TECHNOLOGY GAP AND TECHNICAL EFFICIENCY OF RICE PRODUCTION ECOLOGIES IN SOUTH EASTERN NIGERIA

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ABSTRACT

The study examined the technology gap and efficiency of rice production ecologies in South-Eastern, Nigeria. Descriptive statistics, stochastic frontier and metafrontier were used to analyse the primary data which were collected. A total of 217 rice farmers were randomly selected for the study. The result shows that rice production is male dominated and the average farm size cultivated was 1.0 hectare. The rice production was done by farmers who are within the productive age (31 – 50 years). and that resource inputs such as rice seed, fertilizer, agrochemicals, land significantly affect rice production. Rice farmers are operating in stage 1 of the production frontier characterised by increasing return to scale of (1.03) with a substantial gap in technology between the metafrontier relative to deep water (0.9601) and upland (0.8687) ecologies. The study recommends that land area cultivated to rice be expanded to increase domestic rice production and that rice farmers in deep water and upland could benefit from better production conditions by adopting technology (available at the metafrontier) such as improved rice seed variety for potential improvement in performance of production environment.

KEY WORDS: Technology gap, Stochastic Metafrontier, Deep water, Upland, Ecologies

INTRODUCTION

Rice (*Oryza sativa*) is a major staple food for millions of people with it accounting for over 20 percent of global calorie intake. It is an important food commodity for most people in Sub-Saharan Africa particularly West African region. It is a strategic food security crop produced in all of Nigeria's agro-ecological zones – rain-fed upland, rain-fed lowland, irrigated lowland, deep water and mangrove swamp (Akande, 2002; MARKETS 2009).In Nigeria, rice has become the fastest growing commodity by assuming a strategic position in the food basket of rural and urban households (Akande, 2002; Oyinbo *et al.*, 2013).The demand for rice has been increasing at a faster rate than domestic production, and the volume of domestic rice has been unable to bridge the demand and supply gap of rice as it has not met the consumption demand of the rapidly growing Nigeria population who have "great" preference for parboiled rice (Chikezie, 2008; Ogundari, 2008; Oni, *et al.*, 2009). Oguntade, (2011) and Dontsop, *et al.*,(2011), observed that the inability of Nigeria to attain self-sufficiency in rice sector is attributed to low yield as a result of low resource productivity and lack of high yielding varieties with good grains. Farmers' efficiency can be raised by the adoption of improved technology, however, with the low rate of improved technology adoption by farmers, improving efficiency in production become imperative to enhancing farm level productivity (Saka and Lawal, 2009). The focus of this study is to determine the levels of technical efficiency and technology gap ratio of two main rice ecologies.

METHODOLOGY

Study Area, Method of data Sampling Technique

The study was conducted in South Eastern Nigeria. Primary data were collected through the aid of questionnaire. A multi-stage sampling technique was used. Stage 1 involved the purposive selection of Anambra and Enugu States (states mainly covered by the staple crop processing zone of Agricultural Transformation Agenda:- Adani-Omor staple crop processing Zone). Stage 2 involved the purposive selection of two prominent rice producing local government areas (LGA) from each state. Stage 3 involved the random selection of three rice producing villages from each LGA. Stage 4 involved the random selection of 290 rice farmers, however, data from 217 rice farmers were analysed in this study as a result of incomplete information.

Analytical Technique

Data were analysed using descriptive statistics, stochastic frontier model and stochastic meta-frontier model following (Battese and Rao 2002; Battese *et al.*, 2004; and O'Donnell *et al.*, 2008). Rice farmers in different ecology are faced with different production opportunities and they make choices from different sets of input-output combinations. They differ because of resource endowment. Estimating efficiency in the different ecology involved measuring efficiency in two ways: one relative to a common metafrontier and the other relative to a group frontier (O'Donnell *et al.*, 2008). The approach of O'Donnell et al., 2008 was adopted for this study

