INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS
ICAE
29th | Milan Italy 2015
UNIVERSITÀ DEGLI STUDI DI MILANO AUGUST 8 - 14
AGRICULTURE IN AN INTERCONNECTED WORLD

MULTI- LATERAL MULTI-OUTPUT MEASUREMENT OF PRODUCTIVITY: THE CASE OF AFRICAN AGRICULTURE

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Abstract

Total factor productivity (TFP) of agriculture for eighteen African countries is measured using panel data from Food and Agriculture Organization of the United Nations database for the period 1980 to 2007. Using the Färe-Primont productivity index, TFP was decomposed into measures of technical and efficiency change. The efficiency change was further decomposed into measures of technical, mix and scale efficiency changes. The results reveal TFP and technical change growth rates of 0.85% and 1% respectively. In the same period there is a decline in total technical productivity efficiency, mix efficiency, residual scale efficiency and scale mix efficiency change of 0.15%, 0.23%, 0.02% and 0.25% respectively while technical efficiency improved by 0.1%. From the results it is evident that the main driving force of TFP growth is technological progress while negative efficiency levels are contributing to reduced average productivity growth. Promotion of irrigation facilities, improving governance, improving mechanization and reducing land fragmentation are identified as necessary measures to improve TFP growth.

Key words: *Färe-Primont TFP index; technical efficiency, scale, mix efficiency changes; technical change*

1. Introduction

The significance of agriculture in the development process of any country is well known. In many African countries agriculture remains an important source of livelihood accounting for 30 to 40 percent of total Gross Domestic Product (GDP), and about 60 percent of total export earnings in countries such as Burkina Faso, Burundi, Central African Republic, Chad, Ethiopia, Kenya, Mali, Mozambique, the Niger, among others (IFPRI 2010). There is a general consensus that productivity growth rates have accelerated in recent decades, led by improved performance in developing countries in East, Southeast, and South Asia. While the crop yield per hectare has improved it is disputed whether agricultural productivity and therefore potential yield of most crops and livestock have been fully realized especially in Sub-Saharan Africa (SSA) countries. The importance of this issue is highlighted by the ongoing global deficiency in food that is affecting one eight of the population. Statistics indicate that almost one billion people globally lack enough food to eat, and a further billion lack adequate nutrition (Misselhorn et al. 2012). Approximately six (6) million people worldwide die from hunger and malnutrition each year the majority of whom are located in developing countries even as the global demand for food is expected to increase by 60 percent by 2050 (FAO 2012).

According to the 2012 Global Hunger Index (GHI), most countries with "alarming" GHI values are located in SSA and South Asia while the two of the three countries with "extremely alarming" values are in SSA (Von Grebmer et al. 2012). This food problem has become a major challenge for policy-makers especially in SSA. To avert the food crisis, therefore an increase in food output must come from improvements in productivity (Pratt and Yu 2008). Moreover, achieving food security requires adaptation to climate change measures and adoption of practices that not only support farmers in producing enough food to meet people's nutritional needs, but also halt degradation of the ecosystems that underpin agricultural productivity (UNEP 2013).

As a general principle it is argued that if the agricultural sectors become more productive the increased food production can relieve poverty and hunger of rural populations, bring down the cost of food and especially for the growing numbers of urban poor who need to buy food. This can also lead to improved environmental conditions if productivity improvements are channeled towards strengthening interventions such as provision of insurance to help households cope with production shocks (Dercon and Christiaensen 2011). Increased agricultural productivity is also likely to reduce pressure on marginal lands since the intensification of cultivated land is likely to reduce pressure of moving into farming in fragile marginal lands (Baiphethi and Jacobs 2009). Higher agricultural productivity is also likely to bring about higher growth in other sectors of an economy, including services (Von Braun et al. 2009). Thus any essential element in averting the food crisis is to increase production through improvement in productivity (Moir 2011). Understanding productivity sources and the effects of environmental externalities therefore becomes important for policy makers.

According to Comin (2006), TFP is defined as a measure of output that cannot be explained by the level of inputs used in the production process Technical efficiency on the other hand is measured by the degree to which the actual output of a production unit approaches its maximum. Technical change is defined by how much output will increase per given unit of inputs. Thus the level of output will be determined by the level of efficiency and intensity of utilization of inputs in the production process.

Policy-makers from countries especially in Africa aim to improve productivity by spelling out priority objectives for development of the sector. Typically blue prints are created which focus on long term ways of improving production. For example Kenya's long-term national planning strategy "*Kenya Vision 2030"* identifies the agricultural sector as having the most promising potential to drive Kenya's economic growth through to 2030. Specific strategies include: transformation of the country's key agricultural institutions to promote household and private sector agricultural growth; increasing productivity of crops and livestock; introduction of new land use policies and opening up of new lands for agriculture through development of irrigation infrastructure. Similar blue-prints have been drawn up by the Republic of Gambia whose priority objectives for the agriculture sector under "*Vision 2020*" are to increase agriculture and natural resource output to ensure food security and generate earnings of foreign exchange. Ghana's Economic Recovery Program (ERP) of 1984 identified agriculture as the key economic sector which could rescue Ghana from severe economic dislocation. It is also noteworthy that the heads of state and members of the African Union unanimously adopted a declaration to end hunger in Africa by the year 2025 and which called for a combination of policies to promote sustainable agricultural development with an emphasis on increasing production and productivity. Unfortunately the policies outlined above have rarely been backed up by tangible empirical evidence which identifies the underlying causes of low productivity and low potential of the agricultural sector.

Examining contemporary literature reveals that it has focused on measuring productivity change by employing either non-parametric or parametric methodologies. The non-parametric methodology adopts the Malmquist total factor productivity (MTFP) index approach which is decomposed into technological change and which represents the change in output from the same amount of inputs. In this way it provides an indication of whether there is improvement or deterioration in the performance of best-practice decision making units (DMUs). Secondly it provides a measure of technical efficiency change, which reflects the effectiveness with which a given set of inputs are utilized to produce a given output.

