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Productivity Growth, Technical Progress, And Efficiency Change In ECOWAS Agriculture 1971-2009: A Three-Year-Window (TYW) Extended Malmquist Approach

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***Abstract:** This study employed the use of country-level panel data on agriculture in Economic Community of West African States (ECOWAS) to investigate Total Factor Productivity (TFP) growth in the region during 1971 - 2009. The TFP growth of ECOWAS agriculture was measured using the Three-year-window (TYW) method developed by Nghiem (1999) and Nghiem and Coelli (2000). The method is applied to a panel data on thirteen ECOWAS countries over a period of 39-year from 1971 to 2009. The average TFP growth is 2.1 percent in ECOWAS over entire period considered (1971-2009), which is well below average productivity growth in other developing countries. The study showed that the vast majority of this TFP growth is due to a significant shift in the frontier technology (TECHCH). Within the region, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo experienced positive growth in their TFPs due to the significant shifts in their frontier technologies (TECHCH) over the period examined (1971 - 2009).*

***Keywords:** Three Year Window (TYW) Method, Productivity Growth, Technical Progress, and Efficiency Change, ECOWAS*

I. INTRODUCTION

The ECOWAS agriculture has suffered such problems as limitation of exports to few commodities, low export earnings, low capital formation, weak human assets, a high degree of economic vulnerability, increasing trend towards urbanization, food insecurity and poor rural development as well as ineffective implementation of both regional and national policies due to poor knowledge of the determinants of agricultural productivity and their degrees. Therefore, the growth and development of the agricultural sector is essential for the overall process of socioeconomic development in the ECOWAS sub-region of Africa (ECA, 2002; Ajetomobi, 2009; and Fulginiti et. al, 2004).

Based on the foregoing, for the agricultural sector in ECOWAS to take its rightful place and achieve its major goals of being the major employer of labour, largest supplier of raw materials for the agro-allied and other industries as well as being the mainstay of almost all economies in the ECOWAS sub-region, various governments and institutions at regional and national levels have to come up with excellent broad-based agricultural policy plans that will usher in higher levels of production and a sustained increase of agricultural production through improvement in the technological change and efficiency change in the region. Hence, increasing agricultural productivity in ECOWAS has received a wide spread attention in the literature on economic development and poverty alleviation. Since agricultural growth is linked to farm profit, there had been considerable research works that examined the performance of the agricultural sector in sub-Saharan Africa as well as in ECOWAS sub-region (e.g.

Moock, 1973; Lipton, 1988; Nkamleu et. al., 2003; Ajetomobi, 2009; Ajetomobi, 2008; and Ajao, 2011).

Previous works like Ajetomobi (2009) employed Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA), Ludena (2010) and Ajao (2011) employed the DEA Malmquist Productivity Index while Nadeem et. al., (2010) employed Index Number Approach (Tornqvist Index). A price-based index number method, such as the Tornqvist index, may not be the best approach because of the use of price information and also assume that the economic agents involved exhibit cost minimizing behaviour. Data Envelopment Analysis (DEA) does not require the explicit specification of the underlying production relationship; its key drawback like other non-parametric approaches is that it generally assumes that there is no random error owing to luck, data problems, or other measurement errors while attributing the deviation of a production unit from the frontier entirely to inefficiency. Stochastic Frontier Analysis (SFA) has an advantage over DEA and this lies in its stochastic nature, which enables it to distinguish the effects of data noise from those of inefficiency error, thereby attributing any deviation from the frontier to either or both noise components. But SFA has a major drawback as it imposes a technology structure through the specification of a functional form unlike DEA and associated behavioral assumptions that presuppose the shape of the frontier (Berger and Humphrey, 1997). Although, there is however no consensus on the preferred method for determining the best-practice frontier against which relative efficiencies are measured because of the existing tradeoff between accounting for data noise versus imposing a particular functional form. SFA thus seems the most frequently applied frontier methodologies in agricultural efficiency literature around the globe most especially for studies focusing on the developing agriculture where data generating processes are often influenced by measurement errors. Three Year Window (TYW) method, an extended DEA Malmquist Index is able to handle the degrees of freedom limitations which the methods used in the previous studies like Ajetomobi, 2009; Ludena, 2010; Ajao, 2011; and Nadeem et. al., 2010) could not handle. It is able to relieve degrees of freedom pressure when the number of inputs plus outputs is large relative to the number of firms. TYW method does not require the explicit use of price information, nor does it require the assumption of cost minimising behaviour. TYW method has the advantage that it permits the decomposition of the TFP growth from each region into two components: technical change (shifts in the frontier) and technical efficiency change (catching up to the frontier) (Coelli et. al., 1998). TYW method allows for the inclusion of extra observations from previous years to construct a more robust reference frontier in each year.