The Cobb-Douglas stochastic frontier production function was used to estimate the technical efficiency of rice farmers within the production ecologies. The explicit form of the function

$$Y_i = f(x_i, \beta)e^{V_i - U_i} \equiv e^{x_i \beta + V_i - U_i} \quad \ldots\ldots 2$$

is specified as:

$$lnY_i^k = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + V_i - U_i \ldots\ldots 3$$

Where: Y_i^k represents observed individual i^{th}farmer output (rice yield) for the kth group (kg); X_1 = quantity of seed used by i^{th} farmer (kg); X_2 = quantity of fertilizer used on i^{th} farm (kg); X_3= quantity of agrochemicals used on the i^{th} farm (litres); X_4=total land area cultivated to rice by i^{th} farmer (ha); X_5=number of labour input (family and hired labour) (labour manday); β_s^k= vector of unknown parameters to be estimated; V_i= random variables associated with random factors; U_i= non-negative random variables which are assumed to account for technical inefficiency in production

The stochastic metafrontier production function model defined by Battese and Rao (2002) and Battese *et al.*, (2004) was adopted for the rice industry and is expressed as in equation 1

$$Y_i^* = f(X_i\beta^*)e^{V_i^* - U_i^*} \equiv e^{X_i\beta^* + V_i^* - U_i^*}, \qquad i = 1, 2, \ldots\ldots, N \quad \ldots\ldots 4$$

Where:$N = \sum_{k=1}^{R} N_k$= total number of sampled farms in all K groups; Y_i^* = the metafrontier rice output that dominates all group frontiers,; β^*= denotes the vector of metafrontier parameters which satisfies the constraints:

$$X_i\beta^* \geq X_i\beta^k \quad \text{for all k} = 1, 2, \ldots\ldots K \quad \ldots\ldots 5$$

This implies that the metafrontier function cannot fall below any of the group frontiers.

Results and Discussion

Socioeconomic characteristics

The result of the socioeconomic characteristics of the respondents is presented in table 1. The result indicates that rice farmers are within the economically productive age (31 – 50 years). The mean age for the deep water rice farmers was 44.22 years and 45.46 years for upland ecologies rice farmers. Similarly, 65% of the deep water rice farmers and 61% of the upland ecologies rice farmers were males respectively. This result corroborates that of Ahmadu and Alufohai (2012) and Akintayo and Rahji (2016) who reported male dominance in rice production. Furthermore, most (78% and 87%) rice farmers in the deep water and upland ecologies were married respectively. In the same vein, the distribution according to household size revealed that majority (97% and 96%) of the farmers in deep water and lowland ecologies had average household sizes of 6 and 5 persons respectively. The implication of a large household size is that farmers will have free household labour in carrying out various activities in rice production Tashikalma *et al.*,(2014). The result further indicates that 87% of the rice farmers in deep water and 98% of the rice farmers in upland ecologies had formal education. The implication of this literacy level is that it will aid in boosting their chances of information acquisition and utilization. This result is in affirmation with Okoruwa and Ogundele (2006) and Saliu *et al.*, (2016). The average farm size cultivated by rice farmers in deep water ecology was 1.58ha while the average farm size cultivated by the farmers in the upland ecologies was 0.96ha. The result further shows that farmers in deep water ecology had an average farming experience of 8.94 years while rice farmers in upland ecology had an average farming experience of 5.23 years. These differences may be due to the establishment of the Agricultural Transformation Agenda (ATA) staple crop processing zones at Omor, Anambra state

Table 1: Socio-Economic Characteristics of Rice Farmers in the Study Area.