Most studies of TFP use the Tornqvist index and Malmquist TFP change indicators see for example (Coelli 1995, 1996; Coelli and Rao 2005; Irz et al. 2001; Jin et al. 2010; Thirtle et al. 1993; Thirtle et al. 2003; Van Biesebroeck (2007)) among others which take into account TFP change in terms of technical and efficiency change only. In a number of cases the output mix effect (OME) which measures the effects of changes in the composition of the output while holding the input fixed is overlooked. As well the scale mix efficiency (OSME) which measures the effects of economies of scale and scope of operations has rarely been captured in the literature. These sources of productivity have not been commonly discussed and do not feature in any of the interpretations or decomposition of the TFP index (Coelli 1995). TFP which is considered as the residual growth not accounted for by labor and capital has been attributed to technical progress, technical efficiency, scale of firm operation and other socio- economic factors not captured by the variables used in the production function (Mustapha et al. 2013). Hence if any of these factors are not present in the calculation, the TFP change that is evident in the observed data may be misrepresented.

TFP change can be driven by four different factors i.e. technical change, technical efficiency change, scale efficiency and output mix. The Malmquist TFP change is multiplicatively incomplete since it only decomposes TFP change into technical change and efficiency change. Furthermore, in the presence of non-constant returns to scale, the Malmquist productivity index does not accurately measure productivity change, the bias being systematic, and dependent on the magnitude of the economies of scale (Grifell-Tatjé and Lovell 1995).

Studies using the Färe-Primont productivity index are rare in literature. One such study by O'Donnell (2011) computed the Färe-Primont productivity index for eighteen manufacturing sectors in the US economy for the period 1987 to 2008 and found that they experienced technical progress at an average annual rate of only 0.189%. The author noted that although the firms were scale mix inefficient most of them were technically efficient hence no policy intervention was needed in terms of technical efficiency. However the firms needed to change the structure of their operations (i.e., scale and input mix) which would impact on their levels of scale and mix efficiency in response to expected changes in prices. Similarly Rahman and Salim (2013) estimated changes in TFP indices for agriculture in seventeen regions of Bangladesh covering the period 1948 to 2008 and found that TFP grew at an average rate of 0.57% per year largely powered by technological progress estimated at 0.74% per year. Technical efficiency improved at 0.01% while scale efficiency declined by 0.01% with a decline in mix efficiency of 0.19% per year. Tozer and Villano (2013), decomposed productivity growth of forty five Western Australian grain producers using four years farm level data and found the producers to be technical, mix and scale efficient with results varying according to input and output mix efficiencies. Thus apart from these few studies focusing on individual countries, no other studies are found which utilize the Färe-Primont productivity index to further break down the other sources of TFP in agriculture for a group of countries.

In order to verify where productivity of African agriculture lies, all sources of productivity must be captured. This study fills the gap identified above by measuring the TFP of selected countries in Africa using the Färe-Primont productivity index into measures of TFP, technical and efficiency changes. The efficiency change is further decomposed into measures of technical, mix and scale efficiency change. The intended contribution of this research is consequently to adopt a methodology which can shed light on the sources of TFP growth in African agriculture using recent data. Using the Färe-Primont index, reliable multi-lateral and multi-temporal comparisons (i.e. comparisons involving many countries and time periods) will be made. Results from this study are designed to help policy makers in Africa identify where agricultural productivity growth is strongest and thereby assist in illuminating specific policies and practices that hold promise for improving productivity in other regions.

2. Methodology

2.1 Explaining total factor productivity

TFP is a measure of the ratio of total production output to total inputs used in production. In agriculture this ratio can be the aggregate output quantity of all crop and livestock products and total inputs which are mainly land, labor, capital and materials or an aggregate value of agricultural products. If total output grows faster than total input, then an improvement in real output value or growth is achieved which implies that more output has been obtained from a given production possibilities set. TFP can also change if price effects occur resulting in value increase or through intensification i.e. the increase of inputs not related to land such as capital, labor, water or fertilizer per hectare or through TFP growth.

TFP growth interchangeably defined as technical progress or changes in technology is a measure of how well operators combine inputs to produce outputs. It measures the rate of improvement on previous years' productivity which may be influenced by, among other factors, changes in farm size, the rate of uptake of new technologies, the rate of technological discovery, policy settings, market forces and climate variation all of which can indicate the efficiency of the production processes (Mallawaarachchi et al. 2009). TFP growth is largely driven by changes in technology, improvement of efficiency or changing the product mix. Technical change involves the shift in the production frontier by developing and adopting a new production possibilities set. Efficiency gains on the other hand measure how inputs are used or combined in the most cost-effective way while using the existing technology. The efficiency gains can be further decomposed into finer components of change which are pure technical, allocative or scale efficiency. Technical efficiency gains normally arise from adoption of better management practices and combinations of inputs that result in either higher output or the same output produced at lower inputs. Allocative efficiency gains often occur with better allocation of expenditure among inputs so as to produce the same level of output at a lower cost. Scale efficiency gains on the other hand occur when production costs match with the scale of operations. Output/input mix efficiency is the potential increase in productivity that is obtained from economies of scope. As O'Donnell (2010) defines it, mix efficiency is the ability to improve the overall productivity by changing the output/input mix of a business while holding the input/output set constant. In summary higher TFP can be achieved in a number of ways including, through increasing output while keeping the inputs constant, by producing same level of output while using lower inputs or by changing the mix of inputs and or outputs (Tozer and Villano 2013).

