International Journal of Humanities and Social Science Invention
ISSN (Online): 2319 – 7722, ISSN (Print): 2319 – 7714
www.ijhssi.org Volume 4 Issue 3 || March. 2015 || PP.01-06

Productivity Potential and Technical Efficiency Differences among the Indian Framers

Chandan Kumar Maity
Research Scholar, Department of Economics, University of Burdwan, Burdwan, West Bengal, India.

ABSTRACT: *The Group frontier is a representation of the state of knowledge pertaining to the transformation of inputs into output in the regional level, while the Meta frontier represents the state of the knowledge at the country level. The ratio of the frontier score of Group and the Meta frontier represents the Meta technology Ratio (MTR). The study investigates productivity potentials and efficiencies of the farmers in different states in India by utilizing the concept of Group and Meta frontier technique. Empirical results are derived from a farm level disaggregated input- output data set of 13 Indian states comprising 3615 number of farmers. The results show a large technology gap ratio defined by MTR between the sampled states of the country. For calculating the efficiency measures the Data Envelopment Analysis is applied for the input-output data set.*
KEYWORDS: *Data Envelopment Analysis, Metafrontier Function, Efficiency, Technology Gap*

I. INTRODUCTION

There are numerous studies concerning the technological and productive performance of Agriculture in developing countries including India (Kawagoe et al, [1]; Kawagoe and Hayami [2}; Rosegrant and Evenson [3]; Fulginiti and Perrin [4]; Mark W Rosegrant and Kumar [5]; Trueblood [6]; Fulginiti and Perrin [7]; Fan, Hazell and Thorat [8]; Murgai [9]; Kudaligama and Yanagida [10]; Mukherjee and Kuroda [11]; Nin et al [12]; Coelli et al [13]; Rao [14]; Kumar and Mittal [15]; Bhushan [16]; Alene [17]; Chand et al [18]). These studies have used several yardsticks for such comparisons. Measures such as input intensities, partial productivity measures, TFP indices, efficiencies, input use parameters are in most common used. A general technique of all these procedure is to aggregate over the individual farmers to get region/state/country specific indicators. These aggregative indicators are then used to assess the performances of the farmers. Though the procedure is widely used, it suffers from some serious pitfalls. Aggregation often clouds the differences in individual responses to macro results. In agriculture the problem is more serious because there is a huge difference across the farmer's characteristics when we consider different geographical zone of a country.

Until recently, however, there was very little scope for considering such individual responses in such a huge panorama. However, the recent development of the Data Envelopment Analysis (DEA), have enabled us to consider such unit level differences of Efficiency level even in the macro space. The concept of the Meta production function that was defined by Hayami and Ruttan [19] as "The meta production function can be regarded as the envelope of commonly conceived neoclassical production functions." The journey begun with the classic article written by Førsund [20] where he attempted to made a comparison of farms across various time points. After presenting the standard aggregative measures he commented "It would be a waste of information to stop at presenting results for the average unit". Førsund gave all alternative approach towards measuring aggregative efficiencies. That depends on the definition of the reference technology. The idea was elaborated to the concept of Meta frontier by a number of authors (Battese and Rao, [21]; Rao, O'donnell and Battese [22], Battese, Rao and O'donnell [23]; Nyemeck and Nkamleu, Sanogo [24]; O'donnell, Rao and Battese [25]).

The general idea is to assume that farms of different regions are operating under a Meta production function. The Meta Frontier corresponding to the Meta production function defined as the boundary of an unrestricted technology set. Farmers of different states are however operating under Group frontier. That is restricted version of the Meta Frontier. The non realisation of the Meta Frontier may be argued to have risen from the structure of Economic functioning or the features of productive environment. The individual farm is thus twice constraint. The first is its inability to reach the Group Frontier. The second is the inability of the region to reach the Meta Frontier. Given this assumption it is then possible to have a meaningful discussion of farmer's performances at different cross sectional points. This paper tries to utilise this concept to understand the differences in the farm level performances across the states of India. For example, a farmer in Bihar has twice constant. As an individual farmer he cannot achieve the frontier performance of Bihar. As a farmer in Bihar he is again unable to reach the performance level of a farmer who belongs to Punjab. Thus his problems are twofold – individual level that is a result of his own inefficiencies and a group level that is a result of him being a resident of Bihar.The paper is divided into four sections. Section II discusses the material and methods used for the study. Section III gives us the main results. We conclude in section IV.