Variables	Deep water		Upland	
	Frequency	Percentage	Frequency	Percentage
Age				
≤30	7	7.2	11	9.2
31 – 40	35	36.1	28	23.3
41 – 50	30	30.9	45	37.5
51 – 60	22	22.7	33	27.5
≥60	3	3.1	3	2.5
Mean	44.22		45.46	
Sex				
Male	63	64.9	73	60.8
Female	34	35.1	47	29.2
Marital status				
Single	11	11.3	14	11.7
Married	76	78.4	104	86.7
Divorced	8	8.2	2	1.7
Widow	2	2.1		
Household size				
≤5 persons	31	32.0	58	48.3
6 – 10 persons	63	64.4	57	47.5
11 – 15 persons	3	3.1	5	4.2
Mean	6.16		5.63	
Education level (years of schooling)				
No Formal	13	13.4	2	1.7
Primary	29	29.9	48	40.0
Secondary	45	46.4	43	35.8
Tertiary	10	10.3	27	22.5
Mean	8.67		9	
Farm size(ha)				
≤0.5	27	27.8	26	21.7
0.6 - 1.0	20	20.6	74	61.7
1.1 – 2.0	24	24.7	20	14.2
≥2.1	26	26.8		
Mean	1.58		0.96	
Rice farming experience				
≤10	73	75.3	69	57.5
11 – 20	16	16.5	34	28.3
21 – 30	7	7.2	17	14.2
≥31	1	1.0		
Mean	8.94		5.23	

Source: Computed from survey data 2016

The maximum likelihood estimates of the Cobb-Douglas production frontiers

The result of the maximum likelihood estimation (MLE) of the stochastic frontier function for the two ecologies is presented in table 2. Sigma-square (σ^2) across the rice production ecologies are significant indicating a good fit of the model. The values of gamma (γ) for the two ecologies are 0.6099 and 0.7969, implying that 61.0% and 79.69% of the difference between the observed (paddy rice) and maximum production frontier output for deep water and upland respectively is due to the difference in the farmer's technical inefficiency.

The stochastic frontier production function for the ecologies shows that seed, fertilizer, agrochemicals and land significantly affect rice production. The result further shows that in deep water ecologies, fertilizer (0.1969), agrochemicals (0.1508) and land (0.8947) were positive and significantly (at 10%, 5% and 1% respectively) influenced the output (paddy) of rice farmers. Thus a 10% increase in these inputs will increase rice paddy by 1.9, 1.5 and 8.9 respectively. However, in upland rice only, seed (0.1239) and land (0.7101) significantly (at 10% and 1% respectively) affect rice output. It was also observed that the elasticity estimates for land was high across the production ecologies compared to other production inputs with values of 0.8947 and 0.7101 for deep water and upland respectively, implying that increasing the size of the land will increase rice output. The result shows an increasing return to scale for the production ecologies, with a value of approximately 1.03 for the two ecologies, implying that rice production is in stage I of the production frontier. This finding is in consonance with Ataboh *et al.*,(2014) who reported return to scale value of 1.83 for rice farmers in Kogi state. The mean technical efficiency of individual farmer in the two ecologies is approximately 81.2% and 87.8% respectively for deep water and upland. This implies that an average farmer could improve its technical efficiency by the shortfall of 18.8% and 12.2% in deep waters and upland respectively. The result of the inefficiency model showed that only Age, marital status, household size and farming experience have significant effect on the level of technical efficiency. For variable Age, the older the rice farmers the more inefficiency they become.

Table 2: Maximum likelihood estimates of the stochastic production frontier

	Rice Production Ecologies			
Variables	Deep water	Upland	Pooled	Meta-frontier
Constant	7.8020	6.8831	7.4349	7.6724
	(0.696)	(0.559)	(0.424)	
Seed	-0.2099**	0.1239*	-0.1042*	-0.1518
	(0.106)	(0.749)	(0.056)	
Fertilizer	0.1969*	0.1415	0.2246***	0.1746
	(0.103)	(0.103)	(0.067)	
Agrochemical	0.1508**	0.0678	0.0971**	0.1517
	(0.678)	(0.460)	(0.037)	
Land	0.8947***	0.7101***	0.8428***	0.8665
	(0.119)	(0.113)	(0.076)	
Labour	-0.0049	-0.0174	-0.0463	0.0676
	(0.923)	(0.215)	(0.032)	
Sex	-0.2615	0.2460		
	(0.974)	(0.355)		
Age	-0.0915**	0.0412		
	(0.042)	(0.032)		
Marital status	0.6114	-1.1423***		
	(1.323)	(0.578)		
Education level	0.0359	0.0289		
	(0.098)	(0.050)		
Household size	-0.4269	0.1758***		
	(0.319)	(0.090)		
Farming Experience	0.2278**	-0.0740**		
	(0.104)	(0.032)		
Extension visit	1.1460	-0.0469		
	(1.217)	(1.547)		
Cooperative member	-1.7536	-1.9414		
	(1.436)	(1.740)		
Sigma square σ^2	0.1273***	0.0374***	0.0801***	
	(0.042)	(0.113)	(0.014)	
Gamma γ	0.6099**	0.7969***	0.6662***	
	(0.260)	(0.168)	(0.114)	
Log-likelihood	-13.476	71.899	27.266	
Mean Efficiency	0.812	0.878	0.8417	
RTS	1.0276	1.0259		

