PRODUCTIVITY IMPROVEMENT IN ECOWAS RICE FARMING: PARAMETRIC AND NON-PARAMETRIC ANALYSIS.[1]

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ABSTRACT

This study compares data envelopment analysis and stochastic frontier analysis to assess productivity growth of rice farming in Economic Community of West African States (ECOWAS). The data are collected from Food and Agriculture Organization Statistical (FAOSTAT) database and International Rice Research Institute (IRRI)'s world rice statistics and cover a 45 year period (1961-2005) separated into pre-ECOWAS (1961-1978) and ECOWAS (1979-2005). The results show consistency between the approaches to the extent that: (1) there are potentials for efficiency improvements, but the magnitudes depend on the model applied and segmentation of the data set, (2) there has been a productivity improvement in the sector, in the interval 0.7–15% in the periods studied and (3) technical change has had the greatest impact on productivity, indicating that producers have a tendency to catch-up with the front runners. The average TFP in pre-ECOWAS period is larger than that of ECOWAS period. In both periods, productivity growth is sustained through technological progress. In general, policy-makers should try not to be indifferent with respect to the approach used for productivity measurement as these may give different results.

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1. INTRODUCTION

Growth in agriculture and its productivity are considered by development economists as critical if agricultural output is to increase at a sufficiently rapid rate to meet the rising demands for food (Johnston and Mellor 1961 and Hayami and Ruttan, 1985). Historically, agriculture continues to support the majority of ECOWAS population in terms of employment, income and consumption. At least, in the medium term, agriculture is still seen as the driver of food security, economic growth and development. The sector is characterized by millions of small family-run farms that derive their income and livelihood from producing primary agricultural products. At present, the sector contributes about 30 – 50% of GDP in most ECOWAS countries. For most country in the region the share of agricultural value added exceeds 25% and provides employment for between 50 – 80% of the population in the region. Moreover the sector is also an important source of export. Trade in agricultural products is very important for almost all the countries in the region. For countries such as Burkina Faso, and Benin, agricultural exports account for over 40% of total exports. As regards the composition of trade, the exports and imports of agricultural products are concentrated on a rather narrow range of products. For instant, cocoa beans, coffee and cotton lint accounted for about 57% of agricultural exports in 2001. In terms of imports, rice, wheat, sugar, milk and chicken accounted for more than 50% of total imports (SWAC 2006). In addition to being a high priority, agricultural policy also tends to be sensitive in almost all the ECOWAS countries because of the consequences for incomes, poverty alleviation and food security. Poor people, who derive most of their income from agriculture or spend most of it on food, are highly exposed to changes in farm commodity and/or food prices.

Given the importance of this sector in the national economy, an important policy option of ECOWAS from its establishment has been to make agricultural sector more competitive by furthering production growth and increasing intra regional trade. The main thrust of the ECOWAS reforms as it affects agriculture is on the free movement of unprocessed goods and traditional handicraft products, which should be exempted from import duties and taxes. The list of unprocessed goods and traditional handicraft products as well as the nomenclature of non-tariff barriers to be lifted were approved as far back as 1979, which means that trade in these products has, to all intent and purposes, been liberalized. Generally, the issue of how agricultural markets respond to price liberalization is a central issue in development policy and one that has been surrounded by much controversy. One question has been how large would be any response in agricultural output to liberalization. A second concern has been the effects of removing subsidies on inputs which are often an important policy intervention by governments. A third has been whether innovation, in the sense of adopting new techniques leading to a rise in total factor productivity, is possible by means of liberalization. The agricultural sector of

ECOWAS offers an opportunity to explore these questions. The liberalization policy involving substantial devaluation of the nominal exchange rate had been reported to have largely eliminated the black market premium, increased real producer prices, and eliminates subsidies so that the real prices of inputs rose far faster than the consumer price index. The basic research question is whether liberalization among ECOWAS countries has led to improved productivity of crops relevant to food security in the region. If liberalization can lead to improved productivity there seems plenty of scope with known technologies.

While much evidence has been provided attesting the productive performance of the agricultural sector in Africa and factors influencing it (Thirtle and Townsend, 1995; Coelli et. al 2001; Nkamleu et.al 2004, 2008) there is little evidence on crop – specific and sub – regional productive performance. An assessment of crop – specific efficiency and productivity analysis should be of more interest to policy-makers implementing liberalization policy than overall aggregates. The rationale is twofold; (1) An insight can be gained on the potential for resource savings and productivity improvements of individual crops and, (2) the producers can learn from the front-runners how best to utilize their resources efficiently. Inter alia, issues of interest in this study are: (a) is there any potential for improving the efficiency of rice producers in ECOWAS? If so, what are the magnitudes? (b) Has there been any productivity progress in ECOWAS rice production since 1979? The choice of 1979 as reference point is to account for periods before ECOWAS policies become effective in member states. (c) Are the results of (a) and (b) irrespective of the methodology applied? While questions (a) and (b) are interesting to the extent that the much needed insight on the performance the sector is gained, question (c) provides evidence on the consistency of frontier techniques within two different and most commonly used approaches. This is of considerable interest for policy purpose. If methods do not give results that are similar or highly correlated to each other, the policy may be fragile and depends on which frontier approach is employed. While the vast majority of empirical studies on productivity growth in the agricultural sector mostly have utilized only one method to estimate their efficiencies, this study focuses on two methodological approaches for measuring efficiency as follows:

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

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

The rest of this paper is organized as follows: section 2 presents the trend in the yield of rice. The theoretical foundation for the stochastic and non-stochastic measurement of the TFP and empirical evidence of its application is presented in section 3 and, in section 4, the data used are described and the parameter estimates are reported to infer which factors explain the growth of output. A final section concludes.