2.2 Measuring total factor productivity

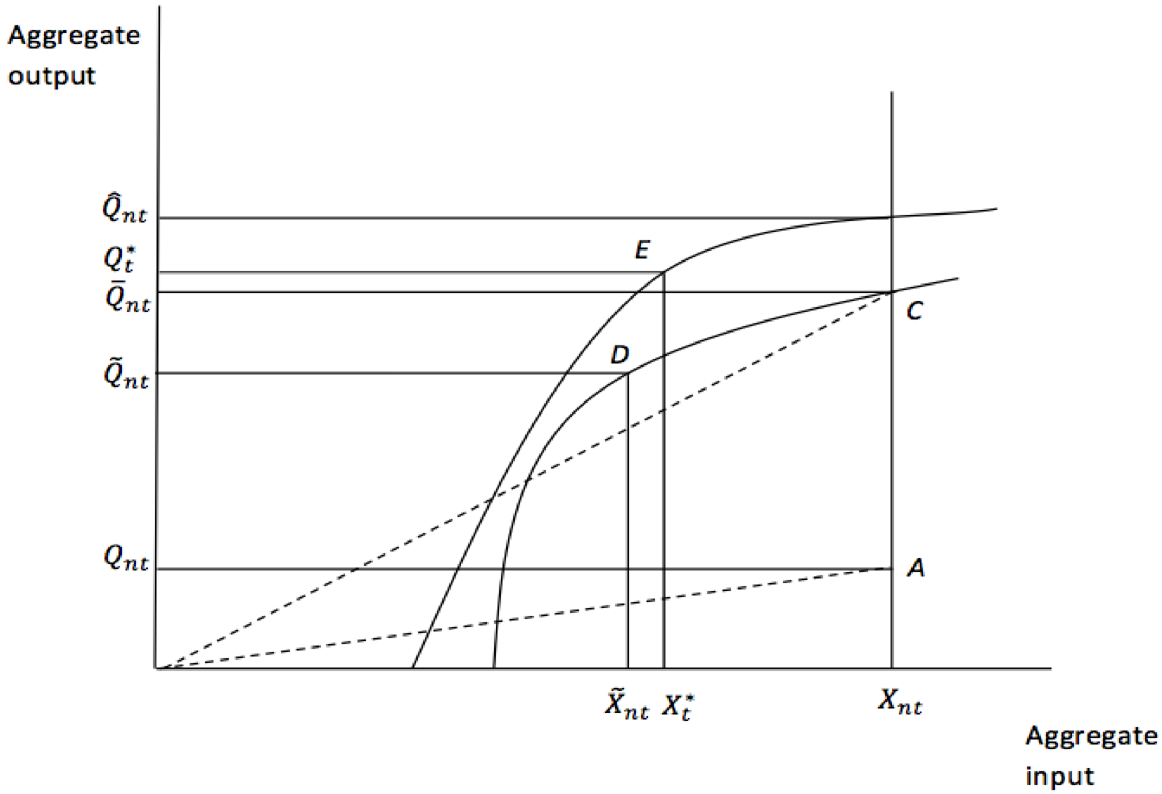
In this study the TFP of African agriculture is measured using the Färe-Primont index. The analytical framework developed by O'Donnell (O'Donnell 2011; O'Donnell 2010) and its corresponding software DPIN version 3.0 was utilized to estimate the technical and mix efficiencies and the TFP for eighteen African countries. The approach uses the aggregate quantity framework to describe a multi-input, multi-output production technology. The advantage of this framework is that it does not require specification of the behavioral objective such as cost or profit maximization. According to O'Donnell (2010), the TFP of a firm with multiple-output multiple-inputs is defined to be the ratio of an aggregate output to an aggregate input. Following O'Donnell (2012), we assume that $xit = (x_{1it} ,..., x_{Kit})'$ and $q_{it} = (q_{1it} ,..., q_{jit})'$ denotes the input and output quantity vectors of firm *i* in period *t*. Then the TFP of the firm is defined as:

$TFP_{nt} = Q_{nt}/X_{nt}$

where $(Q_{nt}) = Q(q_{nt})$ is the aggregate output of a given firm, $(X_{nt}) = X(x_{nt})$ is an aggregate input of the firm in time *t*. In the Färe-Primont index, the aggregate output/input quantities are obtained using aggregator functions with properties that are nonnegative, non-decreasing and linearly homogeneous. The associated index number that measures the TFP of firm *n* in period *t* relative to the TFP of firm *h* in period *s* is $TFP_{hs,nt} = TFP_{nt}/TFP_{hs} = (Q_{nt}/X_{nt})/(Q_{hs}/X_{hs}) = Q_{nt}/X_{hs}$

where $Q_{nt} = Q_{nt}/Q_{hs}$ is an output quantity index and $X_{nt} = X_{nt} /X_{hs}$ is an input quantity index which are multiplicatively complete output and input indexes as defined by O'Donnell (2010). Thus, in this case, TFP growth is expressed as a measure of output growth divided by a measure of input growth. According to O'Donnell (2012), efficiency measures can be decomposed into output technical, mix and residual scale efficiencies or input technical, scale and residual mix efficiencies. The analytical form is as shown in figure 1.

Figure 1: Analytical framework of the aggregator functions



Source: O, Donnell (2010)

The measures of efficiency are obtained based on the orientation of the production technology i.e. whether it is output or input oriented. Under output orientation it maximizes on expansion of output on a given set of inputs while in input orientation the inputs are minimized given the output quantity. In this case the output orientation is adopted since in agriculture maximization of output is considered more realistic in terms of the expectations of farmers. Thus the output oriented technical efficiency is measured as;

$OTE_{nt} = Q_{nt} / \bar{Q}_{nt}$

While output oriented scale efficiency is measured as:

$OSE_{nt} = (\bar{Q}_{nt}/X_{nt}) / (\tilde{Q}_{nt}/\tilde{X}_{nt})$

Output oriented mix efficiency is measured as:

$OME_{nt} = \bar{Q}_{nt} / \hat{Q}_{nt}$

The residual output orientated scale efficiency is defined as:

$ROSE_{nt} = (\bar{\tilde{Q}}_{nt}/X_{nt})/(Q_t{*} / X^*_T)$

The residual mix efficiency is defined as:

$RME_{nt} = (\tilde{Q}_{nt}/\tilde{X}_{nt})/(Q{*}t/ X^*_T)$

where $\bar{Q}_{nt}$ is the maximum aggregate output that can be obtained from a given set of X_{nt} inputs with a scalar multiple of $q_{nt..}$ $\bar{\tilde{Q}}_{nt}$ is the maximum aggregate output that can be obtained from X_{nt} set of input. $\tilde{Q}_{nt}$ and $\tilde{X}_{nt}$ are the aggregate output and input obtained when TFP is maximized subject to the input and output quantities being scalar quantities of q_{nt} *and* x_{nt} (O'Donnell 2010). $Q_t{*}$ and X^*_T are the aggregate output and input that maximizes TFP. When the TFP that can be obtained from a given technology reaches its maximum then $TFP_{it}{*}$ is obtained.