II. MATERIALS AND METHODS

The analysis is based on data drawn from the Department of Agriculture and Cooperation under the Ministry of Agriculture, Government of India through the Cost of Cultivation Scheme. The data were collected for every district of each state in India for each year. In this analysis farm level disaggregate input output data are used pertaining to the year 2010-11. Since the selected crop under study is paddy, we have considered thirteen paddy cultivating states in India. These are Punjab, Haryana, Uttar Pradesh from northern India, West Bengal, Bihar and Orissa from Eastern India, Andhra Pradesh, Kerala, Tamil Nadu and Karnataka from southern India and Gujarat, Madhya Pradesh and Maharashtra from central region of India.

This data set supplies information on various inputs like labour, bullock labour, fertiliser, manure, machine and output of all crops cultivated in value and quantitative terms. For our analysis we have taken only three inputs, namely, human labour hour, material cost (which includes the cost of bullock labour and cost of machinery) and fertiliser that presumably explain production of paddy very well. In the data set output is measured in quintal. All the variables are considered in per unit area. However, all of the paddy cultivating farms do not use positive amount of the inputs. Only 3615 number of farms use positive amount of the considered inputs. We have constructed summery statistics of the variable in the data set for the states under study. These are shown in table 1.

2.1 Group and Meta Frontier Analysis

Farrell [26] originally introduced a production frontier to measure the efficiency of firms. Latter, Hayami & Ruttan [19] defined a metafrontier concept based on the Meta production function. According to him the Meta production function can be regarded as the envelope of commonly conceived neo-classical production function. In this study, the DEA Meta frontier was used to assess Meta frontier function. The non parametric DEA model has the high benefit of not requiring a particular functional shape for the frontier.

DEA is a linear programming technique for constructing a non parametric piece-wise linear envelope to a set of observed output and input data. The mathematical programming approach of DEA makes no room for 'noise' and so does not 'nearly envelop' a data set as the way most econometric models do. It is now possible to define Farrell's input saving efficiency measure based on frontier technology as:

$$E_i = \min_{\alpha_i}\{\alpha_i : F_i(y, \alpha_i, x) \leq 0\} \quad (1)$$

The linear programming approach to measure efficiency from the envelope is to

$$\max_{E_i, \lambda} E_i \quad (2)$$

Subject to $y_i \leq Y\lambda$

$X\lambda \leq E_i x_i$

$\lambda \geq 0$

Where X is an $n \times I$ input matrix with columnsx_i,

Y is an $m \times I$ output matrix with columnsy_i.

λ is an $I \times 1$ intensity vector

'I' is the number of farms in a particular set of observations.