2. PRODUCTIVITY OF RICE IN ECOWAS

Rice production in West Africa represents about 50% of consumers' needs in the sub-region. In terms of per capita apparent consumption, rice is the core staple in Senegal (93 kg per head per year) while it is only one staple in a more diversified diet in Ghana and Nigeria with respectively 25 kg and 29 kg of rice consumed yearly per capita. The shift to rice consumption in Senegal started as early as the colonial period. Production efforts were then driven towards production of groundnuts to the detriment of millet and broken rice was imported from Indochina as cheap staple food. Nigeria has experienced its rice diet transition in the seventies (with a rice per capita consumption annual growth rate of 11%) induced by income growth triggered by the oil industry boom. Ghanaian consumers started to shift to rice only recently compared to the two other countries and experienced a faster growth of rice per capita since 2000 (Lancon and Benz 2007). Most of these countries have adopted enhanced food security as a common policy goal. Dramatic changes in consumption patterns during the past two decades have led to a large increase in the demand for rice from African consumers. Growth in consumption has been most substantial in Africa’s rapidly growing cities, where rice is increasingly becoming the staple diet of the poorest urban households. Rice has therefore become a staple of considerable strategic importance. At present rice imports is still substantial perhaps because the region is not self sufficient in rice production. The way imports have been managed mean that there has not yet been any measurable impact of market opening on the domestic market. But, it is obvious to rice farmers in ECOWAS that the changing domestic and world policy environment require them to pay increasing attention to productivity issues.

To provide an historical perspective on ECOWAS rice production, figure 1 depicts land productivity over the last three-and-a-half decades (1961–2005) using the production - land ratio. Before inception of ECOWAS, ECOWAS rice productivity has been sluggish, with year-to-year fluctuations. Since 1979/1980 production season, there seems to be some improvement in the productivity of rice in all the major producing countries. Largest improvement can be observed in Senegal. Apparently it has the highest rate of per capita consumption in the region.

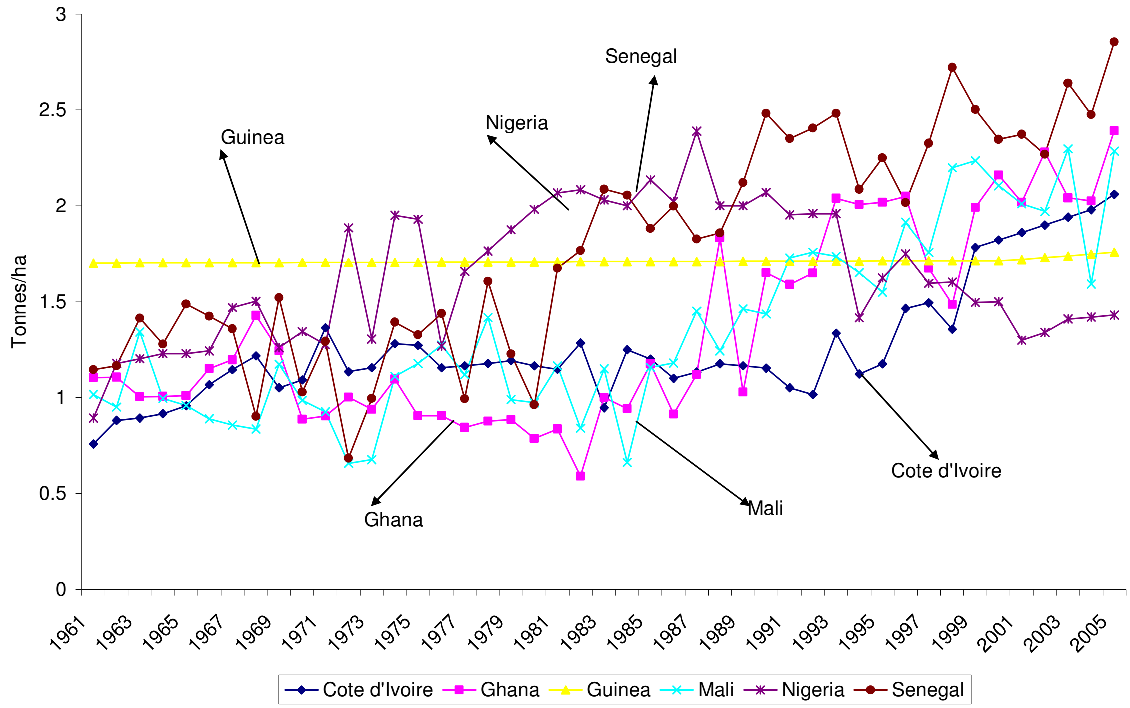

Figure 1: The yield of rice in tonnes per hectare

4. DEA VERSUS STOCHASTIC FRONTIER MEASUREMENT OF TFP INDEX

The Malmquist productivity index (MPI)

The TFP measurement based on the Malmquist index was originally introduced in a consumer theory context as a ratio between 2 deflation or proportional scaling factors deflating two quantity vectors unto the boundary of utility possibilities (Malmquist, 1953). Caves, Christensen and Diwert (1982) later applied the distance function approach in a general production function framework while Fare et. al (1989) in a non parametric DEA framework. The DEA framework is a natural approach which requires neither profit maximization nor cost minimization but only quantity data (Hjalmarsson and Veiderpass 1992). The distance function can be defined in terms of inputs and outputs. An input distance function considers a production technology by looking at a minimal proportional contraction of input vector given an output vector while an output distance function characterized a maximal proportional expansion of the output vector given an input vector. The Malmquist productivity index (MPI), as proposed by Caves, Christensen and Diewert (1982), allows one to describe multi-input, multi-output production without involving explicit price data and behavioral assumptions. The MPI identifies TFP growth with respect to two time periods through a quantitative ratio of distance functions. In this study, output distance functions will be used. Assuming that for each time period t= 1, 2,

