E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(2): 97-102

www.fisheriesjournal.com
Received: 23-01-2019
Accepted: 25-02-2019

Ogunsola AF
Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria

Correspondence
Ogunsola AF
Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria

Economic efficiency determination among marine and lagoon artisanal fisher folks in Lagos state, Nigeria

Ogunsola AF

Abstract
Economic efficiency determination among marine and lagoon artisanal fisher folks in Lagos State was carried out. Oral and structured questionnaire were used in collecting data. Data were analyzed using stochastic frontier and cost frontier model. The maximum likelihood (ML) estimates for the production frontier for marine fisher folk showed the significant variables were Labour, canoe length, distance covered and engine capacity while for lagoon fisherfolks, none of the coefficients listed above was significant. In the marine environment, age, fishing experience, secondary occupation and cooperative membership were the socio- economic factors that significantly affected technical efficiency of the fisher folks while in the lagoon environment, technical efficiency was affected only by age, secondary income and membership of cooperative societies. The coefficient of fishing experience in both water bodies was negatively but significantly related to technical inefficiency. Secondary income was negatively related to technical efficiency (-0.00588 and -0.01177 for marine and lagoon respectively) and the negative relationship was significant at ($P<0.05$) indicating that fisher folks without secondary income were more efficient than those with secondary income. The sampled fisher folks were observed to be technically efficient (0.71) but economically (-0.061) and allocatively (0.061) inefficient.

Keywords: economic efficiency, fisher folks, artisanal fisheries, stochastic frontier, cost frontier

1. Introduction
The Fisheries subsector in Nigeria, West Africa, comprises of Industrial (Commercial Trawlers), Artisanal and Aquaculture (fish farming). All over Nigeria, fishing activities are abundant in areas with naturally available water bodies. Fisheries play a significant role in Nigerian economy in terms of dietary animal protein supply, employment generation and income generation [1]. In Nigeria, fish is relatively cheap and readily available irrespective of the size consumed or the income of consumer [2] and it accounts for 40% of dietary animal protein consumed by Nigerians [3, 4]. The dietary protein (fish) is also known to contain micro nutrients, water soluble vitamin complex, and fat soluble vitamins (A and D) that affect human health positively [5, 6, 7].
According to FAO glossary description, artisanal fisheries is a fish catching operation usually carried out by fisher folks with canoe and simple gear along open coast from the beach, in brackish water, river, lakes and reservoirs. It is commercial in operation but cannot be considered as an industrial fishery because of the following factors:
1. The gears are simple and hand operated.
2. It is labour intensive and of very low capital investment
3. The craft used is simple and traditional i.e. dugout wood or plank canoe
4. Storage and processing plants are not available either on deck or at the jetty or when available, are poorly developed.

It has been observed by Thompson (1983) [8] that the developing countries fisheries have large artisanal section when compared with industrialized countries. These large sections contribute social and economic problems. It is also of concern that years of pressure of commercial fleet on artisanal fishing ground may have resulted in over exploitation and drastic resources failure. Fishing communities depend on fisheries and aquatic resources for their livelihood. The fisheries sector being grassroot oriented employs more people than industrial sector. The people that are gainfully engaged in relation to small scale fisher folks are fish mongers, processors, gear fabricators/mender, canoe builders, crew members or beach landing labour, and out board engine (OBE) mechanics [9, 10, 11]. In any fishing communities, these set of people form the fishery livelihood group. According to FAO (2003) [12] fish product accounted for 50% of non-plant protein consumed in Nigeria.

Artisanal fishers are mostly men. Few women fish mainly in the creeks and rivers. Nigeria category of artisanal fisher folks contributing to Nigerian fish production figure are fulltime, part-time, and occasional fisher folks [13]. Full time fisher folks are proficient and usually do not engage in any other profession though some inherited coconut plantation and other economics crops. They are to be found mostly along the beaches, on lagoons and inland waters. They are highly mobile and follow fish movement about in water bodies. They are not gainfully engaged throughout the year because of seasonality of the fishery and the slack period experienced between July, August and September.

Part-time Fisher folks are men who have other means of livelihood but fish occasionally because they have relevant gears, craft and experience. Occasional Fisher folks are men, women boys who capitalize on seasonal abundance of fish/ shrimp using basket, palm fronds, traps, etc to catch fish for subsistence living.

