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Efficiency and Productivity Analysis of ECOWAS Agriculture (1961- 2009): Hicks-Moorsteen TFP Approach

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ABSTRACT

This study analyse efficiency and productivity changes in ECOWAS agriculture using the Hicks-Moorsteen TFP index developed by O'Donnell (2008, 2009, 2010c). This approach has an advantage over the popular Malmquist productivity index in that it is free from any assumptions associated with firm optimising behaviour, the structure of markets, or return to scale. ECOWAS agriculture is inefficient over the entire period as the most of the measures of pure technical efficiency and scale efficiency over the entire period considered (1961-2009) have their efficiency estimates that were less than unity. The inefficiency of the measures of pure technical efficiency and scale efficiency over the entire period (1961 - 2009) may be due to weak human assets, a high degree of economic vulnerability, increasing trend towards urbanization, limitation of exports to few commodities, low export earnings, low capital formation, 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. The declining behaviour of technical changes (ΔTech) over the entire period (1961-2009) reveals that agriculture sector in all ECOWAS member states are not operating on the same point on the production possibilities set as well as changes in the economic, political and social environment of ECOWAS member states as it tends to capture the effects of technological change and the long term effects of inefficiency of both regional and national policies (with the inclusion of agricultural policies over the entire years) among the ECOWAS member states.

Introduction

The Malmquist index has been used extensively in various studies that have examined total factor productivity growth (see also Sturmand 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.

However, despite extensive literatures on the Malmquist index and its evident popularity as a measure of productivity change, the pros and cons of constant return to scale (CRS) to estimate Malmquist indices have been extensively discussed. Grifell-Tatje and Lovell (1995) demonstrated that with non-constant returns to scale, the Malmquist productivity index does not precisely measure productivity change. They suggest that the bias is systematic and relies on the magnitude of scale economies. Coelli and Rao (2005) maintain the importance of imposing CRS upon any technology that is used for the estimation of distance functions for the calculation of a Malmquist TFP index, applicable to both firm-level and aggregate data; without CRS the result may incorrectly measure TFP gains or losses arising from scale economies. In contrast however, Ray and Desli (1997) and Wheelock and Wilson (1999) argue that the decomposition of the Malmquist index performed by Färe et al. (1994) is not reliable. Wheelock and Wilson (1999) demonstrate that when a firm's location (from one period to another) has not changed, and scale efficiency change is entirely due to a shift in the variable returns to scale (VRS) estimate of technology, there appears no resulting technical change under CRS. They thus conclude that under such circumstances the CRS estimate of technology is statistically inconsistent.

To avoid these problems O'Donnell (2008) proposed a new way to decompose multiplicatively complete TFP indices into a measure of technical change and various measures of efficiency change, without any assumptions concerning firm optimising behaviour, the structure of markets, or returns to scale for a multiple-input multiple-output case.

According to O'Donnell (2008), any TFP index that represents the ratio of aggregate output to aggregate input is said to be multiplicatively complete, where completeness is an essential requirement for an economically-meaningful decomposition of the TFP change. He further demonstrates that the group of complete TFP indices includes Fisher, Konus, Törnqvist, and Hicks-Moorsteen indices, but not the popular Malmquist index of Caves, et al. (1982).

Apart from special cases such as constant returns to scale, O'Donnell (2008) states that the Malmquist index is a biased measure of TFP change. Consequently, the popular Färe et al.

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(1994) decomposition of the Malmquist index also generally leads to unreliable estimates of technical change and/or efficiency change. In this study, therefore, the Hicks-Moorsteen TFP index (O'Donnell, 2008, 2009, 2010c) is employed to analyse productivity changes of ECOWAS agriculture (1961-2009).

Hicks-Moorsteen TFP index

While trying to capture the case of a multiple-input multiple-output firm, O'Donnell (2008) uses the usual definition of total factor productivity as previously done by Jorgenson and Grilliches (1967), and Good et al. (1997); TFPnt = Ynt /Xnt , where TFPnt indicates the TFP of firm n in the period t, Ynt ≡Y (y nt), and X nt ≡X (xnt) that Y nt and X nt are aggregate output and aggregate input respectively. The above definition allows the possibility of defining TFP changes as the ratio of an output quantity index to an input quantity index (a ratio of an output growth to an input growth). The resulting index numbers here are termed as multiplicatively complete indexes.

Apparently, Hicks-Moorsteen TFP index happens to be the only multiplicatively-complete index that can be computed without price data, and has not previously been used to analyse any country or cross-country agricultural productivity studies especially ECOWAS.