Source: Computed from field survey data, 2016

Note: The figures in parenthesis are standard errors. Statistical significance levels are; ***1%; **5%; *10%.
RTS means Return to scale

Technology Gap Ratios and Metafrontier Technical Efficiency

Estimates of technical efficiencies of the stochastic frontier, metafrontier efficiency scores (TE*) and technology gap ratios are presented in table 3. The technology gap ratio (TGR) measures the gap between the metafrontier (unrestricted technology) and the group frontier (restricted technology) (Battese and Rao, 2002). The value of TGR ranges between 0 and 1 with the value of 1 indicating that the group frontier is tangential to the metafrontier (Battese, *et al.*, 2004). The result indicates an average TGR of 0.9601 and 0.8687 for deep water and upland ecologies respectively. TGR was higher in deep water ecology indicating higher difference in investment level relative to farmers in upland ecology.

Furthermore, the standard deviations of the metafrontier TE (TE*) for deep water and upland was 0.078 and 0.075 respectively with mean TE* values 0.7799 and 0.7623 respectively. The implication of the finding is that given the available rice production technology potential, deep water rice farmers produce approximately 78% of potential output; while upland rice farmers produce about 76.2% of potential output if potential metafrontier technology is available to the two ecologies.

Table 3: Statistics of the estimates of technical efficiencies and technology gap ratios

Model		Deep water	Upland
TE w.r.t. production ecology			
	Mean	0.8122	0.8781
	Min	0.4984	0.5826
	Max	0.9371	0.9656
	Std. Deviation	0.0779	0.0686
TE w.r.t. the pooled ecology			
	Mean	0.8327	0.8489
	Min	0.4655	0.6351
	Max	.9606	0.9359
	Std. Deviation	0.0950	0.0490
TE* w.r.t. the metafrontier			
	Mean	0.7799	0.7623
	Min	0.4785	0.4973
	Max	0.9126	0.9446
	Std. Deviation	0.0784	0.0749
Technology gap ratio			
	Mean	0.9601	0.8687
	Min	0.8851	0.7310
	Max	1.0000	1.0000
	Std. Deviation	0.0258	0.0452

Source: Computer from field survey data, 2016

CONCLUSION AND RECOMMENDATIONS

Resource inputs such as rice seed, fertilizer, agrochemical and land significantly affected rice production in the area. However, an increase in land area cultivated to rice would increase farm production. Also, rice farmers are operating in stage 1 of the production frontier characterised by increasing RTS (1.03). There is substantial gain the technology between the metafrontier relative to deep water and upland ecologies. There is a need to expand the land area for domestic rice production so that rice farmers in deep water and upland could benefit from better production conditions by adopting technology (available at the metafrontier) for potential improvement in performance of production environment as suggested by the difference in efficiency measured resulting from the metafrontier.

REFERENCES

Ahmadu, J. and Alufohai, G.O. (2012). Estimation of technical efficiency of irrigated rice farmers in Niger State, Nigeria. *American-Eurasian Journal of Agriculture and Environment Science*, 12(12): 1610-1616

Akande, T. (2002), An Overview of the Nigerian Rice Economy. Available at: http://unep.ch/etb/etb/events/Agriculture/nigeria.pdf. Pp 1-11 Accessed on: 20/06/2010.