Efficiency studies in agricultural production aspect in developing countries like Nigeria, comes in useful in situation with limited resources (fish) and dwindling opportunities for adoption of better technology as a result of inflation [14, 15]. Agricultural production efficiencies can be measured in terms of technical (productive), allocative (prices) and economic efficiencies. Technical efficiency refers to the achievement of maximum possible output with available resources while allocative efficiency deals with the allocation of resource in line with the price of factors (that is, it quantifies how near an enterprise is to using the optimal combination of production inputs when the goal is maximum profit) [16]. Economic efficiency, which encompasses both technical and allocative efficiencies deal with an efficient utilization of resources in the production process [17, 18]. Studies on efficiency indices of artisanal fisheries is scarce but a few researchers have carried out studies on technical efficiencies of gill net artisanal fisheries in Malaysia, technical efficiencies of mechanized and non-mechanized canoes in Lagos state, the efficiency of artisanal catch technologies in Lagos state, technical efficiency and small scale fishing households in Tanzania [19, 20, 21, 22]. Thus, to discourage rural-urban drift, to improve the lots of fisher folks, to supply relevant information towards Government Policy formulation, it is important to carry out efficiency studies of artisanal fisherfolks in Lagos State, Nigeria.

The broad objective is to examine the efficiency levels of artisanal fisheries and its determinants in Lagos State while the specific objectives are to.

Determine the efficiency levels (technical, allocative and economic) of fisher folks in both marine and lagoon communities.

1. To identify the socio-economic factors influencing the level of inefficiency
2. To determine if efficiency indices of fisher folks are not affected or are affected by their socio economics characteristics.

2. Materials and Methods

2.1 Study Area

Lagos State is a maritime State in the South west of Nigeria. It lies within longitude 2 45” east to 4 20” east and from Latitude 6 20”North to 6 43”North in the Tropics. The state has boundary with Ogun State on its Northern side and Eastern sides and on its Western side with the Republic of Benin. Udo and Mamman 1993. The Southern side of the state stretches for 180 Kilometers along the Guinea Coast of the Bight of Benin, on the Atlantic Ocean. About 787 km portion of the total land surface areas of Lagos state is made up of Lagoon, Creeks, and Rivers [23]. The State has two distinct seasons namely, the wet season, (April - October) and dry season (November - March) [24]. Majority of the fishing communities are remotely located in the rural areas.

2.2 Source of Data and Sampling Procedure.

Primary and secondary data were used for this study. The primary data was by means of structured questionnaire administered to respondents from fishing communities. Secondary data was sourced from government establishments such as Federal Department of Fisheries (FDF), Nigerian Institute for Oceanography and Marine Research (NIOMR) and Lagos Agricultural Development Authority (LSADA). Data were collected on socio-economic characteristics of fisherfolks. For measurement of efficiencies, the indices used in the questionnaire were labour during fishing trips and sorting of fish, sales, type of canoe, amount of secondary income, canoe length as proxy for volume, Outboard engine capacity, hours spent on each trip, age of fisherfolks, fishing experience, and membership of Cooperative societies.

Three hundred and sixty respondents were selected through multistage sampling technique. Thirty six communities made up of lagoon and marine communities, were randomly selected out of 110 fishing communities being visited by extension agents of LSADA. This was followed by random selection of 10 fishing households from each community through oral interview conducted at the fish landing site, jetties or beaches. Fourteen questionnaires were however rejected due to inconsistency during data analysis.

The analytical techniques used were descriptive statistics, stochastic frontier production, and cost function model for estimation of efficiency indices. These techniques were used to determine the effect of the socioeconomic variables on the technical and allocative efficiency and level of inefficiency of fisher folks. The analytical framework is presented as follows:

2.3 Efficiencies Estimation

Stochastic frontier production and cost functions were used to determine the effect of socioeconomic variables on the technical and allocative efficiency and level of inefficiency of fisherfolks.

