Econ Rev*: 84 : 66–83.

Fare R. S. Grosskopf and P. Roos. (1998), Malmquist Productivity Indexes: A Survey of Theory and Practice. In R. Färe, S. Grosskopf and R.R. Russell (Eds.), *Index Numbers: Essays in Honour of Sten Malmquist*, Kluwer Academic Publishers, Boston.

Farrell M. J. (1957). The Measurement of Productive Efficiency. *J. Royal Stat. Soc.* 120: 253-81.

Fulginiti L. E. and R.K. Perrin (1998). Agricultural Productivity in Developing Countries. *Agri Econ.* 19: 45-51.

Koopmans T. (1951). An Analysis of Production As An Efficient Combination of Activities In: T. Koopmans, ed., Activity Analysis of Production and Allocation, Wiley, New York.

Kumar Praduman and Mittal Surabhi. (2006) Agricultural Productivity Trends in India: Sustainability Issues. *Agri Econ Res Rev.* 19: 71-88.

Kumar Praduman, W. Rosegrant Mark (1994). Productivity and Sources of Growth for Rice in India. Economic and Political Weekly: December 31:1: A-183 to A-188.

Malmquist S. (1953). Index Numbers and Indifference Surfaces. *Trabajos de Estadistica.* 4: 209–242.

Mukherjee Anit and Y. Khuroda. (2001). Effect of Rural Non-farm Employment and Infrastructure on Agricultural Productivity: Evidence from India. Discussion Paper No. 938: University of Tsukuba, Ibaraki, Japan.

Murgai Rinku. (1999). The Green Revolution and the Productivity Paradox- Evidence from the Indian Punjab. Policy Research Working Paper 2234, The World Bank Development Research Group. Rural Development. November 1999.

Nin Alejandro, Arndt Channing. and Preckel P. V. (2003). Is Agricultural Productivity in Developing Countries Really Shrinking? New Evidence Easing a Modified Nonparametric Approach. *J Develop Econ*: 71: 395-415.

Rao N. Chandrashekhara. (2005), Total Factor Productivity in Andhra Pradesh Agriculture. *Ame Econ Res Rev*: 18: 1-19.

Rahman Sanzidur (2004). Regional Productivity and Convergence in Bangladesh Agriculture. Paper Presented at the Annual Meeting of the American Agricultural Economics Association held in Aug 1-4, 2004, Project MUSE Scholarly Journals Online.

Shephard, R. W. (1970), Theory of Cost and Production, Princeton: Princeton University Press.

Trueblood M.A. (1996). An Intercountry Comparison of Agricultural Efficiency and Productivity. Ph.D dissertation. University of Minnesota.

Worthington, Andrew (2000).Technical Efficiency and Technological Change in Australian Bulding Societies. ABACUS: 36:(2): 180-197.