Thus the overall productive efficiency of a firm denoted as $TFPE_{nt}$ is defined as the ratio of observed TFP to the maximum possible TFP when using a given technology and is given as:

$TFPE_{nt} = TFP_{nt}/TFP_t{*}= (Qnt_{/Xnt})/Q_{nt}{*}/X_{nt}{*}) = OTE_{nt} \ x \ OME_{nt} \ x \ ROSE_{nt} = OTE_{nt} \ x \ OSE_{nt} \ x \ RME_{nt.}$

In an input orientation the various measures of productive efficiency can be expressed as follows:

$TFPE_{nt} = ITE_{nt} \ x \ IME_{nt} \ x \ RISE_{nt} = ITE_{nt} \ x \ ISE_{nt} \ x \ RME_{nt:}$ *where*

$ITE_{nt} = \bar{X}_{nt}/X_{nt}$

$ISE_{nt} = (Q_{nt}/\bar{X}_{nt})/ (\tilde{Q}_{nt}/\tilde{X}_{nt})$

$IME_{nt} = (\hat{X}_{nt}/\tilde{X}_{nt})$

$RISE_{nt} = (Q_{nt}/\tilde{X}_{nt})/(Q_t{*}/X{*}_{nt})$

The estimation of productivity and its components are obtained through distance functions and linear programming. The aggregator functions of Färe-Primont (O'Donnell 2011) are:

$Q (q) = D_0(x_0, q, t_0)$

$X(x) = D_1(x, q_0, t_0)$

Where q and x are vectors of input and $D_0(.)$ and $D_1(.)$ are output and input distance functions respectively. The Färe-Primont is given by O'Donnell (2011) to be:

$TFP_{hs,it} = D_0(x_0, q, t_0)/ D_1(x, q_0, t_0))/ D_0(x_0, q_{hs}, t_0)/ D_{1(}x_{it}, q_0, t_0)$

If the output distance function $D_0(.)$ and the aggregator functions Q(.) and X(.) were known in theory the following will be computed:

$TFP_{it} = Q(q_t)/X(x_t)$ for $t = 1, \ldots\ldots\ldots\ldots T;$

$TFP_{it}^* = max\ x>0,\ q\geq 1$ which is the maximum TFP that can be obtained from a given technology:

$TFPE_{it} = TFP/TFP_t^*$ *for* $t = 1, \ldots\ldots\ldots\ldots T$, which is known as TFP efficiency.

If a regular technology is extended homothetic (EH) and HDr then the output and distance functions take the form:

$D_0(x,q,s) = H(q)^r/[B(s)G(x)]$ *and* $D1(x,q,s) = B(s)G(x)^{1/r}/H(q)$.

The associated Färe-Primont index takes the form as presented by O'Donnell 2011b:

$$TFPIst = \frac{D_0\ (x_{0,}q_{t,}s)}{D_0\ (x_0q_sS)}\frac{D_I\ (x_{s,}\ q,\ s_0)}{D_I\ (x_tqt_s)} = \frac{H(q_t)\ _{r\ G(x_S)1/r}}{H(q_t)\ _{r\ G(x_S)1/r}}$$

The Färe-Primont index can also be rewritten as:

$$TFPIst = \frac{B(S_{t,})}{B(S_s)}\left(\frac{H(q_t)r}{B(S_{t,})G(x_s)1/r}\frac{H(q_t)r\ G(x_s)1/r}{H(q_s)}\right) = \frac{TFPt*}{TFPs*}\frac{TFPEt}{TFPEs}$$

In this approach no assumptions are made about the direction taken to achieve the production frontier, only the choice of orientation as to whether input or output is used to approach the direction of movement to the frontier. The Färe-Primont index is used to obtain TFP and efficiency measures which are specified on variable returns to scale and varying technical change.

3. Data

Data from the United Nations Food and Agriculture Organization (FAOSTAT) statistical database which is an internationally comparable database was used. The data covered the period from 1980 to 2007 for eighteen countries which include Burundi, Cameroon, Côte d'Ivoire, Gabon, Gambia, Ghana, Kenya, Libya, Madagascar, Malawi, Mozambique, Niger, Nigeria, Sudan (former), Tanzania, Togo, Tunisia and Zambia.

The Färe-Primont model was then specified for two outputs: livestock and crop. The FAO output data is based on annual production of 189 crop and livestock commodities which are aggregated into a measure of gross production value. To calculate the production value, the FAO uses a common set of global average commodity prices derived using the Geary-Khamis method from

2004-06 expressed in constant 2005 international dollars. For a detailed description and assessment of how the aggregation has been carried out see Rao (1993). Four traditional agricultural inputs i.e. land, labor, capital and materials (fertilizer) were used. The dataset contained capital stock which is an important input in the mediation process an input rarely used in previous agricultural studies. Due to unavailability of data for capital stock the sample expansion was not feasible beyond the year 2007. The analysis of TFP contained a number of variables of interest: The description of the inputs is as follows:

1) *Agricultural land* includes agricultural area that is arable, under permanent crops and permanent pasture measured in hectares
2) *Agricultural labor* is defined as the total active population in agriculture and who receive remuneration in wages, salary, commission, piece rates or pay in kind
3) *Agricultural capital* is defined by the use of FAO dataset which multiplies unit prices by the quantity of physical assets using 2005 constant prices. For the purpose of aggregation the capital stock was deflated to 2005 constant prices using the purchasing power parity index from the World Bank
4) *Fertilizer* is defined as the aggregate quantity of all fertilizer used in tons.