2.4 Stochastic Frontier Production

Following Broack *et al.* (1980) and Coelli (1996) [25, 26] method of estimating a stochastic frontier production function in which the disturbance term (E) is composed of two parts, a systematic term (v) and one-sided component (u), a Cobb-Douglas production function of the following form was specified:

1. A Cobb Douglas production frontier

$$\text{In } Q = \beta_0 + \beta_1 1_n X_1 + \beta_2 1_n X_2 + \beta_3 1_3 X_4 + \beta_4 + \beta_5 1_n x_5 (V_1 - U_1) \quad \text{.......... Equation 1}$$

Where

Q = Total fish output (kg)

X_1 = Labour input in man hours
X_2 = Length of canoe
X_3 = Outboard engine capacity in horse power
X_5 = Number of hours per trip in hours
β_1 = Parameter to be estimated (I = O, 1, 2, 3, 4, 5)
V_t = Is the two-sided, normally distributed random error
U_1 = Is the one-sided efficiency component with a half-normal distribution

2. A Cobb-Douglas cost frontier

In (C_i) = $\delta_0 + \delta_1$ In Q_i + (v_i + u_I)…………………Equation 2

Where
C = Cost incurred in fish production (N)
Q = Output of fish in Kg
δ = parameters to be estimated (i = 0, 1, 2)
V = is the two-sided, normally distributed random error.
U = is the one-sided efficiency component with a half-normal distribution

2.5 Inefficiency Model

Multiple regression analysis was used to investigate the association between efficiency indices and six socioeconomic characteristics. The level of efficiency, which is the dependent variable, lies between 0 and 1; the model is specified as:

In EI = $\beta_0 + \beta_1 1_n X_1 + \beta_2 1_n + X_3 + \beta_3 1_n X4 + \beta_4 1_n X_4 \ldots \beta_6 1_n X_6 + e$……………………………………………Equation 3

EI = levels of efficiency
X_1 = age of the fisherfolk in years
X_2 = fishing experience in years
X_3 = Amount of secondary income in Naira
X_4 = Membership of cooperatives society (1-yes, 0=no)
β = Parameters to be estimated (i=0, 1, 2, 3, 4, 5)
E = Error term

3. Results and Discussion

3.1 Efficiency Determination of Fisher Folks in Marine and Lagoon Communities

3.1.1 Technical efficiency determination

In this study, the variables used for frontier production functions are labour (manpower used during fishing trips and sorting), canoe length (as proxy for volume), distance covered during the trip, engine capacity, and hours spent per trip. The results of the stochastic production frontier model are presented in Table 1 for Marine and Lagoon respondents respectively. For Lagoon, none of the coefficients listed in Table 1 above was significant. This suggested that the variables included in the stochastic production frontier analysis for lagoon did not significantly determine the level of artisanal fishing output in the study area. From the maximum likelihood (ML) estimates for marine fisher folks, sigma squared (0.0429) and Gamma (0.0376) were significantly different from zero at 1%, indicating a good fit and the correctness of the specified distribution assumption. For the marine artisanal fishing (Table 1), the significant variables with their coefficients were, labour (1.714), canoe length (0.334) distance covered (0.0903), outboard engine capacity (0.162) and were statistically significant at (P<0.01) with the expected positive signs, except coefficient of outboard engine capacity (OBE with statistical significance (P<0.05). The estimated coefficients show that fish output was inelastic to changes in the variables considered. For instance, a 10% increase in engine capacity and canoe size will result in a less than proportionate change of about 1.62% and 0.9 increase in fish output respectively. In like manner, a bigger size canoe with a higher engine capacity will enable the fisher folks go further and faster into the sea which may result in higher fish output. This is important because the nearby coastal waters are usually over exploited and therefore depleted [1].

3.1.2 Allocative efficiency determination

Table 2 presents the results of the stochastic cost frontier for marine and lagoon respectively. From the Table, the coefficients of output were not significant for marine and lagoon stochastic cost frontier model. However the results presented in Table 3 for pooled data of both water bodies showed estimate of Lambda (1.870) and Gamma (0.401) are large and significantly different from zero at one percent, indicating a good fit and the correctness of the specified distribution assumption. The coefficient at 1%; it has positive correlation with cost of production. This is an indication that fisher-folks with higher output have better capacity to employ improved farm input (Technology) with the associated cost which is usually higher.

3.1.3 Source of Inefficiency

Results of the inefficiency model from the stochastic frontier regression analysis in Table 4 are summarized for marine, lagoon and pooled data. The socio economic factors that significantly affected the technical efficiency of the fisher-folks were age, fishing experience, secondary occupation and cooperative membership.