…, T, $x_t \in R_+^N$ and $y_t \in R_+^M$ denote respectively an 1 × *N* input vector and an 1 × *M* output vector for period *t*. (*t*=1,2,…, T). The set of production possibilities is given by the closed set,

$$S_t = \{(x_{t,} y_t): x_t \text{ can produce } y_t\} \quad (1)$$

where technology is assumed to have the standard properties such as convexity and strong disposability, as described in Färe *et al,* (1994). The output sets are defined in terms of S_t as :

$$P_t(x_t) = \{y_t : (x_t, y_t) \in S_t\} \quad (2)$$

According to Shephard (1970), the output distance function in *t* for any productivity unit would be:

$$d_o^t(x_t, y_t) = \inf\{\theta : (\mathrm{y_t} / \theta) \in P_t(x_t)\} \quad (3)$$

Where subscript "o" stands for "output oriented". The distance function was the Farrell's reciprocal measurement (Farrell, 1957). This distance function represents the smallest factor, θ by which an output vector y_t is deflated so that it can be produced with a given input vector x_t under period t's technology. That is to say $d_o^t(x_t, y_t)$ provides a standardized average of distance of a unit in the period t to frontier t of production set when inputs are constant. It will take the value of less than 1 if the output vector y is an element of the feasible production set. It will take the value of 1 if y is located on the outer boundary of the feasible set and value of greater than 1 if y is located outside the feasible production set. The productivity change using technology of period *t* as reference is as follows:

$$M_o^t(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_o^t(x_{t+1}, y_{t+1})}{d_o^t(x_t, y_t)}\right] \quad (4)$$

Similarly, we can measure Malmquist productivity index with period t+1 as references as follows:

$$M_o^{t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_o^{t+1}(x_{t+1}, y_{t+1})}{d_o^{t+1}(x_t, y_t)}\right] \quad (5)$$

in order to avoid choosing arbitrary period as reference, Fare *et al.,* (1994) specifies the Malmquist productivity index as the geometric mean of the above two indices

$$M_o(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{d_o^t(x_{t+1}, y_{t+1})}{d_o^t(x_t, y_t)} * \frac{d_o^{t+1}(x_{t+1}, y_{t+1})}{d_o^{t+1}(x_t, y_t)}\right]^{1/2} \quad (6)$$

Equation (13) can be decomposed into the following two components namely efficiency change index which measures the output-oriented shift in technology between two periods. When it is greater or less than one, there exist some improvements or deterioration in the relative efficiency of this unit. The second component is the geometric average of both components and measures technical change between period t+1 and *t.* The first component in technical change measures the position of unit *t+1* with respect to the technologies in both periods. The second component also estimates this for unit *t*. If the technical change is greater (or less) than one, then technological progress (or regress) exists.

$$EFFCH = \frac{d_o^{t+1}(x_{t+1}, y_{t+1})}{d_o^t(x_t, y_t)} \tag{7}$$

and

$$TECHCH = \left[\frac{d_0^t(x_{t+1},, y_{t+1})}{d_o^{t+1}(x_{t+1}, y_{t+1})} X \frac{d_o^t(x_t, y_t)}{d_o^{t+1}(x_t, y_t)} \right]^{1/2} \tag{8}$$

In order to take cognizance of the return to scale properties of the technology, Grifell – Lovell (1995) used a one input, one output example to illustrate that Malmquist index may not correctly measure TFP changes when Variable Return to Scale (VRS) is assumed for the technology. Hence, Constant Return to Scale is imposed upon the technology used to estimate the distance functions for the calculation of the Malmquist index for this study. There exist several methods of estimating the distance functions which makes up the Malmquist TFP index. The most popular and widely adopted in recent time has been the DEA- like linear programming (LP) methods suggested by Fare et. al (1994) and its parametric equivalent – stochastic frontier method. Given availability of panel data, Fare et al (1994) used DEA method to estimate and decompose the Malquist TFP index. The DEA method is a non parametric approach in which the envelopment of decision making units (DMU) can be estimated through LP methods to identify the best practice for each DMU. For the ith firm, Fare et al 1994 calculated four distance functions to measure TFP change between 2 periods. Assuming CRS technology in their analysis, the required LPs are:

$$\left[d_o^t(x_t, y_t)\right]^{-1} = \text{Max}_{\phi,\lambda}\phi. \tag{9}$$

$$\begin{aligned} &s.t - \phi y_{it} + Y_t\lambda \geq 0 \\ &x_{i,t} - X_t\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned}$$

$$\begin{aligned} &\left[d_o^{t+1}(x_{t+1}, y_{t+1})\right]^{-1} = Max_{\phi,\lambda}\phi. \\ st \quad &-\phi y_{i,t+1} + Y_{t+1}\lambda \geq 0 \\ &x_{i,t+1} - X_{t+1}\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \tag{10}$$

$$\left[d_o^t(x_{t+1}, y_{t+1})\right]^{-1} = \text{Max}_{\phi,\lambda}\phi \tag{11}$$

St

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

$$\left[d_o^{t+1}(x_t, y_t)\right]^{-1} = Max_{\phi,\lambda}\phi \quad (12)$$

$$st \quad -\phi y_{i,t} + Y_{t+1}\lambda \geq 0 \quad (12)$$
$$x_{i,t} - X_{t+1}\lambda \geq 0$$
$$\lambda \geq 0$$

Where λ is a N x 1 vector of a constant and θ is a scalar with θ greater than 1

Stochastic Frontier Method

The distance measures require for the Malmquist TFP index calculations can also be measured relative to a parametric technology using stochastic production function. The stochastic production function for panel data can be written as

$$\ln(y_{it} = f(x_{it}, t, \alpha, v_{it} - u_{it}) \quad (13)$$

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

Where y_{it} is production of the ith firm in year t, α is the vector of parameters to be estimated. The v_{it} are the error component and are assumed to follow a normal distribution $N(0, \sigma_{it}^2)$, u_{it} are non negative random variables associated with technical inefficiency in production which are assumed to arise from a normal distribution with mean μ and variance σ_μ^2 which is truncated at zero. $f(.)$ is a suitable functional form (e.g translog), t is a time trend representing the technical change.