The Decomposition of Productivity Index Numbers (DPIN version 3.0) software was used to compute TFP indices and its components of technical change and various measures of technical, scale and mix efficiency change. The software used was downloaded from the Centre for Efficiency and Productivity Analysis (CEPA) of the School of Economics, University of Queensland website.

Using the bootstrap technique as proposed by Simar and Wilson (2007), a bootstrap truncated regression was run using Matlab to determine the drivers of efficiency which are an important component of TFP. The variables used include labor ratio as a proxy for labor growth in agriculture, area endowed with irrigation as a proxy for land quality, rainfall which is a natural environment factor, tractors as a proxy for mechanization, political instability as a proxy of governance and per capita land as a proxy for land size. The data variables for this stage were obtained from The World Bank database. The annual rainfall data used in this study was drawn from Mitchell et al. (2004) and Jefferson and O'Connell (2004). The determinants of TFP were as follows:

1) *Labor ratio* is captured by the ratio of total number of people economically active in agriculture to the total population. Agriculture in Africa is heavily labor intensive indicating the importance of evaluating its impact on efficiency and productivity
2) *Area endowed with irrigation* is captured by the total agricultural area covered by irrigation measured in hectares and which served as a proxy of land quality
3) *Rainfall* is measured by the average annual precipitation (in mm) for each country. Given Agriculture in Africa is largely rain-fed, fluctuations in efficiency or TFP can also be determined by average annual rainfall
4) *Tractors* is measured by the number of tractors available for agricultural use and which serves as a proxy for mechanization. Tractors are used for a range of farm activities such as ploughing, harrowing, planting and harvesting
5) *Governance* is captured using the governance index provided by the World Bank and is used to indicate the presence or absence of political stability, terrorism or threats. Countries with a negative index is an indication of politically instability and hence assigned 0 while those with a positive index are assigned 1
6) *Per capita land* is obtained by dividing the amount of land available for agriculture by the agriculture population. This variable is included in order to capture land size per person. Agriculture in most African countries is heavily dependent on land expansion and hence requires increasing alternative and sustainable sources of productivity.

Table 1: Summary statistics of variables

Variable	Mean	Min	Max	STDEV
Crops	2574268	50726	33676254	4636890
Livestock	712768.7	16099	5058603	909868.8
Capital stock	165803.3	59.7036	1757674	345400
Total agricultural land	26282.92	495	136615	29509.03
Total agricultural population	4047.544	77	15693	3724.215
Fertilizer	226138.7	100	62151574	2764365

Source: FAOSTAT 2013 and Author's calculation

4. Results

4.1 Total factor productivity and components

In this section the Färe-Primont productivity index and its components results are presented. The annual means of TFP and its components are reported in Table 2. The average annual TFP output value for all the eighteen (18) countries for the period 1980 to 2007 was 0.22. The maximum TFP (TFP^*) given the technology for the same period was 0.48, while the technical factor productivity efficiency (TFPE) was 0.45. The pure technical efficiency estimate was 0.92, while scale efficiency was 0.94. The average output mix efficiency was 0.92 while residual scale, scale mix efficiency and residual mix efficiency was 0.54, 0.49 and 0.52 respectively. The output mix efficiency varied over the said period with a maximum of 0.96 and a low of 0.85. The low values of between 0.85 and 0.89 of output mix corresponded with the years of natural disasters and in particular floods, droughts and epidemics phenomenon which were experienced by a number of countries (see Table 4). The low residual scale, mix and residual mix efficiency imply that these countries have yet to reach maximum productivity even though they appear to be technically, scale and/or mix efficient in their use of inputs.

Examining the average input efficiencies for the said period referred to in Table 3 reveals that the input technical efficiency was 0.91 while the input scale efficiency was 0.95. The input mix efficiency was 0.69, the residual input scale efficiency 0.72 and the input scale mix efficiency 0.50. The average input mix efficiency ranged from 0.61 to 0.77 with the lowest score corresponding to the years of flooding or low rainfall years (See Table 4). This indicates a difficulty in adjusting the input mixes to correspond with the changing production system given most crop inputs are applied at the beginning of the planting season with limited flexibility to adjust with change in weather patterns. The scale efficiency was considerably higher than the other efficiencies which is consistent with the findings of Thirtle et al. (1993) that imply that TFP growth in many countries was largely driven by land expansion especially in the 1980s. It also involved moving of input resources such as fertilizer and improved varieties into more profitable crops and products for which prices had risen in recent years and did not come from growth through technological change. Many countries during this period including Nigeria, Ghana, Cameroon, Malawi and Kenya heavily subsidized their farmers to produce crops for exports such as coffee by providing augmented inputs hence increasing output without necessarily increasing TFP.

From the results it is evident that the overall technical efficiencies of both inputs and outputs are relatively meaning that the eighteen African countries are performing well in these areas. However the variation can be shown to be due to differences in the technical factor productivity efficiency (TFPE) and the mix efficiencies i.e. the output residual scale, scale mix, residual mix efficiency and input mix efficiencies. The discrepancy between TFP and the frontier TFP can therefore be attributed in large part due to technical factor productivity efficiency which was driven by lower levels of output residual scale, scale mix and residual mix efficiencies.