Table 1: Summary Statistics of the variables in the data set

States	AP	BI	GU	HA	KA	KE	MA	MP	OR	PU	TN	UP	WB
No. of farmers	445	394	129	145	116	225	62	98	450	250	361	368	572
Mean													
Output	149.38	40.45	124.65	125.41	107.34	71.25	25.08	50.48	82.23	231.34	115.78	41.28	65.74
Labour	2062.9	1354.11	2444.43	1554.7	2117.4	937.07	1187.6	1150.57	2700.82	1460.76	1582.13	805.5	1924.5
Cost	14145	4171.94	7973.95	9452.2	17701	9939.9	7531.69	5319.44	8424.37	18426.8	17096.93	3201.3	6243.1
Fertilizer	594.28	143.31	581.92	556.8	607.86	293.13	129.52	190.63	256	738.23	561.79	186.03	235.98
Crop area	3	1.76	2.81	2.67	2.06	1.66	1.05	2.04	2.58	3.57	2.32	1.21	1.61
S.D													
Output	140.99	44.26	158.81	130.03	182.56	110.62	25.29	73.09	88.03	201.73	127.98	53.88	55.32
Labour	1920.3	1018.8	2727.71	1246.3	2284.9	1480.4	1194.79	1259.12	2315	1118.59	1771.91	659.8	1584.9
Cost	12506.6	3500.89	10206.94	8918.8	26423	14808	8942.3	4796.79	8295.03	18542.8	17563.19	4909.5	5748.2
Fertilizer	536.39	150.92	768.89	507	1165.1	466.61	147.76	252.04	413.62	633.77	599.93	223.32	251.23
Crop area	6.56	1.33	3.16	2.27	2.71	2.42	1.46	1.92	2.21	2.91	2.46	2.9	1.3

Minimum													
Output	3.75	1.8	2.4	8	2	1.44	1	1	5	10	3.8	2.1	0.3
Labour	84	20	53	108.33	220	39.5	69.33	53.33	165.67	74.5	110.08	87.5	11.5
Cost	93.77	24	100	5	964	150	425	51	480	481.03	107.5	1.52	2.62
Fertilizer	28	2.76	4.6	32	27	6	10.12	6.4	13	23	20	7.8	0.85
Crop area	0.2	0.06	0.07	0.25	0.15	0.05	0.07	0.2	0.2	0.2	0.11	0.06	0.01
Maximum													
Output	820.75	270.7	991	788	1006	723.97	145.38	495	1061.5	1010	835.65	590.5	395.66
Labour	14470	5343	13004.8	5979.3	14052	10214	4633.6	7031.5	26346.7	6446.8	14135.1	4674.9	13126
Cost	73100	17127	62710	44314	155419	98750	49751.6	22034	91087.9	111092	97065	34939.5	33828
Fertilizer	3230.5	971	3884.12	2397	6840	2914.2	863.6	1679.2	5209.2	2997	3844.63	1909	2832.6
Crop area	129.6	6.63	15.85	12	15.2	14.48	7.3	9.75	24	14.4	15.36	53	10.12

Notes: AP=Andhra Pradesh, BI=Bihar, GU=Gujarat, HA=Haryana, KA=Karnataka, KE=Kerala, MA=Maharashtra, MP=Madhya Pradesh, OR=Orissa, PU=Punjab, TN=Tamil Nadu, UP=Uttar Pradesh, WB=West Bengal

Output is in quintal, labour means human labour hour, cost mean material cost in Rupees fertilizer is measured in Kg and area means cultivated Area under paddy in hector.

Problem 2 has been solved for I time to get each producer's efficiency score which is being evaluated under different sets of observations as envelope. Following this analysis, we get efficiency scores for each of the individual farmer. Regarding frontier technology, the most common restrictions are strong disposability of input and output and convexity of the set of feasible input-output combinations. One can assume three types of return to scale viz., (i) Constant Return to Scale (CRS) (ii) Non Increasing Return to Scale (NIRS) (iii) Variable Return to Scale (VRS). These returns to scale assumptions impose certain restrictions on the intensity vectorλ. Under the CRS assumption, λ is unrestricted. NIRS is incorporated within a DEA structure by adding to equation 2 the constraint $e^T \lambda \leq 1$ where e is a $I \times 1$ vector of ones.Similarly; VRS might be specified by adding to equation 2 the constraint$e^T = 1$. According to Coelli (29), the VRS specification has been the most commonly used specification in the 1990's. This study also opted for both CRS and VRS specifications. If we have data on L_k number of states, the above linear program is solved L_K times for each period to obtain group technical efficiency. The Metafrontier is constructed using a DEA model for all the states in the country. Therefore, to obtain the technical efficiency with respect to Metafrontier, we re –run the above linear program model with the input and output matrices with data for all the states in the country together. I have used Data Envelopment Analysis Computer Programme, - DEAP 2.1- and a multi stage DEA procedure (Coelli, [29]) to run the model.
If we denote the efficiency of a state 'r' relative to its frontier (group frontier) by TE_r^r, and the technical efficiency of the same state evaluated at the country level (meta Technology) by TE_r^*, the productivity potential or Meta Technology Ratio (MTR) of the state can be defined as (Battese et al., [23]):