The Hicks-Moorsteen TFP is defined as a ratio of Malmquist output and input quantity indexes, and the name came because Diewert (1992, p. 240) attributed its origins to Hicks (1961) and Moorsteen (1961). Though Caves et al. (1982) advocated the application of Malmquist indexes; they ignored the application of the ratios of resulting indexes in developing a complete TFP index in the role of an aggregate output to an aggregate input ratio. Their indexes are complete if and only if the technology is of a restrictive form (O'Donnell, 2008, p.10).

where *P* denotes the period-T production possibilities set. The use of DEA allows for the calculation of these distance functions. Thus, O'Donnell (2009) develops a DEA methodology for computing and decomposing the Hicks-Moorsteen TFP index (O'Donnell 2010c).

The approach used by O'Donnell (2008) provides greater insights into the relationships between aggregate quantities and also capture different alternative components of TFP change; measures of technical change and various measures of efficiency change; pure technical efficiency, mix efficiency, scale efficiency, residual scale efficiency and residual mix efficiency.

The Hicks-Moorsteen TFP index operates as follows:

$$TFP_{HM}^{t,t+1}=\left(\frac{D_0^{t+1}\left(x^{t+1},y^{t+1}\right)D_0^{t}\left(x^{t},y^{t+1}\right)D_I^{t+1}\left(x^{t},y^{t+1}\right)D_I^{t}\left(x^{t},y^{t}\right)}{D_0^{t+1}\left(x^{t+1},y^{t}\right)D_0^{t}\left(x^{t},y^{t}\right)D_I^{t+1}\left(x^{t+1},y^{t+1}\right)D_I^{t}\left(x^{t+1},y^{t}\right)}\right)^{1/2}. \quad (1)$$

Where Do (x, y) and D1 (x, y) are output and input distance functions, respectively, defined by Shephard (1953) as:

$$D_0^T\left(x,y\right)=\min\left\{\delta>0:\left(x,y/\delta\right)\varepsilon P\right\}. \quad (2)$$

and

$$D_I^T\left(x,y\right)=\max\left\{\rho>0:\left(x/\rho,y\right)\varepsilon P\right\}. \quad (3)$$

where *P* denotes the period-T production possibilities set. The use of DEA allows for the calculation of these distance functions. Thus, O'Donnell (2009) develops a DEA methodology for computing and decomposing the Hicks-Moorsteen TFP index (O'Donnell 2010c).

The approach used by O'Donnell (2008) provides greater insights into the relationships between aggregate quantities and also capture different alternative components of TFP change; measures of technical change and various measures of efficiency change; pure technical efficiency, mix efficiency, scale efficiency, residual scale efficiency and residual mix efficiency.

Material and Method

Panel data on the 13 ECOWAS countries for the period 1961–2009 were accessed from the FAOSTAT database (FAO, 2011). The data was collected from FAOSTAT include: (a.) Output data (1961-2009) which is Per Capita Value of Agricultural Production (1961-2009). (b.) Input data (1961-2009) which are: (i.) Agricultural land which will 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. The 13 ECOWAS member states include: Benin, Burkina Faso, Cote D'Ivoire, Gambia, Ghana, Liberia, Nigeria and Sierra Leone, Togo, Mali, Niger, Senegal, and Guinea.

Result and Discussion

The fact that the Hicks-Moorsteen index is a distance-based index allows for the DEA methodology developed by O'Donnell (2009; and 2010c) to be employed in estimating the distances under VRS. The interpretation is straightforward. An efficiency estimate equal to unity indicates that the particular ECOWAS member states lie on the boundary of the production set, and, accordingly, are (relatively) efficient. An estimate below unity indicates that the ECOWAS member states are positioned under the frontier and are (relatively) inefficient. The estimates of output-oriented efficiency levels are reported in Table 1 over the period 1961-2009.

Both Table 1 and Graph 1 present the measures of pure technical efficiency, scale efficiency and mix efficiency respectively for each year for the ECOWAS agriculture. They both revealed that ECOWAS agriculture is inefficient over the entire period as the most of the measures of pure technical efficiency and scale efficiency over the entire period considered (1961-2009) have their efficiency estimates that were less than unity. The mean of the ECOWAS agriculture's mix efficiency appear to be efficient over the entire period and this may be attributed to the efficient agriculture scale size as well as the independence of all ECOWAS member states in terms of managing their agricultural production inputs-outputs. The inefficiency of the measures of pure technical efficiency and scale efficiency over the entire period (1961 - 2009) may be due to weak human assets, a high degree of economic vulnerability, increasing trend towards urbanization, limitation of exports to few commodities, low export earnings, low capital formation, 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.