Table 2: Summary of annual TFP means and its components

Year	TFP	TFP*	TFPE	OTE	OSE	OME	ROSE	OSME	RME
1980	0.20	0.43	0.46	0.91	0.93	0.91	0.56	0.51	0.55
1981	0.20	0.39	0.50	0.89	0.95	0.94	0.61	0.57	0.60
1982	0.20	0.43	0.47	0.89	0.95	0.93	0.57	0.53	0.55
1983	0.20	0.45	0.44	0.90	0.95	0.93	0.53	0.49	0.52
1984	0.20	0.45	0.44	0.94	0.94	0.93	0.51	0.47	0.51
1985	0.20	0.45	0.44	0.94	0.94	0.94	0.50	0.47	0.50
1986	0.20	0.48	0.42	0.93	0.92	0.94	0.49	0.46	0.50
1987	0.20	0.51	0.40	0.91	0.93	0.93	0.48	0.44	0.48
1988	0.21	0.54	0.39	0.94	0.95	0.92	0.45	0.41	0.43
1989	0.21	0.53	0.40	0.94	0.95	0.93	0.46	0.42	0.45
1990	0.21	0.50	0.42	0.94	0.96	0.91	0.49	0.44	0.46
1991	0.21	0.49	0.43	0.93	0.92	0.92	0.51	0.47	0.51
1992	0.21	0.47	0.45	0.91	0.95	0.93	0.53	0.49	0.51
1993	0.21	0.45	0.47	0.95	0.95	0.91	0.55	0.50	0.53
1994	0.21	0.43	0.48	0.92	0.95	0.93	0.56	0.52	0.55
1995	0.22	0.43	0.51	0.93	0.94	0.96	0.57	0.55	0.58
1996	0.22	0.42	0.53	0.95	0.94	0.93	0.60	0.56	0.59
1997	0.22	0.43	0.52	0.92	0.94	0.94	0.60	0.56	0.60
1998	0.23	0.46	0.49	0.93	0.93	0.92	0.58	0.53	0.57
1999	0.23	0.49	0.48	0.93	0.94	0.90	0.57	0.51	0.54
2000	0.23	0.51	0.46	0.92	0.96	0.92	0.54	0.50	0.52
2001	0.24	0.52	0.45	0.90	0.95	0.91	0.55	0.50	0.53
2002	0.23	0.54	0.43	0.87	0.95	0.92	0.55	0.50	0.53
2003	0.24	0.56	0.42	0.84	0.96	0.94	0.53	0.50	0.52
2004	0.24	0.56	0.43	0.89	0.97	0.91	0.53	0.49	0.50
2005	0.25	0.57	0.43	0.93	0.93	0.89	0.52	0.47	0.50
2006	0.25	0.56	0.44	0.89	0.95	0.88	0.56	0.49	0.52
2007	0.25	0.57	0.44	0.94	0.93	0.85	0.56	0.47	0.51
Geomean	0.22	0.48	0.45	0.92	0.94	0.92	0.54	0.49	0.52
Growth	0.85	0.10	-0.15	0.10	0.00	-0.23	-0.02	-0.25	0.85

Source: author's calculation from levels computed using Färe-Primont aggregator functions

Note: TFP/TFP* = total factor productivity; TFPE = total factor productivity efficiency; OTE = output technical Efficiency; OSE = output scale efficiency; OME = output mix efficiency; ROSE = residual output scale efficiency; OSME = output scale mix efficiency and RME = residual mix efficiency. These definitions apply in preceding tables. Geomean is the geometric mean while Growth is the average annualized growth rate in %.

Table 3: Summary of annual input usage: 1980-2007

Year	ITE	ISE	IME	RISE	ISME
1980	0.90	0.95	0.75	0.69	0.52
1981	0.87	0.96	0.77	0.75	0.58
1982	0.87	0.97	0.76	0.71	0.53
1983	0.89	0.96	0.74	0.68	0.50
1984	0.92	0.95	0.70	0.68	0.48
1985	0.93	0.94	0.69	0.68	0.47
1986	0.91	0.94	0.71	0.66	0.47
1987	0.89	0.94	0.71	0.63	0.45
1988	0.94	0.96	0.67	0.62	0.41
1989	0.93	0.95	0.68	0.63	0.43
1990	0.94	0.96	0.68	0.65	0.44
1991	0.90	0.95	0.71	0.67	0.48
1992	0.90	0.96	0.69	0.71	0.49
1993	0.94	0.96	0.67	0.75	0.50
1994	0.91	0.96	0.68	0.78	0.53
1995	0.93	0.94	0.71	0.77	0.55
1996	0.94	0.94	0.71	0.78	0.56
1997	0.91	0.95	0.72	0.79	0.57
1998	0.92	0.94	0.70	0.77	0.54
1999	0.93	0.94	0.68	0.76	0.51
2000	0.92	0.96	0.67	0.75	0.50
2001	0.90	0.95	0.68	0.74	0.50
2002	0.87	0.95	0.69	0.73	0.50
2003	0.85	0.95	0.69	0.73	0.50
2004	0.88	0.97	0.65	0.74	0.49
2005	0.93	0.93	0.61	0.76	0.46
2006	0.89	0.95	0.64	0.77	0.50
2007	0.94	0.93	0.62	0.77	0.47
Geomean	0.91	0.95	0.69	0.72	0.50
Growth	-0.24	0.16	-0.07	-0.67	0.36

Source: author's calculation from levels computed using Färe-Primont aggregator functions

Note: ITE = input technical efficiency; ISE = input scale efficiency; IME = input mix efficiency; RISE = residual input scale efficiency and ISME = input scale mix efficiency. These definitions apply in preceding tables.

Table 4: Summary of policy events and policy changes: by country

Country	Policy and events	Policy changes made
Burundi	Up to 1999: economy was centrally planned with many resulting inefficiencies; fifteen years of civil war since 1991; continued land degradation and deforestation	Signing of the Arusha Peace Accord in 2000; Poverty Reduction Strategy Paper (PRSP) for the country's economic and social welfare finalized in 2006; creation of the Priority Action Plan for 2007-2010 to guide the implementation of its poverty reduction strategy; decentralizing of the economy
Cameroon	Up to 1994: drop in commodity prices (petroleum, cocoa, coffee, and cotton) in the mid-1980s; overvalued currency; economic mismanagement and recession	Economic reform programs supported by World Bank and IMF began in the late 1980s; CFA franc devalued by 50% in January 1994
Côte d'Ivoire	Up to 2000: political and social unrest resulting in a military coup d'état in 1999; a drop in world commodity prices; recession in 2000; poor cocoa and coffee harvests and a fall in the price of coffee	Devaluation of the CFA franc in 1994; freeze on public investment since late 1999
Gabon	Up to 1994: violent demonstrations and strikes by students and workers in early 1990; two coup d'état attempts in 1990	Structural adjustment and trade liberalisation programmes
Gambia	Up to 1990: controlled product and input markets; controlled exchange rates; subsidy of inputs and in particular fertiliser	Liberalisation of markets; improvement in exchange rates; re-introduction of the Package Deal Programme in the year 2000
Ghana	Up to 1983: food import substitution policy; promotion of mechanisation; government controlled grain marketing board	Economic recovery program; trade liberalisation and foreign exchange controls lifted
Kenya	Up to 1993: structural reforms started in the 1980s but small improvement by 1991; slow pace in changing	Liberalization of maize market; abolition of maize movement controls; fertilizer subsidy policy in place; cereals marketing policy; output marketing for a variety