This paper therefore addresses such questions such as: What is the status of agricultural productivity in ECOWAS? Has ECOWAS agricultural productivity declined sharply as perceived? The broad objective of the study is to analyze the productivity growth, technical progress and efficiency change in ECOWAS agriculture from 1971 to 2009.

II. MATERIALS AND METHOD

Productivity growth has been extensively described in terms of the improvement and technical change with which inputs are transferred into outputs in the production process; see e.g. Shih-Hsun *et al.*, 2003. Indexes of productivity can therefore be simply referred to as the ratio of aggregate output index to an index for total factor use. In assessing growth, sustainability, and competitiveness in the agricultural sector, proper identification and measurement of agricultural productivity growth, particularly when technical change in the sector is factor-biased rather than Hicks-neutral is very important.

TFP growth measures how much productivity grows or declines over time. When there are more outputs relative to the quantity of given inputs, then TFP has grown or increased. TFP can grow when adopting innovation, this kind of growth is due to “technological change” (TECHCH). TFP can also grow when an economic sector uses its available technology and economic inputs more efficiently; they can produce more while using the same level of inputs, or more generally, this kind of growth is due to “technical efficiency” (EFFCH). Therefore, any change in TFP from one year to another is comprised of technological change and changes in technical efficiency. Technical efficiency change (catch-up) measures the change in efficiency between current (t) and next (t+1) periods, while the technological change (innovation) captures the shift in frontier technology (Jajri, 2007).

An increase in the level of productivity reflects an increase in the efficiency of inputs. Hence, the same level of inputs can produce a higher output level, which means that the cost of production reduces. In other words, it reflects an improvement in the quality of inputs. There are several factors affecting productivity such as level of technology and socio-demographic (Bhatia, 1990). TFP does not merely mean technological improvement, but also improvement in quality of inputs due to other factors like Human Resource Development (HRD) and Human Resource Management (HRM) and has been argued by researchers like Kartz (1969) to be a contribution of technological advancement.

A large volume of works done on the empirical analyses of agricultural productivity have most of the time focused on global (e.g. Rao and Coelli, 1998), regional (e.g. Fulginiti *et. al.*, 2004; Nkamleu et. al, 2003; Ajetomobi, 2009 and Ajao, 2011) and country level performance (e.g. Bhatia, 1990; Alabi, 2005; Jajri, 2007). There are different methods for estimating the total factor productivity (TFP) growth e.g. Malmquist and Tornquist indexes. The former had gained popularity in recent years since Fare *et al.*, (1994) apply the linear programming approach to calculate the distance functions that make up the Malmquist index.

According to Shih *et al*, (2003), since Data Envelopment Analysis (DEA) type of analysis can be directly applied to calculate the index, the Malmquist index has the advantage of computational ease, does not require information on cost or revenue shares to aggregate inputs or outputs, consequently, less data demanding and it allows decomposition into changes in efficiency and technology. This method does not attract any of the stochastic assumptions restriction, however, it is susceptible to the effects of data noise, and can suffer from the problem of 'unusual' shadow prices, when degrees of freedom are limited (Coelli and Rao, 2003).

The Malmquist index measures the total factor productivity change (TFPCH), between two data points over time, by calculating the ratio of distances of each data points relative to a common technology. The Malmquist index has been used extensively in various studies that have examined total factor productivity growth (see also Sturm and Williams, 2004; Coelli and Rao, 2005; Chen and Lin, 2007; Mukherjee et. al, 2001; and Sufian, 2006). Caves et. al, (1982) had initially introduced the Malmquist productivity index as the theoretical index. Later, Fare et. al, (1992) did merged Farell's (1957) to subsequently demonstrate that the resulting Total Factor Productivity (TFP) indices could be decomposed into efficiency change and technical change components. Fare et. al, (1994) later did decomposed the efficiency change into pure technical efficiency change and changes in scale efficiency, a development which led to the Malmquist index becoming widely popular as an empirical index of productivity changes.