In this parametric case, the measures of technical efficiency and technical change can be used to get the Malmquist TFP via (6), (7) and (8). The technical efficiency of production for the ith region at the tth year can be predicted using Coelli et. al (1998). The technical efficiency are obtained as

$$TE_{it} = E(\exp)(-u_{it}) / v_{it} - u_{it}) \quad (14)$$

This can be used to compute the efficiency change component by observing that $TE_{it} = d_o^t(x_{it}, y_{it})$ and $TE_{i,t+1} = d_o^{i,t+1}(x_{i,t+1}, y_{i,t+1})$ the efficiency change (EC) is

$$EC = TE_{it} / TE_{i,t+1} \quad (15)$$

This measure can be compared directly to (7). An index of technological change between the two adjacent periods t and $t+1$ for the ith region can be directly calculated from the estimated parameters of the stochastic production frontier. This is done by simply evaluating the partial derivatives of the production function with respects to time at x_{it} and $x_{i,t+1}$. If technical change is non neutral, the technical change may vary for the different input vectors. Following Coelli et al (1998), the technical change (TC) index is

$$TC_{it} = \left\{ \left[1 + \frac{\delta f(x_{it}, t+1, \alpha)}{\delta t + 1} \right] X \left[1 + \frac{\delta f(x_{it}, t, \alpha}{\delta t} \right] \right\}^{1/2} \tag{16}$$

This measure may be compared directly with (8). The TFP index can be obtained by simply multiplying the technical change and the technological change i.e

$$TFP_{it} = EC_{it} * TC_{it} \tag{17}$$

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

Empirical Specification

This study utilized data on output and inputs of rice, from major producers of the crops to construct indices of TFP using the two methods described by equations 1 – 17. The sample data comprise annual measures of the output of each crop and 6 direct inputs (land area, seed, fertilizer, labour, capital and irrigation). The major countries producing rice are : Cote d'Ivoire Ghana Guinea Mali Nigeria Senegal. For the purposes of the present study, several functional forms were fitted beginning with Cobb-Douglas technology. The underlying stochastic production frontier function upon which the results and discussion of this study are based is approximated by the generalized Cobb-Douglas form (Fan 1991). The function may also be viewed as a translog specification without cross terms, i.e. a strongly separable-inputs translog production frontier function. For rice the specification is:

$$\ln y_{it} = \alpha_0 + \alpha_h \ln H_{it} + \alpha_s \ln S_{it} + \alpha_f \ln F_{it} + \alpha_l \ln L_{it} + \ln K_{it} + \ln I_{it} + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2 + \alpha_{ht} (\ln H_{it})t + \alpha_{st} (\ln S_{it})t + \alpha_{ft} (\ln F_{it})t + \alpha_{lt} (\ln L_{it})t + \alpha_{kt} (\ln K_{it})t + \alpha_{It} (\ln I_{it})t + v_{it} - u_{it} \tag{18}$$

The symbols are defined as follows:

y_{it} is the output of crop i in the tth year

H_{it} is the hectares of land cultivated to each crop

S_{it} is the quantity of seed planted in '000 tonnes

F_{it} is the quantity of fertilizer used in '000 tonnes

L_{it} is amount of labour used in mandays

K_{it} is the amount of capital used

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

$\ln$ is the natural log

$\alpha_i s$ are unknown parameters to be estimated

$v_{it} s$ are $iidN(0, \sigma_{v^2})$ random errors and are assumed to be independently distributed of the $u_{it} s$ which are non negative random variables associated with TE inefficiency. The distribution of the $u_{it} s$ are obtained by truncation at zero. The mean is defined as:

$$u_{it} = \beta_0 + \beta_1 \frac{K_{it}}{L_{it}} + \beta_2 M_{it} + \beta_{dj} \sum_{j=1}^{n} D_{tj} \qquad (19)$$

Where

$\frac{K_{it}}{L_{it}}$ is capital – labour ratio for crop i in the tth year

D_j is the dummy variable which takes the value of 1 for the jth state producing the selected crops.

βs are unknown parameters to be estimated.

Where M indicates import of rice milled measured in tonnes.

Data and estimation of TFP

Data for inputs and outputs are collected principally from FAOSTAT 2007.This is supplemented with International rice research institute's (IRRI) world rice statistics. The data covered a period of 45 years from 1961 to 2005. The data are from six countries producing more than 80% of rice paddy in ECOWAS. They are Cote d'Ivoire, Ghana, Guinea, Mali, Nigeria and Senegal. The data set contains six inputs namely land area, seed, fertilizer, labour, tractor, irrigation and country dummies. The descriptions of the input-output data used in this study are:

Outputs:

This is the Quantity of rice production in tones. This is taken from FAOSTAT database

Inputs

Fertilizer: Fertilizer use is proxyed as the total fertilizer use in metric tones times the share of rice harvested fields over arable land (FAO).

Labour: This is measured as the amount of labor in each crop production proxyed as the economically active agricultural labor force per unit of agricultural land times rice harvested area (FAO). Some studies have used active workers in rural areas (World Bank). This was tried also but the results were not as good as when the former was used.

Capital : Capital as used in this study refers to the amount of capital used in rice production. It is proxyed as tractors used per unit of agricultural land times rice-harvested area (FAO).

Land: Expressed in '000 ha, it is measured as land area under rice cultivation. Land data is also drawn from FAOSTAT data base

Seed: Drawn from FAOSTAT data base and expressed in '000 metric tones, it covers quantity of rice seed planted.

Irrigation: This is the proportion of rice land area that is irrigated. It is taken from IRRI world rice statistics.

Import: This is included in the inefficiency model. It is measured as the metric tones of rice milled imported by the major producers considered in this study.