	agricultural policy	of enterprises including cotton, dairying, sugar, and coffee liberalized; adoption of improved maize varieties
Libya	Up to 1985: long-term loans from government to individuals to purchase land from Italian settlers; nationalisation of all banks; political unrest	1981-85 development plan; agricultural credit provided by the National Agricultural Bank; introduction of land and private sector reforms; political unrest
Madagascar	Up to 1983: state controlled trade in agricultural products and inputs; domestic food price subsidization	Liberalization began in 1983; exchange rate made flexible in 1994; creation of Export Processing Zone in 1989
Malawi	Up to 1994: agricultural production and marketing heavily controlled by government; fertilizer subsidies provided; civil war from 1975-1992	All input and output prices were set free except for maize; production and marketing of hybrid seed maize liberalized; fertilizer subsidy still currently in place
Mozambique	Up to 1994: centrally planned economy after independence; conflict and civil war from 1975-1992; collapse of the economy in 1986	Economic and social rehabilitation program introduced reforms in 1989; price liberalization in 1989–1993; since 1996 trade liberalization and simplified tariff structure in place; privatization program implemented in 1989; end of civil war in 1993
Niger	Up to 1994: financial and economic problems; civil unrest (coup d'états) in 1996 and 1999	1994 CFA franc devaluation; decentralisation of services
Nigeria	Up to 1984: overvalued currency; public expenditure concentrated in sectors other than agriculture; price controls and trade restrictions; output markets controlled; massive agricultural imports; fertiliser subsidies	Structural adjustment program: devaluation of the naira; ban on food imports; agricultural development projects initiated; on-farm adaptive research on cassava
Sudan	Up to 1999: interventionist policy; distorted markets; civil war and rainfall fluctuations	Long-term plan with substantial economic reforms: currency devaluation; exchange rate liberalisation; abolition of most export and import licenses; liberalisation of most domestic markets
Togo	Up to 1994: state-controlled output and input markets	1994 CFA franc devaluation; elimination of taxes on food crops

Tunisia	Up to 1986: state control of the economy; input subsidization; price support programs	Becomes a member of the World Trade Organization (WTO) in 1995; promotion of investment projects in agriculture and credit facilities; liberalization
Tanzania	Up to 1985: Heavily state-controlled economy; inadequate policy led to economic stagnation; war with Uganda	Economic recovery program begun in mid-1986; currency devaluation; international and domestic trade and marketing liberalization; elimination of price controls; phasing out of petroleum and fertilizer subsidies; Agriculture Sector Development Programme launched in 2006
Zambia	Up to 1991: heavy government involvement in agricultural markets; heavy fertilizer, transport and milling subsidies;	Liberalization of maize and cotton markets; large-scale involvement in maize input and output markets through Zambia Food Reserve Agency (FRA) and Fertilizer Support Programme beginning in the early 2000s

Source: Adapted from Nin Pratt and Yu (2008)

Table 5: Natural disasters experienced: by country

Country	Drought	Floods	Storms	Epidemics	Pests	Volcano
Burundi	1999, 2005, 2008 & 2009	2007	2004	1997, 1999 & 2000		
Cameroon	1990	2007, 2008 & 2010		1992, 1993 & 2004		1986 & 1999
Côte d'Ivoire		1989, 2007 & 2008		1995, 2001 & 2008		
Gabon		1988		1988, 1994, 1996, 2001& 2007		
Gambia	1980	1996, 1999 & 2010	2003 &2004	1997		
Ghana	1983	1991, 1995, 1999 & 2001				
Kenya	1991, 1994, 1997, 1999, 2004, 2005 & 2008;	1997 & 2006		1994		

Libya	Hot and dry	1995	Dust and sand storms			
Madagascar	1981, 1988 &2002		1994, 1997, 1999, 2000, 2002, 2004 & 2008			
Malawi	1979-1980, 1987, 1990, 1992, 2002 & 2007	1997, 2001, 2002 & 2007				
Mozambique	1981, 1991, 2002, 2005 & 2007	1981, 1985, 2000 & 2001	1994		1997-2000	
Niger	1983	1988, 1994, 1998, 1999, 2001 & 2009				
Nigeria	1983	1988, 1994, 1998, 1999, 2001 & 2009				
Sudan (former)	1983, 1987, 1990, 1991, 2000 & 2009	1988, 1998, 2003 & 2007				
Togo	1989	1994, 1995, 1998, 1999, 2007 & 2010				
Tunisia	1988	1986, 1990, 2003, 2007 & 2009			1988	
Tanzania	1984, 1988, 1991, 1996, 2003, 2004 & 2006	1989, 1993 & 1990				
Zambia	1991, 1995 & 2005	1989, 1998, 2001, 2004, 2007 & 2009				

Source: Prevention web

4.2 TFP change and its components: 1980-2007

The growth rate for TFP and its components are reported in Table 6. The results show the average change in TFP was 2.11 and for technological change was 1.13 while the overall productive efficiency was 1.88. The average change in technology was considerably lower than the overall productive efficiency implying that the countries examined still had low technology change. For example low adoption of technology has been noted for countries such as Ghana, Madagascar, Mozambique, Zambia and Tanzania where poor technological capability and adoption among farmers has been cited as one of the reasons for low agricultural productivity (Akudugu et al. 2012; Lall and Pietrobelli 2002; Odhiambo et al. 2004). In terms of growth rate the results reveal an increase in TFP by 0.85%, a 1% change in technology and an overall productive efficiency change of -0.15%. Over the same period the technical efficiency and residual mix efficiency changed by 0.01% and 0.85% respectively while the mix, residual scale and scale mix efficiencies declined by 0.23 %, 0.02% and 0.25% respectively;. Scale efficiency showed no growth. The change in TFP is shown to emanate from countries striving to reach the production frontier and from improved change in technical efficiency rather than growth in overall productive efficiency change.