$$MTR_r^* = \frac{TE_r^*}{TE_r^r} \qquad (3)$$

Thus, the technical efficiency relative to the Meta frontier function is the product of the technical efficiency relative to the frontier for a given state (which is called group frontier) and the MTR. These shows that technical efficiency measured with reference to the Meta technology can be decomposed into the product of the technical efficiency measured with reference to the group 'r' technology, and Meta technology ratio between the group technology and the Meta technology. Because the technical efficiency relative to the Meta frontier is always less than the technical efficiency relative to the group frontier, TGR is bound between zero and one.

III. RESULTS AND DISCUSSION

After delving through the maze of data we finally arrive at the door step of our analysis. The analysis begins with the estimation of efficiency scores using both CRS and VRS techniques. This micro comparison over the span of thirteen states of India gives us a deep insight into the work of individual farms across length and breadth of the country. No aggregate analysis can hope to reveal such a vast panorama in our eyes. Table 2 shows the average efficiency scores of the farmers in each of the sampled states**.** It is observed from the table that the mean efficiency scores with VRS are generally higher than those of CRS technology. The table also shows that the ranking of the states in terms of the efficiency scores for two types of returns to scale also different.

Table 2: Technical Efficiencies Obtained from Group Frontier

	CRS				VRS			
State	Mean	Rank	Maximum	Minimum	Mean	Rank	maximum	Minimum
AP	0.5476	6	1	0.041	0.7227	4	1	0.101
BI	0.4989	11	1	0.111	0.5918	11	1	0.28
GU	0.5413	7	1	0.153	0.6993	6	1	0.273
HA	0.6878	2	1	0.187	0.7303	3	1	0.475
KA	0.5175	9	1	0.078	0.6339	10	1	0.274
KE	0.6159	4	1	0.162	0.7515	2	1	0.315
MA	0.2800	13	1	0.18	0.5892	12	1	0.384
MP	0.5765	5	1	0.151	0.7047	5	1	0.294
OR	0.5044	10	1	0.331	0.678	8	1	0.48
PU	0.7005	1	1	0.347	0.7878	1	1	0.472
TN	0.6172	3	1	0.194	0.6937	7	1	0.256
UP	0.3102	12	1	0.069	0.5816	13	1	0.161
WB	0.5219	8	1	0.186	0.666	9	1	0.38
Average	0.5323		1	0.168	0.6793		1	0.318

Notes: as on Table 1

From the sampled Indian states, the technical efficiency score ranged from 0.041 to 1.00 with an average 0.5323, indicating that the agricultural sector produce on an average 53% of potential output given the technology available in Indian agricultural sector as a whole. So as far the VRS specification is concern, the technical efficiency score of the Indian farmers ranged from 0.101 to 1 with an average 0.6793, indicating that this sector produce 68% of potential output as a whole. A state-wise comparison of average efficiency of the farmers shows that there are 6 numbers of states which recorded the average efficiency less than all India average efficiency scores (Such as Bihar, Karnataka, Maharashtra, Orissa, UP, and West Bengal). The states from southern India (i.e., Andhra Pradesh, Tamil Nadu and Kerala) recorded efficiency scores higher than the all India Average. It is observed from table 2 that Punjab appears to be the best state in terms of average efficiency scores for both CRS and VRS specification. The average efficiency score for the state is found to be 0.7005 and 0.7878 respectively under CRS and VRS specification. With CRS specification Haryana appears to be the second best zone with average efficiency 0.6878, however, under VRS specification, Kerala appears to be the second best performing state. Consequently, Maharashtra recorded as the least performing state under CRS as well as VRS specification. From a policy point of view, these state wise differences show the type of interventions needed to be putted in place in each state for enhancing the productivity of Indian farmers. It should be in the form of raising technology or with the improvement of the technical know- how.