In both marine and lagoon water bodies, age and fishing experience were negatively related to technical inefficiency and the coefficients were significant at (P<0.05). This means that younger fisher-folks are more agile than older ones but in terms of fishing experience older fisher-folks tends to be more efficient in fishing operation in the study area due to enhanced ability to acquire more technical knowledge on good location and signs of fish abundance. This brings them closer to the frontier output. Secondary income was negatively related to technical efficiency at (P<0.05) significant level. The implication is that fisher-folks without secondary income were more efficient. For those with secondary income, less attention may be paid to fishing operation or income can be used to purchase or pay excess production inputs or for unnecessary labour. Membership of cooperative or association tends to operate at lower efficiency level than their counterparts. This is not in line with general belief but it could be due to moribund nature of many of the associations.

3.2 Socio-Economic Factor Affecting Allocative and Economic Inefficiency

Results of the inefficiency model from the stochastic cost frontier are presented in Table 5. Allocative and economic inefficiency were conducted for only pooled data because in the cost frontier, sigma and gamma were not significant for the two water bodies.

The Table revealed that type of canoe had negative and significant effect on allocative inefficiency (P<0.01) and economic inefficiency. In the marine environment, age, fishing experience, secondary occupation and cooperative membership were the socioeconomic factors that significantly affected the technical efficiency of the fisher folks. While in the lagoon environment, age, secondary income and membership of cooperative societies were the socioeconomic factors that significantly affected the technical efficiency of the fisherfolks. In water bodies (pooled data), there was a negative relationship between age and technical inefficiency of the fisherfolks in the study area and the coefficient was significant. ($p<0.10$).

3.3 Technical Efficiency of Fisherfolks

The distribution of technical efficiency of the fisherfolks (Table 6) revealed that none of the fisherfolks had a technical efficiency of less than 50%. In general, the results suggest that the sampled fisherfolks were fairly technically efficient. The mean technical efficiency of 71% suggested that there is scope for increasing fish landing in the study area by 29% if they were to operate at the frontier. The result is in line with observations made that artisanal fisherfolks in developing nations are technically efficient but poor. The distribution of allocative efficiency of the fisherfolks revealed that majority (62%) of the fisherfolks had allocative efficiency of less than 30%.

Table 1: Frontier production Function Estimate for Marine and Lagoon Respondents

		Marine	Respondents	Lagoon	Respondents
S/N	**Variables**	**Coefficient**	**T-Ratio**	**Coefficient**	**T-Ratio**
0.	Constant	1.5113	0.169	2.1724	0.072
1.	Labour (days per month)	.714	2.144***	0.2374	1.467
2.	Length of Canoe (meter)	0.3344	5.0685*	0.3436	1.026
3.	Distance covered (nautical miles)	0.9031	2.217*	0.032	0.432
4.	OBE Capacity (horse power)	0.1621	1.800*		
5.	Hours Per Trip	-0.02351	-0.316	-0.0739	-1.114
Variable parameter					
	Sigma-squared	0.0429	9.319*	0.0949	9.347*
	Gamma	0.0376	3.309*	0.0229	0.001
	Log likelihood	25.58		-40.7115	
	Mean efficiency	0.73		0.68	
	Observations	164		169	

Source: 2014 Field Survey

Table 2: Frontier Cost Function Estimates for Marine and Lagoon Respondents

Marine Respondents				**Lagoon Respondents**		
Variable	**Mean (SD)**	**Stochastic Frontier (OLS)**	**ML**	**Mean (SD)**	**Stochastic Frontier (OLS)**	**ML**
Constant	-	10.077 (78.458)***	10.137 (23.329)***	-	9.6545 (76.311)***	9.6347 (1.424)
Output (Q)	10.123 (0.18757)	0.0081 (0.357)	0.0082 (0.411)	9.6969 (0.25258)	0.00901 (0.338)	0.0090 (0.319)
Lambda λ	-	-	0.413 (0.138)	-	-	0.098*** (0.003)
Sigma σ	-	-	0.1963 (1.577)	-	-	0.2525 (0.474)
Log Likelihood	-	-	42.842	-	-	-7.128

Source: Results from data analysis 2014
The numbers in parenthesis are t-values ***Significant at 1%