Technological change (TECHCH) is the development of new products or the development of new technologies that allows methods of production to improve and results in the shifting upwards of the production frontier. More specifically, technological changes include new production processes, called process innovation and the discovery of new products called product innovation. Technical efficiency change (EFFCH), on the other hand, can make use of existing economic inputs like land, labour, fertilizer and machinery and other inputs to produce more of same product. With panel data, the estimation of technical progress (the movement of the frontier established by the best- practiced firms) as well as changes in technical efficiencies over time (the distance of the inefficient firms from the best practice firm) or catching up (Jajri, 2007).

III. DATA ENVELOPMENT ANALYSIS (DEA)

The Data Envelopment Analysis (DEA) was first introduced in the work of Farrell (1957) and developed further by Charnes *et al.*, (1978). DEA is a piecewise-linear combination that connects the set of the best-practice or frontier observations, yielding a convex production possibility set. It envelopes all observations in order to identify an empirical frontier that is used to evaluate the performance of production units represented by those observations. By construction, DEA does not require the explicit specification of the underlying production relationship. However, a key drawback of DEA like other non-parametric approaches is that they generally assume that there is no random error owing to luck, data problems, or other measurement errors while attributing the deviation of a production unit from the frontier entirely to inefficiency. The implication of this is that if random errors exist, the measured efficiency may be confounded with these random deviations from the true efficiency frontier. DEA can either be input or output oriented depending on the objectives. The input-oriented method, defines the frontier by seeking the maximum possible proportional reduction in input usage while the output is held constant for each country. The output-oriented method seeks the maximum proportional increase in output production with input level held fixed. These two methods, that is, input-output oriented methods provide the same technical efficiency score when a constant return to scale (CRS) technology applies but are unequal when variable returns to scale (VRS) is assumed (Coelli and Rao, 2001). Fare *et al.*, (1994) used Data Envelopment Analysis (DEA) methods to estimate and decompose the Malmquist productivity index. The DEA method is a non-parametric approach in which the envelopment of decision-making units (DMU) can be estimated through linear programming methods to identify the "best practice" for each DMU. The efficient units are located on the frontier and the inefficient ones are enveloped by it. Four linear programs (LPs) must be solved for each DMU in this study (Country) to obtain the distances defined in equation (iii) and they are:

$$\text{(i)} \quad \left[d_o^t\,(x_t,\, y_t)\right]^{-1} = Max_{\phi,\,\lambda}\ \phi,$$
$$s.t \quad -\phi y_{it} + Y,\ \lambda \geq 0$$
$$x_{i,t} - X,\ \lambda \geq 0$$
$$\lambda \geq 0$$

$$\text{(ii)} \quad \left[d_o^{t+1}\,(x_{t+1},\, y_{t+1})\right]^{-1} = Max_{\phi,\,\lambda}\ \phi,$$
$$s.t \quad -\phi y_{i,t+1} + Y_{t+1}\ \lambda \geq 0$$
$$x_{i,t+1} - X_{t+1}\ \lambda \geq 0$$
$$\lambda \geq 0$$

$$\text{(iii)} \quad \left[d_o^t\,(x_{t+1},\, y_{t+1})\right]^{-1} = Max_{\phi,\,\lambda}\ \phi,$$
$$s.t \quad -\phi y_{i,t+1} + Y_t \lambda \geq 0$$
$$x_{i,t+1} - X,\ \lambda \geq 0$$
$$\lambda \geq 0$$

$$\text{(iv)} \quad \left[d_o^{t+1}\,(x_t,\, y_t)\right]^{-1} = Max_{\phi,\,\lambda}\ \phi,$$
$$s.t \quad -\phi y_{i,t} + Y_{t+1}\ \lambda \geq 0$$
$$x_{i,t} - X_{t+1}\ \lambda \geq 0$$
$$\lambda \geq 0$$

Where λ is a N X 1 vector of a constant and ϕ is a scalar with $\phi \geq 1$. Over time best practice are natural and to include frontier shifts, that is, technical change, the Malmquist productivity index is a well-established measure.