In Meta Frontier, however, envelop is chosen as the background. Since, envelop encompasses all the input – output combination, the problem of incomparability does not arise here. The empirical exercise now concentrates on the Meta Frontier analysis. Ideally this analysis should be made over all the observations. It is now feasible, not very advisable to represent the analysis obtained these huge data. The table 3 represent the average efficiency scores of the state obtained from Meta Frontier.

Table 3: Technical Efficiencies Obtained from Meta Frontier

	CRS				VRS			
State	Mean	Rank	maximum	Minimum	Mean	Rank	maximum	Minimum
AP	0.2733	7	1	0.041	0.4458	2	1	0.081
BI	0.2706	8	0.975	0.047	0.3476	11	1	0.064
GU	0.2613	9	0.949	0.071	0.4160	5	1	0.111
HA	0.3225	2	1	0.075	0.4129	6	1	0.146
KA	0.2281	12	0.604	0.033	0.3122	12	0.721	0.041
KE	0.3114	3	1	0.077	0.4268	4	1	0.015
MA	0.1795	13	0.48	0.053	0.2295	13	0.545	0.082
MP	0.2746	6	1	0.074	0.3739	10	1	0.115
OR	0.2578	10	0.975	0.088	0.3940	8	0.981	0.173
PU	0.4428	1	0.762	0.15	0.6680	1	1	0.304
TN	0.2460	11	0.555	0.067	0.3805	9	0.789	0.121
UP	0.2969	4	1	0.069	0.4431	3	1	0.129
WB	0.2868	5	0.987	0.071	0.4097	7	1	0.144
Average	0.2809		0.8682	0.0705	0.4046		0.9258	0.1174

Notes: as on Table 1

It is clear from the table that the technical efficiency under CRS specification of the farmers obtained from Meta frontier ranged from 0.033 to 1.00 with an average of about 0.2809, indicating that farmers are produce on an average 28% of the potential output given the available technology. The farmers from Punjab achieved the highest mean technical efficiency and from Maharashtra achieved the least average efficiency

score relative to the Meta frontier. The technical efficiency of the states from northern India (i.e. Punjab, Haryana and UP) are higher than the all India average efficiency score in terms of Meta technology. Among the states from Eastern India, West Bengal is only the state for which the technical efficiency score is higher than the all India average level in terms of Meta frontier.

The more interesting feature is the difference between the average technical efficiency scores from the Group and the Meta frontier model. For example, the average technical efficiency for Punjab relative to the Meta technology is only 0.44% under CRS technology and 66% under VRS technology, while its mean efficiency is quite large with respect to its own Group frontier (70% under CRS and 78% under VRS). The difference between the two efficiency scores indicate the order of bias of the technical efficiencies obtained by using the Group frontiers, relative to the technology available for the agricultural sector in India. Generally, the technical efficiencies from the Group frontier should be greater than those obtained from the Meta production frontier, because the constraints in the Group linear programming problem.

The Group frontier is a representation of the state of knowledge/technology pertaining to the transformation of agricultural inputs into output in the region (state), while the Meta frontier represents the state of the knowledge/technology at the country level. The ratio of the frontier score of region and the Meta frontier represents the Meta technology ratio (MTR) of the region (or State). Now the study estimates the Meta technology ratio (MTR) as presented in table 4.