Table 3: Frontier Cost Function Estimates for pooled data

Variable	**Mean (SD)**	**Stochastic Frontier**	
		OLS	**ML**
Constant	-	9.1340 (92.703)***	9.4342 (82.850)***
Output (Q)	9.9014 (0.3088)	0.1500 (7.885)***	0.1466 (6.962)***
Lambda λ			1.870 (4.211)***
Sigma σ			0.401 (12.492)***
Log likelihood			-51.417

Source: Results from data analysis 2014
The numbers in parenthesis are t-values ***Significant at 1%

Table 4: Socio-Economic Factors Affecting Technical Inefficiency among the Marine and Lagoon Respondents

	Marine Respondents		**Lagoon Respondents**	
Variables	**Coefficient**	**T-Ratio**	**Coefficient**	**T-Ratio**
Constant	1.5130	0.169	1.021	0.336
Age	-0.251	-1.923*	-0.1781	-9.347***
Fishing experience	-0.061	-2.203**	-0.0557	-1.290
Secondary income	-0.00588	2.150**	-0.01177	-2.900***
Type of gear	-0.1259	1.880*	-0.1765	-1.090
Member of association	0.02219	4.920***	-0.9086	-2.680**
Type of canoe	0.4560	1.170	0.08779	1.100

Source: Field Survey 2014

Table 5: Socio-economic factor affecting allocative and economic inefficiency of respondents

	Allocative		Economic	
Variables	**Coefficient**	**T-Ratio**	**Coefficient**	**T-Ratio**
Constant	0.217	3.277***	0.157	2.912***
Age	0.030	0.638	0.052	1.046
Fishing experience	-0.030	-0.648	-0.030	-0.615
Secondary income	0.061	-1.327	-0.061	-1.253
Type of gear	-0.076	-1.332	-0.089	-1.485
Member of association	-0.024	-0.486	0.002	0.033
Type of canoe	-0.187	-2.837**	-0.161	-2.332**

***Source*:** Field Survey 2014

Table 6: Distribution of Technical Efficiency of Fisherfolks

	Marine		Lagoon		Pool	
Category	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
< 0.3	0	0.00	0	0.00	0	0.00
0.3 - < 0.4	0	0.00	0	0.00	0	0.00
0.4 - < 0.5	0	0.00	0	0.00	0	0.00
0.5 - < 0.6	1	0.60	22	12.22	23	6.65
0.6 - < 0.7	39	23.49	73	40.56	112	32.37
0.7 - < 0.8	115	69.28	76	42.22	191	55.20
> 0.8	11	6.63	9	5.00	20	5.78
Total	166	100.00	180	100.00	346	100.00
Mean	0.73		0.68		0.71	
Minimum	0.56		0.51		0.51	
Maximum	0.83		0.83		0.83	

***Source*:** 2014 Field Survey

4. Conclusion

Based on the evidence revealed by the stochastic production and cost frontier, it can be concluded that the sampled fisherfolks were fairly technically efficient. Outboard engine (O.B.E) is one of the de-facto tools in fishing operation. The coefficient of O.B.E capacity (0.162) obtained from technical efficiency analysis for marine is a pointer to the fact that reduction of tariffs on imported fishing inputs such as O.B.E will enhance technical efficiency as fisherfolks will be able to go faster and farther into the water bodies, thereby preventing over exploitation. Government policies that would facilitate provision of enhanced extension service to fisherfolks, reducing tariffs on imported fishing inputs;, encouragement of active and financially viable cooperative societies formation should be considered. All these will go a long way in enhancing the economic efficiency of the fisherfolks.