5. EMPIRICAL RESULTS AND ANALYSIS

The Results of the Stochastic Frontier Model

Parametric productivity measures are based on the estimated parameters of the stochastic frontier function (18), and so a brief discussion of these estimates and their statistical properties precedes our comparative analysis of productivity indices. The estimated parameter of the stochastic quasi translog production frontier function is estimated using FRONTIER 4.1 software (Coelli, 1996). The parameter estimates of the model for the whole period (1961-2005), pre-ECOWAS period (1961-1978) and ECOWAS period (1979-2005) are presented in Table 1. The variance parameters, σ^2, and γ are significantly different from zero. This provides statistical confirmation of the presumption that there are differences in technical efficiency among farmers. The mode of the truncated normal distribution μ, is significantly different from zero, providing statistical evidence that the distribution of the random variable μ, has a non-zero mean and is truncated below zero. The ratio of the country specific variability to total variability measured by γ is positive and significant at 1% significant level for all the crops. This implies that the country specific technical efficiency is important in explaining the total variability of rice output produced in ECOWAS. Thus the stochastic frontier production function is empirically justified. Further, the statistical significance of modeling country effects is further examined using likelihood ratio tests. The logarithm of the likelihood function indicates a satisfactory fit for the generalized Cobb Douglas specification. The statistical significance of all of the parameters, σ^2, γ,. and L, reinforces the view that technical efficiency affects productivity.

Table 1: MLE Estimates of The Stochastic Frontier Model For ECOWAS Rice

	1961 – 2005		1961 – 1978		1979 – 2005	
Coefficient	estimate	t-ratio	estimate	t-ratio	estimate	t-ratio
α_0	-1.44	-3.42	2.00	5.54	1.10	5.44
α_h	0.61	6.81	0.73	4.96	0.56	16.13
α_f	-0.052	-3.67	0.056	2.86	-0.0097	-0.74
α_l	0.41	9.94	-0.020	-0.28	0.26	8.49
α_s	0.33	6.25	0.098	1.71	0.021	0.76
α_i	0.029	1.28	0.13	1.39	0.43	12.75
α_k	0.012	0.85	-0.12	-7.36	0.058	4.91
α_t	0.12	9.81	-0.066	-0.92	0.082	6.20
$0.5\alpha_{tt}$	0.0011	5.64	-0.0067	-6.74	0.0011	5.12
α_{ht}	0.0044	1.39	0.025	9.09	0.012	4.59
α_{ft}	0.0020	3.02	-0.0053	-2.06	0.00032	0.34
α_{lt}	-0.012	-7.36	-0.00064	-0.11	-0.015	-7.66
α_{st}	-0.013	-6.31	-0.013	-1.11	-0.0053	-2.23
α_{it}	0.0065	5.79	0.00042	0.23	-0.013	-6.76
α_{kt}	0.0020	3.28	0.0051	6.84	0.00088	0.90
β_0	0.37	0.93	-0.21	-0.51	0.88	1.93
β_1	-0.97	-3.52	0.79	2.37	-0.017	-4.43
β_2	-0.00060	-3.55	-0.55	-1.31	0.59	0.84
β_3	0.56	1.47	-0.56	-1.52	-0.83	-1.76
β_4	0.51	1.32	0.15	0.37	-0.039	-0.096
β_5	-1.64	-3.95	-0.83	-2.26	-1.36	-3.55
β_6	0.30	0.77	0.40	1.03	0.61	1.55
β_7	0.45	1.18	0.15	0.40	0.85	2.02
β_8	0.18	0.48	0.50	1.37	1.65	3.21
σ^2	0.054	8.54	0.048	6.31	0.041	10.86
γ	0.99	3.04	1.00	56642	1.00	6124100
L	173.33		78.51		183.79	

*, +, ^ indicate significant at 1, 5, and 10% respectively.

The Maximum Likelihood Estimates (MLE) results indicate that fourteen out of twenty two variables are found to be statistically significant. Apart from fertilizer, the coefficients of all the variables have the expected positive signs over the entire analysis period. However, in pre-

ECOWAS era, the coefficient of fertilizer follows a priori expectation of positive and significant sign while in ECOWAS it is insignificant. The result is a reflection of the political economy of fertilizer in the region. The removal of fertilizer subsidies appears to have drastically limited or delayed the availability of fertilizer to the rice farmers at when needed and/or at affordable price in the region. The negative coefficient of fertilizer over the entire analysis period suggests operation in stage III of the production function where there is considerable congestion in the use of fertilizer. Such congestion might be due to late availability of fertilizer to farmers in the region. Over the analysis period the coefficient of both labour and capital are positive and significant. The capital - labour ratio however has negative impact on the rice technical efficiency. The coefficient on the time trend indicates positive technological progress in rice production between 1961 and 2005. The frontier is shifting upwards at annual rate of 12%. The technological progress actually takes place in the ECOWAS era as the results indicate technological decline in pre-reform period.

Tfp and its decomposition

Malmquist productivity indices: SFA

The summary description of the average annual TFP obtained from using the stochastic frontier analysis and its decomposition into efficiency and technical changes over the entire period for each country are presented in Table 2. The evolution is made clearer in figure 2. It should be recalled that if the value of the Malmquist index or any of its components is less than one, it implies regress between two adjacent periods, whereas values greater than 1 imply progress or improvement. In order to obtain the magnitude of progress or regress, the values of Malmquist indices or any of its components can be subtracted from 1. The values of the indices capture productivity relative to the best performers. In this study, the Malmquist indices measure year to year changes in productivity. The evolution in Figure 2 indicates that differences exist among the years.