Table 4: State wise Meta technology ratio (MTR) Estimates

States	CRS	VRS
AP	0.4991	0.6169
BI	0.5424	0.5874
GU	0.4827	0.5949
HA	0.4689	0.5654
KA	0.4408	0.4925
KE	0.5056	0.5679
MA	0.6411	0.3895
MP	0.4763	0.5306
OR	0.5111	0.5811
PU	0.6321	0.8479
TN	0.3986	0.5485
UP	0.9571	0.7619
WB	0.5495	0.6152

Notes: as on Table 1

The sampled Indian states have Meta Technology Ratio ranging between 0.3986 and 0.9571. These values can be interpreted as the technological gap faced by the farmers in those regions when their performances are compared with the all India level. Under CRS specification, farmers of Tamil Nadu have the lowest productivity potential ratio followed by Karnataka. This suggest that even if Punjab and Haryana achieved best practice with respect to the technology observed in the Group frontier as well as Meta Frontier, they will still be lagging behind because their technology lag behind all India technology level with a technology gap ratio of 0.6321 and 0.4688 respectively. For VRS technology same type of conclusion can also be drawn. In the inefficiency studies two types of causes viz. man-made errors (e.g., machines failure, input indivisibility etc.) and natural factors (e.g. abnormal rainfall, drought etc.) are identified to explain the productivity potential of the farmers. Of these two, the influence of natural factors, particularly rainfall, is considered to be the important factor of determining productive potential of Indian farmers.

IV. CONCLUSIONS

The study investigates productivity potentials and efficiencies of the farmers in different states in India by utilizing the concept of Group and Meta frontier technique. Since technology is a representation of the state of knowledge pertaining to the transformation of agricultural inputs into output, the existence of an over-arching technology, referred to as the Meta technology, represented by the Meta frontier production function has been conceptualize. The methodology enables the estimation of state wise Meta Technology Ratio (MTR) by using decomposition result involving both the Group and Meta frontier which examines comparative changes in the efficiency of groups with respect to the Meta Frontier. Empirical results are derived from a disaggregated farm level input output data set for the year of 2009-10 from 13 Indian states comprising 3615 number of farmers.

The results of this study show a large technology gap ratio defined by MTR between the sampled states of the country. These values can be interpreted as the technological gap faced by the agricultural sector in those regions when their performances are compared with the all India level. In terms of technical efficiency, the states from northern region such as Punjab and Haryana achieved the highest technical efficiency relative to their group frontier as well as Meta frontier.

From a policy point of view, these Group differences show the type of interventions needed to be putted in place in each region for enhancing the productivity of Indian Agriculture. In some states like Punjab, Haryana, Andhra Pradesh, the first target should be on raising technology while in other states like in Maharashtra, Karnataka it will be more urgent to first deal with the improvement of the know- how.

REFERENCES

[1] Kawagoe T., Hayami Y., Ruttan V. The inter country agricultural production function and productivity differences among countries, Journal of Development Economics, 19, 1985, 113-132.

[2] Kawagoe T., Hayami Y. An inter country comparison of agricultural production efficiency, American journal of Agricultural Economics, 67, 1985, 87-92.

[3] Rosegrant Mark W, Evenson, The rate of growth of Total Factor Productivity in Indian crop sector 1957-1985, American Journal of Agricultural Economics, August, 1992, 757-763.

[4] Fulginiti L. E., and Perrin R.K, Agricultural Productivity in Developing Countries, Agricultural Economics, 19, 1988, 45-51.

[5] Mark W. Rosegrant, Kumar P, Productivity and Sources of Growth for Rice in India, Economic and Political Weekly 29(53), 1994, A-183 to A-188.

[6] Trueblood M.A. An inter country comparison of agricultural efficiency and productivity, PhD dissertation, University of Minnesota, 1996.

[7] Fulginiti L. E., & Perrin R.K, Prices and Productivity in Agriculture", Review of Economics and Statistics, 75, 1993, 471-482.

[8] Fan Shenggen, Hazell Peter, and Thorat Sukhadeo, Government Spending, Growth and Poverty: An Analysis of Inter linkages in Rural India, EPTD Discussion Paper No. 33, Environment and Production Technology Division, International Food Policy Research Institute, USA, 1998.