The illustrations in Table 2 and Graph 2 list measures of ECOWAS agriculture's total factor productivity changes (ΔTFP) and its components, technical change (ΔTech) and efficiency change (ΔEff), among all the ECOWAS member states between 1961 and 2009. The table and graph presented the components of the ΔTech; changes in output-oriented pure technical efficiency (ΔOTE), residual scale efficiency

Table 1. Measures of Output-Oriented Technical Efficiency (OTE), Scale Efficiency (OSE) and Mix-Efficiency (OME).

Year	OTE	OSE	OME
1961	0.6330	0.3966	1.0000
1962	0.6001	0.4135	1.0000
1963	0.6217	0.3754	1.0000
1964	0.6311	0.3792	1.0000
1965	0.6293	0.3573	1.0000
1966	0.6422	0.3296	1.0000
1967	0.6489	0.3551	1.0000
1968	0.6032	0.3877	1.0000
1969	0.5987	0.4169	1.0000
1970	0.5713	0.3746	1.0008
1971	0.5948	0.3761	1.0005
1972	0.6376	0.3508	1.0003
1973	0.6055	0.3616	1.0004
1974	0.6537	0.4248	1.0000
1975	0.6741	0.3803	1.0023
1976	0.6894	0.3275	1.0007
1977	0.7332	0.3323	1.0000
1978	0.7236	0.3722	1.0000
1979	0.7515	0.3477	0.9998
1980	0.7573	0.3508	1.0000
1981	0.7399	0.3258	1.0000
1982	0.7255	0.3321	1.0000
1983	0.7667	0.3195	1.0002
1984	0.7383	0.3698	0.9989
1985	0.7426	0.3622	1.0000
1986	0.7582	0.2927	1.0000
1987	0.7546	0.1827	0.9993
1988	0.7587	0.9736	1.0001
1989	0.9701	0.9745	1.0003
1990	0.9627	0.9792	0.9995
1991	0.9804	0.9564	1.0000
1992	0.9661	0.9696	1.0000
1993	0.7667	0.3195	1.0002
1994	0.9758	0.9555	1.0000
1995	0.9476	0.9697	1.0000
1996	0.9952	0.9462	1.0000
1997	0.9850	0.9665	1.0000
1998	0.9818	0.8936	1.0000
1999	0.9877	0.9162	1.0000
2000	0.9504	0.9216	1.0000
2001	0.9609	0.9223	0.9999
2002	0.9360	0.8976	1.0000
2003	0.9770	0.8804	1.0002
2004	0.8837	0.9041	0.9949
2005	0.8779	0.8620	1.0000
2006	0.8519	0.8045	1.0000
2007	0.7763	0.7974	1.0000
2008	0.8418	0.8073	1.0000
2009	0.8336	0.8071	1.0000

Source: Authors' Calculations, 2014.

Table 2. Total Factor Productivity Changes and Its Various Components Assuming VRS.