Akintayo, O.J.and Rahji, M.A.Y. (2016). Technical efficiency in rice ecologies of north central Nigeria: Implications for national self-sufficiency. *Uganda Journal of Agricultural Sciences*, 17(1): 99 – 110

Ataboh, O.E., Umeh, J.C. and Tsue, P.T. (2014). Determinants of technical efficiency among rice farmers in Kogi State, Nigeria. *Journal of Agriculture and Sustainability*, 6(1): 39-49

Battese, G. E. and Rao, D. S. P. (2002). Technology Gap, Efficiency, and a Stochastic Metafrontier Function. *International Journal of Business and Economics*, 1 (2): 87-93.

Battese, G. E., Rao, D. S. P. and O'Donnell, C. (2004). A Metafrontier Production Function for Estimation of Technical Efficiencies and Technology Gaps for Firms Operating under Different Technologies. *Journal of Productivity Analysis*, 21: 91–103.

Chikezie, C. (2008). Income distribution among rice based farming households in Okigwe Agricultural zone of Imo State. Available at: http://futoportal.silveredgeprojects.com/Research/FUTO/130.pdf. Pp 1-106. Accessed 20/03/2016.

Dontsop, N.P.M., Diagne, A., Okoruwa, V.O., and Ojehomon,V. (2011). Impact of improved rice technology on income and poverty among rice farming household in Nigeria: A Local Treatment Effect (LATE) Approach. *Quarterly Journal of International Agriculture*, 50(3): 267-291

MARKETS (2009): Package of practices for rice production. Available at: http://www.nigeriamarkets.org/files/Rice_POP_English_June_2009%5B1%5D.pdf. Accessed 28/03/2016.

O'Donnell, C.J., Rao, D.S.P. and Battese, G.E (2008). Metafrontier Frameworks for the study of Firm-level Efficiencies and Technology Ratios. *Empirical Economics* 34(2):231-255

Ogundari, K. (2008). Resource-Productivity, allocative efficiency and determinants of technical efficiency of rainfed rice farmers: A guide for food security policy in Nigeria. *Journal of Sustainable Development in Agriculture and Environment*. 3(2):20-33

Oguntade, A.E. (2011). Assessment of protection and comparative advantage in rice production technologies in Nigeria: *African Journal of Food, Agriculture, Nutrition and Development*, 11(2): 4632-4646

Okoruwa, V.O and Ogundele, O.O (2006). Technical efficiency differential in rice production Technologies in Nigeria. Available at: http://www.csae.ox.ac.uk/conferences/2006-EOI-RP/papers/csae/Okoruwa.pdf. Pp 1-17. Accessed 20/03/2016

Oni, O., Nkonya, E., Pender, J., Phillips, D. and Kato, E. (2009). Trends and drivers of agricultural productivity in Nigeria. International Food Policy Research Institute. Nigeria Strategy Support Program (NSSP), Report 001

Oyinbo, O.,Omlehin, R.A and Abdulsalam, Z. (2013). Analysis of the demand for rice in Kaduna State, Nigeria. *Agris on-line Papers in Economics and Information*, 5(3): 45-52.

Saka, J.O. and Lawal, B.O. (2009). Determinants of adoption and productivity of improved rice varieties in South-western Nigeria. *African Journal of Biotechnology*, 8(19): 4923-4932

Saliu, J.O., Ibrahim, M.K. and Eniojukan, F.O. (2016). Socio-economic determinants of improve rice technoloies' adoption among small scale farmers in Kogi State, Nigeria. *FACTA UNIVERSITATIS Series: Economics and Organization*, 13(2): 217-232.

Tashikalma, A.K., Giroh, D.Y. and Ugbeshe, V.A. (2014). Swamp rice production in Ogoja local government area of Cross River State, Nigeria: An imperative for rice value chain of the agricultural transformation agenda. *International Journal of Agricultural Policy and Research*, 2(8): 281-287.