THE EXTENDED MALMQUIST DEA METHOD

The data available for this study contains only thirteen observations (corresponding to countries of ECOWAS regions) for each year. Therefore, the standard Malmquist DEA method of Fare et al (1994) may produce unstable TFP indices because the sparse data will not be able to construct approximately "smoothed-surface" frontiers in each period. To overcome this problem, the *Three Year Window* (TYW) method was developed and it is discussed extensively below.

THE THREE-YEAR-WINDOW (TYW) DEA METHOD

The DEA window method was introduced by Charnes, Clark, Cooper and Golany (1985);

Charnes, Cooper, Dieck-Assad, Golany and Wiggins (1985); and Charnes, Copper, Divine, Lopp and Stutz (1992). This study is benchmarking the work by Nghiem and Coelli (2000) which pioneered the application of the window DEA method to calculating the Malmquist Productivity Index (MPI). The window DEA technique is as follows. The panel of T cross-sections of data is divided into a series of shorter overlapping sub-panels, each having S (arbitrarily chosen) time periods. Thus, the first sub-panel contains periods {1, 2, …, S}; the second sub-panel contains periods {2, 3, …, S+1} and so on until the last sub-panel, which contains periods {T-S+1, T-S+2,…, T}. The procedure is to construct a series of frontiers from the sub-panels and use these frontiers to calculate the distance functions needed for the Malmquist TFP calculations. The advantage of this method is to relieve degrees of freedom pressure when the number of inputs plus outputs is large relative to the number of firms.

In this study also, the width of the window adopted was informed by those used in the works of Nghiem (1999) and Nghiem and Coelli (2000) and it was arbitrarily chosen at three. Thus, the first subpanel contains periods {1971, 1972, 1973}, the second sub-panel contains periods {1972, 1973, 1974} and the last sub- panel contains periods {2007, 2008, 2009}. Thus, in each year the frontier is constructed from 38 observations. The frontier was then constructed using 1971-1973 data as our 1973 frontier; the frontier constructed using the 1977-1979 data as our 1979 frontier; and so on until the frontier construction ended with 2007 - 2009 data which then represented the 2009 frontier. Otherwise, the LPs are identical to those in equations (i) to (iv).

This method is clearly quite computationally intensive. There are two publicly available computer programs that can be used to readily calculate the standard Malmquist DEA TFP index. These are DEAP, written by Coelli (1996) and OnFront written by EMQ (1997). However, this study employed the DEAP software written by Coelli (1996), as there is no publicly available computer program that can readily calculate the new Malmquist Productivity Index (MPI) method adopted in this study.

IV. METHODOLOGY

The study was based on the data that were drawn from the FAO web site (AGROSTAT) and it covers a period of 39 years (1971-2009). Panel data on output and conventional agricultural inputs (land, labor, fertilizer, and machinery) for 13 ECOWAS countries for the period 1971–2009 was accessed from the FAOSTAT database (FAO, 2011). The data that were collected from FAOSTAT include: (a.) per capita value of Agricultural Production (1971-2009). (b.) Input data (1971-2009) which are: (i.) Agricultural land which include total arable land area, permanent cropland and pasture measured in '000 ha. (ii.) Fertilizer consumption measured in metric tonnes. (iii.) Agricultural machines which are number of tractors – wheel and crawler – used in agriculture as a measure of the use of modern technological tools. (iv.) Labour measured in thousands and covers the economically active population involved in agriculture.

V. RESULTS AND DISCUSSION

This study is benchmarking the works by Nghiem (1999) and Nghiem and Coelli (2000) which pioneered the application of the window DEA method to calculating the Malmquist Productivity Index (MPI). This study therefore used an Extended Malmquist Productivity Index to measure the productivity growth of agricultural sector of thirteen out of fifteen countries in ECOWAS sub-region of Africa during 1971 - 2009. This method allowed for the construction of the best-practice frontier in agricultural production sector in the sampled ECOWAS countries and then compared with the overall status of the ECOWAS sub-region. Extended Malmquist productivity indexes as well as efficiency change and technological change components for each country of ECOWAS sampled were calculated. Since this index is based on discrete time, each country has an index for every pair of years.