Year	∆TFP	∆Tech	∆Eff	∆OTE	∆ROSE	∆OME
1961/62	0.8630	0.8900	0.9957	0.9750	1.0298	1.0000
1962/63	0.9628	0.9979	0.9654	1.0486	0.9304	0.9999
1963/64	0.9453	0.8518	1.1323	1.0149	1.1131	1.0000
1964/65	0.8656	1.0585	0.8180	1.0008	0.8234	0.9999
1965/66	0.8983	0.9905	0.9087	1.0188	0.8969	0.9999
1966/67	0.9525	0.8436	1.1437	1.0418	1.0948	1.0000
1967/68	0.9325	0.8385	1.1421	0.9388	1.2164	1.0000
1968/69	1.0021	0.8648	1.1610	1.0421	1.1235	1.0000
1969/70	0.8931	0.9491	0.9486	0.9880	0.9476	1.0000
1970/71	1.0026	0.9185	1.0989	1.1056	1.0025	1.0000
1971/72	0.8276	0.9094	0.9235	1.0865	0.8457	1.0000
1972/73	0.9619	0.6373	6.9044	0.9513	7.2822	1.0000
1973/74	1.0873	0.6331	1.9738	1.2459	1.5155	0.9995
1974/75	1.0968	0.9232	1.2021	1.0182	1.1194	1.0023
1975/76	0.9274	1.2307	0.8013	1.0321	0.7612	0.9991
1976/77	0.9688	0.8817	1.1013	1.0940	1.0061	0.9992
1977/78	1.0150	1.0180	1.0083	0.9756	1.0330	1.0000
1978/79	0.8771	1.1073	0.9083	1.0731	0.8251	0.9998
1979/80	1.0783	1.0980	1.0503	1.0147	1.0414	1.0001
1980/81	0.9215	1.0382	0.9706	0.9647	0.9882	1.0000
1981/82	1.1157	1.0862	1.0267	0.9786	1.0174	1.0000
1982/83	0.8635	0.8428	1.0277	1.0800	0.9488	1.0002
1983/84	0.9826	1.1048	0.8954	0.9610	0.9289	0.9990
1984/85	0.9498	0.9086	1.0602	1.0146	1.0444	1.0010
1985/86	1.0440	1.1292	0.9516	1.0345	0.9110	1.0000
1986/87	1.0619	1.7788	0.6573	0.9820	0.6498	0.9993
1987/88	1.0102	1.0076	1.0043	1.0373	0.9676	1.0006
1988/89	1.0087	0.9871	1.0275	0.9558	1.0704	1.0001
1989/90	1.0050	0.9345	1.0735	0.9752	1.1024	1.0013
1990/91	1.1140	0.9057	1.2251	1.0601	1.1158	0.9987
1991/92	0.9502	1.1364	0.8369	0.9249	0.8948	1.0000
1992/93	0.9773	0.9844	0.9933	0.9989	0.9938	1.0000
1993/94	0.9746	0.8619	1.1330	0.9830	1.1607	0.9999
1994/95	0.9765	1.4673	0.7895	0.9184	0.8694	1.0001
1995/96	1.0114	1.4574	1.0594	1.0229	1.0283	1.0003
1996/97	1.0539	1.0242	1.0394	0.9944	1.0442	0.9995
1997/98	1.1692	1.0134	1.1619	1.0924	1.0594	0.9840
1998/99	1.0612	1.1103	0.9445	1.0050	0.9055	1.0221
1999/2000	0.9623	0.9119	1.0656	1.0369	1.0582	0.9733
2000/2001	1.2871	0.8501	1.5197	1.1699	1.2378	1.0061
2001/2002	0.9554	1.0199	0.9357	0.9322	0.9843	1.0290
2002/2003	1.3329	0.9738	1.3563	1.1291	1.1046	0.9714
2003/2004	0.8879	0.9226	0.9778	0.9269	1.0190	1.0355
2004/2005	0.9807	0.9633	1.0184	1.0110	1.0076	1.0000
2005/2006	0.9181	1.0158	0.9054	1.0583	0.8558	0.9999
2006/2007	0.9051	1.0068	0.8995	0.9701	0.9284	1.0022
2007/2008	1.0881	0.9881	0.9768	1.0337	1.0112	0.9978
2008/2009	0.9628	1.9370	0.4418	1.0293	0.9534	0.9937

Source: Authors' Calculations, 2014.

(ΔROSE) and mix efficiency (ΔOME). Any estimated value greater than unity indicates an improvement in the measures considered, and any estimated value less than unity indicates deterioration in the concerned measures. Both Table 2 and Graph 2 show the declining behaviour of technical changes (ΔTech) over the entire period (1961-2009). The table and graph revealed that agriculture sector in all ECOWAS member states are not operating on the same point on the production possibilities set. The implication is that agricultural sector in all ECOWAS member states are not affected equally by the expansions and contractions in the production possibilities set. Any change in the production possibilities set (ΔTech) can be attributable to any changes in the economic, political and social environment of ECOWAS member states as it tends to capture the effects of technological change and the long term effects of inefficiency of both regional and national policies (with the inclusion of agricultural policies over the entire years) among the ECOWAS member states.

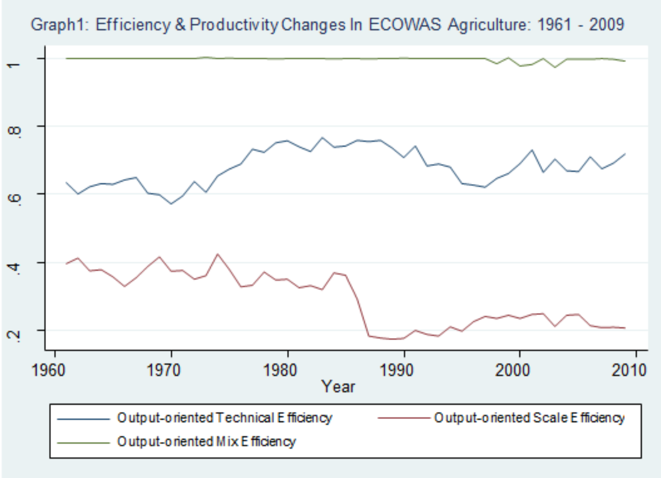
A general comparison of the different indexes presented in Table 2 and Graph 2 revealed that the important components of ECOWAS agriculture TFP changes have been technical changes and changes in residual output-oriented scale efficiency (ROSE). ECOWAS agriculture has been experiencing a significant deterioration of ΔTFP between 1961 - 2009. Each of these periods was associated with a significant fall in the technical changes. In terms of output mix efficiency (OME), all the ECOWAS member states on the average experienced positive changes over the periods (1961 - 2009). Graph 3 shows the growth of Total Factor Productivity of ECOWAS Agriculture (1961 - 2009) which has been typified upward and downward spiral movements and this may be due to failure of proper implementation of both regional and national policies that were meant to drive the agricultural sector of their diverse economies.