[9] Murgai Rinku, 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, 1999.

[10] Kudaligama Viveka P. and Yanagida John F, A Comparison of Inter country Agricultural Production Functions: A Frontier Function Approach, Journal of Economic Development, 25(1), 2000, 57-73.

[11] Mukherjee, Anit and Y. Kuroda, Effect of Rural Nonfarm Employment and Infrastructure on Agricultural Productivity: Evidence from India. Discussion Paper No. 938. University of Tsukuba, Ibaraki, Japan, 2001.

[12] Nin Alejandro, Arndt Channing, Preckel Paul V, Is agricultural productivity in developing countries really shrinking? New evidence using a modified nonparametric approach, Journal of Development Economics 71. 2003, 395-415.

[13] Coelli Tim, Rahman Sanzidur and Thirtle Colin, A Stochastic Frontier Approach to Total Factor Productivity measurement in Bangladesh crop agriculture, Journal of International Development, 15, 2003, 321-333.

[14] Rao N. Chandrashekhara, Total Factor Productivity in Andhra Pradesh Agriculture, American Economics Research Review, 18(1), 2005, 1-19.

[15] Kumar Praduman, Mittal Surabhi, Agricultural Productivity Trends in India: Sustainability Issues", Agricultural Economics Research Review 19 (Conference No.), 2006, 71-88.

[16] Bhushan Surya, Total Factor Productivity Growth of Wheat in India: A Malmquist Approach, Indian Journal of Agricultural Economics, 60(1),2005, 32-48.

[17] Alene Arega D, Productivity Growth and the Effects of Research and Development in African Agriculture, Contributed paper prepared for the presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 2009.

[18] Chand Ramesh, Kumar Praduman and Kumar Sant, 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 2011.

[19] Hayami, Y. and Ruttan, V.W., Agricultural Development: International perspective. (Baltimore, John Hopkins University Press), 1971.

[20] Førsund F.R. Malmquist Indices of Productivity Growth: An Application to Norwegian Ferries. In H.O. Fried, A.K. Lovel, S.S. Schmidt (eds), The Measurement of Productive Efficiency: Techniques and Applications. (Oxford: Oxford University Press), 1993, 352-373.

[21] Battese, G.E. and Rao, D.S.P., Technology gap, efficiency, and a stochastic Metafrontier function. International Journal of Business and Economics 1(2), 2002 87-93

[22] Rao, D.S.P., O'donnell, J. and Battese, G.E., Metafrontier functions for the study of inter-regional productivity differences. Centre for Efficiency and Productivity Analysis Working Paper 1, 2003.

[23] Battese, G.E., D.S.P.Rao and C.J. O'Donnell, A Meta Production Function for Estimation of Technical Efficiencies and Technological Gaps for Farms Operating Under Different Technologies, Journal of Productivity Analysis. 21, 2004, 91-103.

[24] NKamleu, G.B, J. Nyemeck and D. Sanogo, Meta frontier Analysis of Technology Gap and Productivity Difference in African Agriculture, Journal of Agriculture and Food Economics; 1 (2), 2006, 111-120.

[25] O'Donnell, C. J., D.S.P.Rao and G.E. Battese, Metafrontier Frameworks for the Study of Farm-Level Efficiencies and Technology Ratios, Empirical Economics, 34, 2008, 231-255.

[26] Farrell, M.J., The Measurement of Productive Efficiency, Journal of the Royal Statistical Society, Series A, 120(3), 1957, 253-281.

[27] Fare, R., Grosskopf S., & Lovell C.A.K., Production Frontiers, (Cambridge University Press, Cambridge, 1994)

[28] Government of India, Ministry of Agriculture, Ministry of Agriculture and Cooperation, http://eands.dacnet.nic.in/Cost_of_Cultivation.htm

[29] Coelli, Tim, A guide to DEAP version 2.1: A data envelopment analysis (computer) program. Centre for Efficiency and Productivity Analysis Working paper 96/08, 1996