The results from DEA Three Year Window (TYW) Malmquist Approach presented both in the tabular (Table 1) and graphical representation (Figure 1) show a better performance of agriculture in ECOWAS between 1971 and 2009. A simple average of TFP measures at the country level for a sample of 13 ECOWAS countries shows a positive annual productivity growth of 2.1 percent per annum (i.e. the TFP index value for the period was 1.021) as a result of a 2.1 percent increase in the technological progress (TECHCH) over the period considered. On the average In ECOWAS, there is no real catching-up growth. Thus, the source of the growth of TFP is the technological progress over the entire period. Table 2 shows from the TFP of the members of ECOWAS that ECOWAS agriculture is characterized by low productivity as the agricultural yields among its member states are extremely low and the region's economic growth is still grossly below the minimum 7% required to attain the Millennium development Goals (MDGs) (Akinleye, 2008; Ajetomobi, 2008; Ajetomobi, 2009; Nkamleu et. al, 2003; ECOWAS Online, 2011; World Bank, 2011).

The TYW result presented in Table 2 showed that countries like Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo experienced positive growth in their TFPs due to the significant contributions from their technological change over the period examined (1971 - 2009). The six leading countries among those that experienced TFP growth are Sierra Leone (at 20.3 percent growth rate per annum), Togo (at 16.1 percent growth rate per annum), Nigeria (at 15.9 percent growth rate per annum), Senegal (at 14.6 percent growth rate per annum), Niger (at 10.5 percent growth rate per annum), and Mali (at 6.2 percent growth rate per annum) respectively while ECOWAS countries like Benin, Burkina Faso, Cote D'Voire, Gambia, Ghana and Guinea failed to achieve agricultural productivity growth over the entire period of 39 years (1971-2009) and this may due to setbacks suffered in the areas of not having comparative advantage in the export markets, foreign exchange balance as well as of the internal terms of trade against industry, and these setbacks have also hindered their industrial production capacity (Hayami and Ruttan, 1970; Coelli and Rao, 2003; Ajetomobi, 2009). The declining nature of TFP in certain ECOWAS countries may be due to: the number of people producing and how well they are

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producing in those countries; prevalence of low per capita production of food and cash crops; weak human assets; a high degree of economic vulnerability; poverty, which places all the countries of the sub-region in the lowest part of the United Nations' table of human development index; persistence of conflicts over the last decade; unstable climatic conditions in the sub-region, including recurrent droughts and a general trend towards desertification; ineffective collaboration, linkages and coordination among institutions of environmental management; Inadequate human, technological and financial capacities; unharmonized economic and financial policies; Inadequate and/or inefficient government policies; high cost of production factors; institutional weaknesses; ecological and land tenure constraints; weak use of innovative technologies; effects of political conflicts, and the impact of the international environment; increasing trend towards urbanization, consumption of imported food grains and demand for diversified foodstuffs; decrease in export earnings, low capital formation, food insecurity and poor rural development; recurrent drought and adverse terms of trade movements (Repello et. al, 1996; Colander,2001; Boutong and Downswell,2002; ECA, 2002; Ajetomobi, 2009; Seka, 2009; World Bank, 2011; ECOWAS Online, 2011). The upturns and downturns (fluctuations) in Total Factor Productivity (TFPCH) of ECOWAS as shown in figure 1 was as a result of the variations in the technological progress (which may due to changes in policy direction or shift in agricultural policy issues) of some of the ECOWAS countries over the entire period (1971 -2009).

Methodology	Period	Effch	Techch	Tfpch
Standard DEA Three Year Window Method	Pre-ECOWAS: 1971 – 1978	0.999	0.954	0.954
	ECOWAS: 1979 – 2009	1.002	1.0323	1.034
	ENTIRE: 1971 – 2009	1.000	1.021	1.021

Year	Effch	Techch	Tfpch
1972	1	1.171	1.171
1973	1.002	0.998	0.998
1974	1.005	0.889	0.889
1975	1.002	0.974	0.974
1976	1	0.792	0.792
1977	1.001	0.883	0.883
1978	1	0.917	0.917
1979	0.997	2.9	2.892
1980	1.002	0.939	0.94
1981	1.001	0.72	0.721
1982	1	0.855	0.855
1983	1	0.903	0.903
1984	1.001	0.919	0.92
1985	0.999	0.952	0.951
1986	1.001	1.823	1.824
1987	1	0.343	0.343
1988	1	1.955	1.955
1989	1.001	0.905	0.906
1990	1	1.005	1.006
1991	1	1.11	1.109
1992	1	0.967	0.967
1993	0.999	0.83	0.83
1994	1.001	0.969	0.97
1995	1	1.006	1.005
1996	0.829	3.23	2.676
1997	1.207	1.029	1.242
1998	1.002	0.949	0.949
1999	1.005	0.926	0.926
2000	1.002	1.232	1.232
2001	0.999	1.031	1.03
2002	1	0.99	0.99
2003	1.001	1.001	1.001
2004	1	1.009	1.009
2005	1.002	1.059	1.058
2006	1.005	0.675	0.676
2007	1.002	1.049	1.049
2008	0.999	0.972	0.972
2009	1	0.993	0.993
mean	1	1.021	1.021