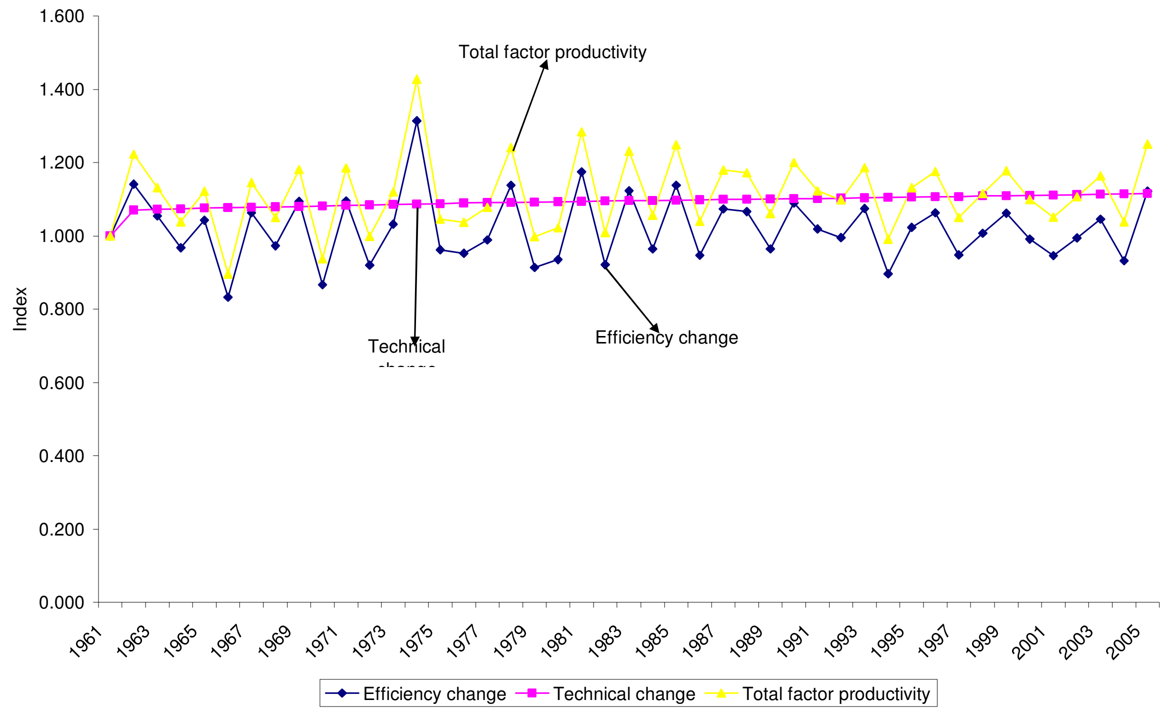

Figure 2: Rice TFP and its decomposition by year using SFA

A comparison of the productivity in the pre-ECOWAS era with ECOWAS in Table 2 shows that more technological progress and hence more improvement in productivity is recorded in pre-ECOWAS than in ECOWAS period. The mean technical change in pre-ECOWAS and ECOWAS periods are 1.131 and 0.992 respectively. The annual TFP growth over the whole period is 15.2%. The breakdown of the results by different rice producing countries indicates productivity growth in all the major rice producing countries on the average. The mean across the nations indicate that the highest growth is however recorded by Guinea with 28.11% growth rate on the average. The growth is more due to technological progress rather than improvement in efficiency. Cote d'Ivoire and Ghana have the lowest TFP growth. A look at the period by period breakdown in Table 3 shows that Guinea has the highest TFP in all the three periods.

This implies that Guinea is especially good at moving toward the frontier than other major producers. A major contributor to rice TFP growth in all the countries has been the technical change. All the countries have impressive technological progress on the average. The TFP changes indicate more progress in ECOWAS than in pre-ECOWAS era. Two things could be responsible for this phenomenon. First, the impressive performance of West Africa Rice Development Association (WARDA) and International Institute for Tropical Agriculture (IITA) which led to adoption of over 20 improved varieties of rice in West Africa including NERICA.

The second is the ECOWAS liberalization schemes which tend to boost farmers' income through increase in prices of agricultural export commodities.

Dea Result

The same sample data were used to calculate the set of indices using DEA-like method described in equations 9 to 12. The calculations were done using a DEAP version 2.1 Computer programme and the evolution is shown in Figure 3. The overall TFP growth rate is 4.3% and it is driven mainly by technical change as is the case with the stochastic approach. In general however, the two approaches agree that over the analysis period, there have been a productivity progress in the ECOWAS rice production sector. Like the SFA approach, the DEA approach show on the average that efficiency change indices are smaller than the technical change components. Also, it can be observed that the TFP of SFA are higher than DEA's perhaps because the efficiency scores of SFA tends to be higher than DEA's. Quite similar conclusion was reached by Kwon and Lee 2004 when considering the TFP of Korean rice using both DEA and SFA methods. The finding is however contrary to Odeck 2007 who discovered that the DEA's efficiency scores and TFPs tend to be higher than SFA in Norwegian grain farming.