5. References

1. Akanni KA, Akinwunmi JA. Determinant of variation in Fish catch levels in Artisanal Fishing of Lagos State. Nigeria Research Journal of Fishery and Hydrobiology. 2007: 2(i):1-12
2. Akpaniteaku RC, Weimin M, Xinhua J. Evaluation of the contribution of fisheries and Aquaculture to Food Security in Developing Countries. NAGA, WORLD FISH Centre Newsletter. 2005; 28:1-2.
3. Dada BF. Contribution of Fisheries to Employment, National Economy and food Security in Nigeria. Being a paper presented at the Fison Public Lecture. Held at the Nigeria Society of Engineers, 2003, 25.
4. Federal Department of Fisheries FDF. Fisheries Statistics of Nigeria 4th edition (2002-2008), 2008, 60.
5. Kaushik SJ. Applied Nutrition for Sustainable Aquaculture Development. In book of Synopses. 2000, 155-158.
6. Tacon AGJ. Increasing the contribution of aquaculture for food security and poverty alleviation in the Third millennium; Subasinghe RP, Bueno P, Phillips MJ, Hough SE, McGladtery eds. Technical Proceedings on Aquaculture in the third Millennium. Bangkok, Thailand. 20-25 NACA, Bangkok and FAO, Rome, 2000, 2001, 63-67.
7. Kudi TM, Bako FP, Atala TK. Economics of Fish Production in Kaduna State, Nigeria. Asian Research Publishing Network (APRN). 2008; 3(5-6):17-21.
8. Thompson DB. Conflicts within the fishing industry. In FAO Paper presented at the expert consultation on the regulation of fishing efforts (Fishing mortality) Rome, 1983, 17-26.
9. Malberg-calvo C. Case study on the role of women in rural transport SSATP working papers. No. 11 World Bank, Washington., D.C. 20433, USA. 1, 1994.
10. Lambert LR, Abram. An assessment of role of women in fisheries in Kosrae FMS Field Report. 2001; 3:15.
11. Okpanefe A. Agricultural and Marketing Resources. Fisheries Statistics survey in Nigeria. Niomr, Lagos, 1997, 39.
12. Food and Agricultural Organisation FAO. FAO Country Programming cFramework (CPF) Fed Republic of Nigeria. Fiat, Paris, 2003, 1-41.
13. Federal Department of fisheries FDF Publication. Fisheries Statistics of Nigeria 4th Edition. 2002-2008, 2002, 60.
14. Obwona MB. Efficiency differential among small and medium scale farmers in Uganda. A case of tobacco growers. A report presented at AERC Biannual Workshop; Nairobi, Kenya, 2000.
15. Ali M, Chaudhary MA. Inter-regional farm efficiency in Pakistan Punjab; Frontier Production Study: Journal of Agricultural Economic. 1990; 41(i):62-74.
16. Awotide DO, Rahji MAY, Adejobi AO, Bamire AS. Technical Efficiency and Management Factors in Plantain production in humid forest Zone in Nigeria, Assimulation analysis. South African Journal of

Economic and Management Science (SAJEMS). 2005; 8(2):238-245.

17. Farrel MJ, Fieldhouse M. Estimating Efficiency Production under Increasing Return to Scale. Journal of the Royal Statistics society A (General). 1962; 125(2):252-1167.
18. Ajibefun IA, Battese GE, Daramola AG. Determinant of Technical Efficiency in small Scale holder food crop farming. Application of Stochastic frontier production Quart. Journal inter. Agricultural. 2002; 41:225-240.
19. Dales S, Quetin Grafton R, Alam MF, Omar IH. Technical Efficiency in the Analysis of Gill Net Fishery: US Marine Fisheries Services South West Fisheries Science Centre P.O. Box 271. La Jolla Ca, 2003, 15.
20. Sesabo JK, Tal RST. Technical Efficiency and small scale fishing households in Tanzania marine Villages, an Empirical analysis F.N.U., 2005, 95.
21. Kareem RO, Dipleolu AO, Aromolaran AB, Williams SB. Economic Efficiency of Fish Farming in Ogun State. Aquaculture Economics and Management. 2008; 13:39-52.
22. Dawang NC, Manggoel W, Dasbak MA. Journal of Economics and Sustainable Development. 2012; 3(5):62-71.
23. Lagos State Agricultural Development Authority (ADA). Village listing Survey Report, 2005, 25.
24. NIOMR. Diagnostic Survey of Lagos Survey Lagos state Fisheries- Nigeria Institute of Oceanography and Marine Research (NIOMR) Lagos. Nigeria, 1990, 150.
25. Broack JV, Forsund FR, Hjalmarson L, Meeusen W. On the Estimation of Deterministic and Stochastic Frontial Production Functions: A comparison. Journal of Econometrics. 1980; 4:23-30.
26. Coelli TJ. A guide to Frontier Versions 4.1 Computer Programme for frontier production Estimation CEPA Working Paper 96/97 Dept. of Econometrics University of New England, Armidale, 1996.