**Results in this table are the geometric means of the annual results.*

Table 1: TYW Estimates of Annual Average Malmquist Catch-up, Technical Change and TFP Change In ECOWAS (1971 – 2009)

Entire Period (1971 – 2009) (TYW)			
Country	TEC	TC	TFP
Togo	1.001	1.16	1.161
Sierra Leone	1.002	1.201	1.203
Senegal	1.001	1.145	1.146
Nigeria	1	1.159	1.159
Niger	1.003	1.102	1.105
Mali	1.001	1.061	1.062
Liberia	1.002	0.957	0.959
Guinea	1.001	0.978	0.979
Ghana	1	0.94	0.94
Cote D'Voire	1.001	0.919	0.92
Burkina Faso	1.002	0.904	0.906
Benin	1.001	0.863	0.864
Gambia	1.003	0.964	0.967

Table 2: Ranking of ECOWAS member states based on Malmquist index Summary of Country Means

[Note that all Malmquist index averages are geometric means]

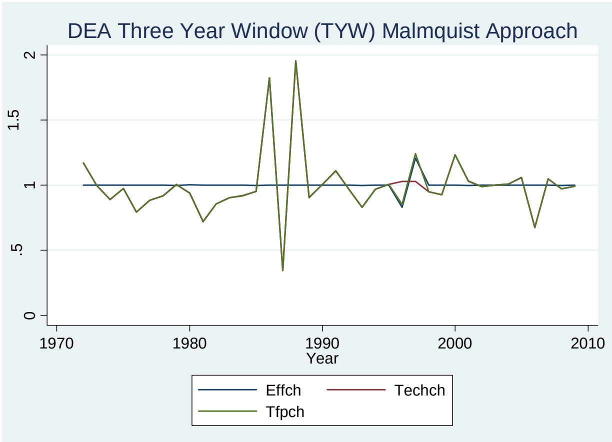

Figure 1: Three Year Window Estimates of Efficiency and Productivity Components of ECOWAS Agriculture: 1971 - 2009

VI. CONCLUSIONS

This study has made two significant contributions. The first is the application of an extended Malmquist DEA method which caters for the problem of a limited number of cross-sectional observations in the calculation of productivity change. The three year window (TYW) method developed by Nghiem and Coelli (2000) was applied in this study. This approach deals with the degrees of freedom problem by pooling observations from previous years to obtain improved estimates of the frontier in each year of the analysis. This avoids the danger of obtaining unstable results derived from frontiers constructed using only a few observations. The second significant contribution of this study is the provision of valuable information on productivity growth in ECOWAS agriculture. A three year window (TYW) method, which is an extended Malmquist DEA TFP method was applied to a panel data on ECOWAS countries over the 39-year period from 1971 to 2009. The results show a positive annual productivity growth of 2.1 percent per annum due to a 2.1 percent increase in the technological change (TECHCH) over the period considered. On the average, in ECOWAS, there is no real catching-up growth (that is, the agricultural sector of ECOWAS has not been able to use its available technology and production inputs more efficiently and hence the region has not been able to produce more from its available input base). Thus, the source of the growth of TFP is the technological progress over the entire period. Table 2 shows from the TFP of the members of ECOWAS that ECOWAS agriculture is characterized by low productivity as the agricultural yields among its member states are extremely low and the region's economic growth is still grossly below the minimum 7% required to attain the Millennium development Goals (MDGs) (see Akinleye, 2008; Ajetomobi, 2008; Ajetomobi, 2009; Nkamleu et. al, 2003; ECOWAS Online, 2011; World Bank, 2011).

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