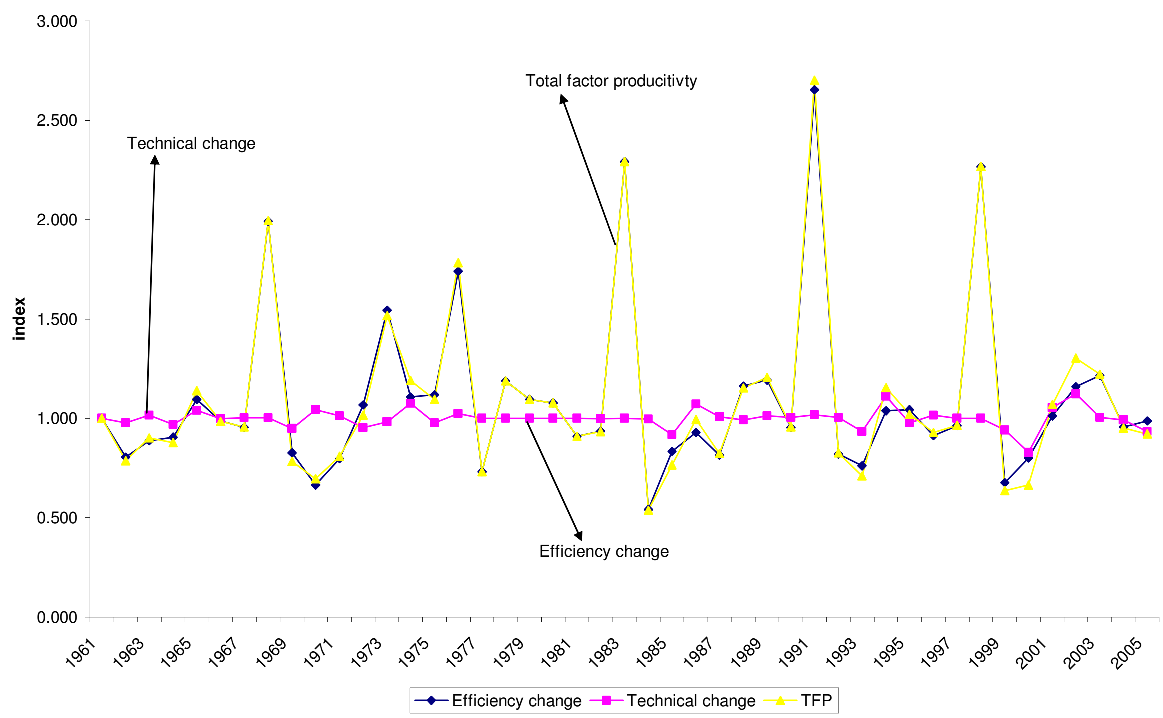

Figure 3: Rice TFP and its decomposition using DEA

Over the entire analysis period, the efficiency change is about 0.998 which is by far lower than 1.052 obtained in case of stochastic approach. However, an even greater difference is observed in the technical change component. Though both methods indicate TFP progress, the SFA indicates more productivity progress than the DEA method over the analysis period. Table A7 shows a summary description of the average performance of each country over the entire time period of 1961 – 2005; pre-ECOWAS era (1961-1978) and ECOWAS era (1979 – 2005). Taking a look at the result, the entire period (1961 – 2005) productivity increased on the average for Mali, Nigeria and Senegal over the 1961 – 2005 periods while Cote d'Ivoire, Ghana and Guinea regressed in their performances. On the average, that growth was due mainly to technical change rather than improvement in technical Efficiency. In the Pre-ECOWAS and the ECOWAS era, productivity maintained its increase in Mali, Nigeria and Senegal. However TFP decline on the average in pre-ECOWAS period whereas the average changes in the total factor productivity index in ECOWAS period is 4.5%. The growth in ECOWAS era is due mainly to innovation rather than improvement in efficiency.

Table 2: TFP and its Decomposition

	Stochastic frontier analysis (SFA)			Data Envelopment Analysis (DEA)		
Year	Efficiency Change	Technical Change	Total Factor productivity	Efficiency Change	Technical Change	Total Factor productivity
1961	1.000	1.000	1.000	1.000	1.000	1.000
1962	1.141	1.071	1.222	0.806	0.976	0.787
1963	1.055	1.072	1.131	0.888	1.017	0.902
1964	0.967	1.073	1.038	0.905	0.970	0.878
1965	1.043	1.075	1.121	1.097	1.039	1.140
1966	0.832	1.077	0.896	0.986	0.998	0.984
1967	1.063	1.078	1.146	0.954	1.002	0.956
1968	0.973	1.079	1.050	1.991	1.002	1.995
1969	1.094	1.080	1.181	0.826	0.949	0.784
1970	0.866	1.081	0.937	0.665	1.045	0.695
1971	1.094	1.083	1.185	0.797	1.014	0.808
1972	0.920	1.085	0.998	1.067	0.953	1.017
1973	1.032	1.085	1.120	1.544	0.983	1.517
1974	1.314	1.087	1.428	1.107	1.075	1.190
1975	0.962	1.088	1.046	1.120	0.977	1.095
1976	0.952	1.090	1.037	1.740	1.025	1.783
1977	0.988	1.090	1.078	0.733	1.000	0.733
1978	1.137	1.091	1.241	1.189	1.000	1.189
1979	0.914	1.092	0.997	1.095	1.000	1.095
1980	0.935	1.092	1.022	1.078	1.000	1.078
1981	1.174	1.094	1.284	0.909	1.000	0.909
1982	0.922	1.095	1.009	0.935	1.000	0.934
1983	1.123	1.096	1.231	2.292	1.000	2.292
1984	0.964	1.096	1.057	0.541	0.996	0.539
1985	1.138	1.097	1.249	0.834	0.918	0.765
1986	0.947	1.098	1.039	0.929	1.072	0.995
1987	1.073	1.099	1.179	0.816	1.008	0.822
1988	1.066	1.099	1.172	1.162	0.992	1.153
1989	0.964	1.100	1.061	1.192	1.013	1.207
1990	1.089	1.102	1.200	0.954	1.004	0.958
1991	1.019	1.102	1.123	2.653	1.018	2.701
1992	0.996	1.103	1.098	0.822	1.006	0.826
1993	1.075	1.104	1.186	0.761	0.933	0.710
1994	0.897	1.105	0.990	1.039	1.111	1.154
1995	1.023	1.105	1.131	1.045	0.978	1.021
1996	1.063	1.106	1.175	0.915	1.016	0.929
1997	0.948	1.107	1.050	0.964	1.001	0.965
1998	1.006	1.108	1.116	2.267	1.001	2.269
1999	1.062	1.109	1.178	0.676	0.941	0.636
2000	0.991	1.110	1.100	0.800	0.829	0.664
2001	0.946	1.111	1.051	1.014	1.055	1.069
2002	0.995	1.112	1.106	1.159	1.124	1.303
2003	1.045	1.113	1.163	1.217	1.005	1.223
2004	0.932	1.114	1.038	0.957	0.993	0.950
2005	1.122	1.115	1.251	0.987	0.934	0.922