In general, the results in Tables 1 and 2 as well as Graphs 1, 2 and 3 indicate that all the agricultural sector of ECOWAS member state are not on the same production possibilities set. In ECOWAS agriculture, there has been a significant deterioration of ΔTFP between 1961 and 2009 even though the outputs mix efficiency (OME) in all the ECOWAS member states have presented positive changes over the entire periods (1961 - 2009).

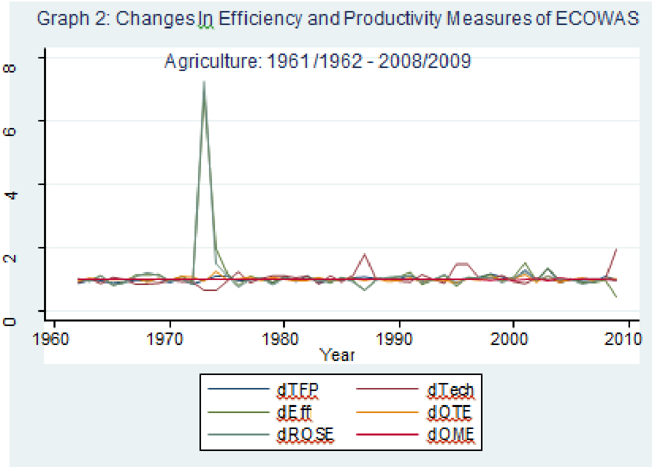
Conclusions and Recommendations

This paper has employed the Hicks-Moorsteen TFP index developed by O'Donnell (2008. 2009, 2010c) to analyse efficiency and productivity changes for the first time in ECOWAS agriculture. Four different components of productivity changes were estimated; i.e. technical changes, changes in pure technical efficiency, changes in scale efficiency, and changes in mix efficiency. Different efficiency measures were also computed. Hicks-Moorsteen is an advanced DEA methodology and as with DEA, there is one technical problem with DEA that should be addressed in future study; DEA does not have any statistical foundation, hence it is not possible to make inferences about its scores.

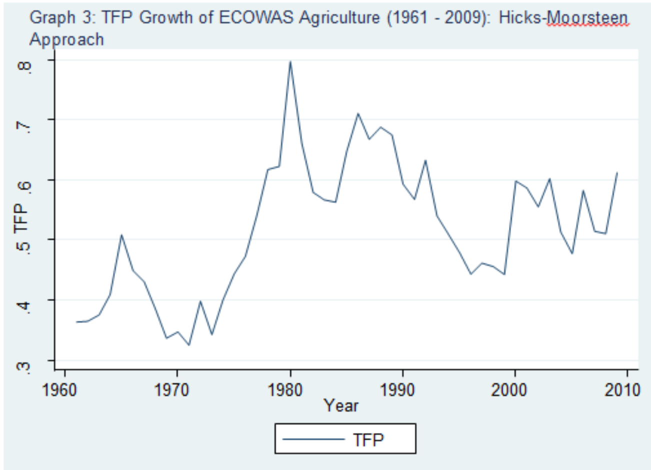
The major finding of this paper can be summarized as follows: First, the mean of ECOWAS agriculture's mix efficiency appear to be efficient over the entire period and this may be attributed to the efficient agriculture scale size as well as the independence of all ECOWAS member states in terms of managing their agricultural production inputs-outputs. Second, the inefficiency of the measures of pure technical efficiency and scale efficiency over the entire period (1961 - 2009) may be due to weak human assets, a high degree of economic vulnerability, increasing trend towards urbanization, limitation of exports to few commodities, low export earnings, low capital formation, 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 among ECOWAS member states.



Source: Author's Graphical Illustration, 2014.



Source: Author's Graphical Illustration, 2014.



Source: Author's Graphical Illustration, 2014.

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