Turning to country-by-country results in Table 3, Senegal has the highest TFP over the entire analysis period. The results show a sharp contrast to the SFA estimates which indicates that Guinea has the highest TFP. The DEA result implies that Senegal was especially good at moving toward the frontier or “catching up” in the pre-ECOWAS period. The result of this study differ significantly from few examples of rice – specific TFP studies such as Cassman and Pingali 1995 and Pardey et.al 1992. While they discover decline in rice TFP in Asia, the result of this study indicates increase. Another major difference is that the major source of rice productivity growth in Asia is efficiency change while in ECOWAS it is due mainly to technical change. The use of inputs efficiently in Asia contributes more to TFP growth than net gains from technological change. This signals a thorough perusal of ASEAN green revolution by ECOWAS and WARDA to enhance improve their policies as it affects rice productivity in the region. The agricultural policy content of each rice producing country in ECOWAS could be re-defined to accommodate productivity increasing policies inherent in ASEAN green revolution.

Table 3: Total Factor Productivity by Reform Periods:

Country	1961 – 2005			1961-1978			1979 – 2005		
	EFFCH	TECH	TFP	EFFCH	TECH	TFP	EFFCH	TECH	TFP
				Stochastic Frontier Analysis (SFA)					
C.Ivoire	1.025	1.097	1.125	0.965	1.138	1.098	0.970	0.989	0.960
Ghana	1.019	1.095	1.116	0.986	1.067	1.052	1.015	1.004	1.019
Guinea	1.179	1.087	1.281	1.029	1.033	1.063	1.009	1.002	1.011
Mali	1.026	1.107	1.136	1.027	1.144	1.175	1.023	1.003	1.026
Nigeria	1.038	1.084	1.125	1.030	1.166	1.201	1.009	0.960	0.969
Senegal	1.027	1.097	1.127	1.056	1.135	1.198	1.014	0.993	1.007
Mean	1.052	1.095	1.152	1.016	1.114	1.131	1.007	0.992	0.999
				Data Envelopment Analysis (DEA)					
C.Ivoire	0.998	0.846	0.844	0.997	0.964	0.962	0.997	0.907	0.905
Ghana	0.998	0.892	0.891	1.000	0.963	0.963	0.999	0.917	0.916
Guinea	0.996	0.941	0.938	0.996	1.001	0.997	0.997	0.952	0.949
Mali	0.999	1.162	1.161	0.999	1.093	1.093	0.999	1.123	1.122
Nigeria	0.997	1.199	1.195	0.975	1.193	1.163	1.006	1.179	1.186
Senegal	1.000	1.230	1.230	1.000	1.241	1.214	1.000	1.189	1.189
Mean	0.998	1.045	1.043	0.995	1.076	1.065	1	1.045	1.045

6. CONCLUSION AND POLICY RECOMMENDATION

The present research applied non-parametric and parametric models to a sample of panel data of ECOWAS rice production for the period of 1961–2005. The productivity growth was estimated using the Malmquist index obtained through both parametric and non-parametric approaches. The productivity measures are decomposed into two sources of growth namely efficiency change and technical change. The results show evidence of phenomenal growth in the rice TFP. Millet however has the most impressive results among the crops. A closer look at the TFP in ECOWAS and pre-ECOWAS sub-period shows larger TFP in ECOWAS period (1979-2005). In both periods, productivity are sustained through technological progress. Several inferences may now be drawn from the comparative analysis of DEA and SFA efficiency and productivity models examined. First, the non-parametric results tend to fluctuate widely. This is clearly the consequence of the assumption on the stochastic component, something which may be intensified for agricultural data. The second is that inefficiency and productivity growth exists among rice producing countries in ECOWAS. The magnitude of inefficiency and the extent of productivity growth that has taken place vary between the approaches applied. Third, examining the components relating to the shift in the frontier (TC) and efficiency change (EC), technical change turned out to be a more important source of growth in both parametric and non-parametric models. A promising finding thereupon is that the two approaches applied are, on average, in conformity to each other although the magnitudes are different. In terms of efficiency measurements, the differences between the methodologies are very sensitive on levels of segmentations. In this respect, the somehow conform to previous findings in the literature e.g., Wadud and White (2000). In terms of productivity measurement, even though both approaches track total productivity similarly, they do not map each well at the decomposition level. The deviations between DEA and SFA could have been anticipated because the SFA incorporates stochastic factor while DEA does not. The differences between the techniques applied here suggests that policy-makers as well as researchers should not be indifferent as to the choice of technique for assessing efficiency and productivity, at least with respect to the magnitudes of potential for efficiency improvements and productivity growth. Finally, studies have not been able to detect why and how the different approaches are so different with respect to the decomposed productivity measures. In this respect necessary caution should be observed against widespread application of either SFA or DEA until such time that the field of efficiency and productivity measurement understand how and why these approaches portray efficiency and productivity the way they do. To this end, there is a need for continuous research in understanding the differences observed, which in this study concerns the magnitudes rather than conflicts. Further limitation of the study is that the data used as shown in the yield curves tend to fluctuate considerably. This mean that the productivity measures are based on low productivity year. Also a six country panel data is relatively short to draw convincing results on variation in productivity among the producing country. It is unlikely that the differences in productivity among the countries can be sustained rather it is confined to the specific data period and countries. Given the caution in interpreting the results, the following policy recommendations are suggested from the findings:

1. The government of the major producers of rice and cotton should invest more in functional agricultural extension services to enhance efficient use of available productivity increasing inputs.
2. Given differences in the contribution of efficiency change and technological progress to the TFP of the selected crops, ECOWAP should take a leave from EU CAP, by marrying policy with specific crop need.
3. Future works should quantify parametrically, further the determinants of the productivity growth in the crops.

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