Examining the change in inputs over time as shown in Table 7 reveals that a decline in all input efficiencies except in pure technical efficiency (ITE) and residual rise in scale efficiency (RISE). The most pronounced decline was observed in input scale mix efficiency (ISME) indicating a failure to combine appropriate mix of inputs and scale in order to achieve optimal input usage. This scenario is common in SSA where failures in agricultural input markets have been noted as a major constraint to productivity growth. Druilhe and Barreiro-Hurlé (2012), point out that farmers particularly in SSA who typically face high fertilizer prices, poor output price incentives and poor access to credit are subject to inefficiency in input usage. Studies have indicated that even those few farmers who apply inorganic fertilizers do not use the recommended rates due to the high cost and unavailability of such fertilizers (Shekania and Mwangi 1996). Thus important policy implication is that that improving access to improved and affordable technology such as improved seed and inorganic fertilizers is a vital step in TFP growth in SSA.

Table 6: Summary of TFP change and its components: 1980-2007

Year	dTFP	dTech	dTFPE	dOTE	dOSE	dOME	dROSE	dOSME
1980	1.93	1.00	1.93	0.91	0.93	0.91	2.33	2.12
1981	1.93	0.92	2.10	0.89	0.95	0.94	2.52	2.36
1982	1.96	1.01	1.94	0.89	0.95	0.93	2.35	2.19
1983	1.95	1.05	1.85	0.90	0.95	0.93	2.19	2.04
1984	1.93	1.05	1.84	0.94	0.94	0.93	2.12	1.97
1985	1.93	1.05	1.83	0.94	0.94	0.94	2.09	1.95
1986	1.98	1.12	1.76	0.93	0.92	0.94	2.03	1.90
1987	1.98	1.19	1.66	0.91	0.93	0.93	1.98	1.84
1988	2.02	1.26	1.61	0.94	0.95	0.92	1.87	1.71
1989	2.03	1.23	1.66	0.94	0.95	0.93	1.90	1.77
1990	2.03	1.17	1.73	0.94	0.96	0.91	2.02	1.84
1991	2.04	1.14	1.79	0.93	0.92	0.92	2.10	1.94
1992	2.03	1.09	1.86	0.91	0.95	0.93	2.19	2.04
1993	2.06	1.04	1.98	0.95	0.95	0.91	2.29	2.09
1994	2.04	1.01	2.01	0.92	0.95	0.93	2.33	2.18
1995	2.11	1.00	2.12	0.93	0.94	0.96	2.37	2.27
1996	2.15	0.98	2.19	0.95	0.94	0.93	2.49	2.32
1997	2.16	1.00	2.16	0.92	0.94	0.94	2.49	2.34
1998	2.18	1.07	2.05	0.93	0.93	0.92	2.40	2.21
1999	2.27	1.14	1.98	0.93	0.94	0.90	2.35	2.12
2000	2.26	1.18	1.92	0.92	0.96	0.92	2.25	2.08
2001	2.29	1.22	1.88	0.90	0.95	0.91	2.28	2.09
2002	2.28	1.26	1.81	0.87	0.95	0.92	2.27	2.09
2003	2.30	1.30	1.77	0.84	0.96	0.94	2.22	2.10
2004	2.33	1.31	1.79	0.89	0.97	0.91	2.22	2.02
2005	2.40	1.33	1.81	0.93	0.93	0.89	2.18	1.94
2006	2.38	1.31	1.83	0.89	0.95	0.88	2.34	2.06
2007	2.44	1.32	1.85	0.94	0.93	0.85	2.31	1.97
Geomean	2.11	1.13	1.88	0.92	0.94	0.92	2.23	2.05
Growth (%)	0.85	1.00	-0.15	0.10	0.00	-0.23	-0.02	-0.25

Source: author's calculation from Färe-Primont indexes estimates

Note: dTFP = total factor productivity change; dTFPE = total factor productivity efficiency change; dOTE = output technical efficiency change; dOSE = output scale efficiency change; dOME = output mix efficiency change; dROSE = residual output scale efficiency change; dOSME = output scale mix efficiency change and dRME = residual mix efficiency change. These definitions apply in preceding tables.

Table 7: Change in inputs: 1980-2007

Year	dITE	dISE	dIME	dRISE	dISME	dRME
1980	0.90	0.95	1.46	1.47	2.15	2.27
1981	0.87	0.96	1.51	1.59	2.40	2.50
1982	0.87	0.97	1.48	1.50	2.22	2.30
1983	0.89	0.96	1.44	1.44	2.08	2.16
1984	0.92	0.95	1.38	1.44	1.99	2.10
1985	0.93	0.94	1.36	1.45	1.96	2.08
1986	0.91	0.94	1.38	1.40	1.94	2.06
1987	0.89	0.94	1.39	1.34	1.86	1.98
1988	0.94	0.96	1.31	1.31	1.72	1.80
1989	0.93	0.95	1.32	1.34	1.77	1.87
1990	0.94	0.96	1.32	1.39	1.84	1.91
1991	0.90	0.95	1.39	1.43	1.99	2.10
1992	0.90	0.96	1.36	1.52	2.06	2.14
1993	0.94	0.96	1.32	1.59	2.09	2.19
1994	0.91	0.96	1.33	1.66	2.20	2.30
1995	0.93	0.94	1.39	1.64	2.28	2.42
1996	0.94	0.94	1.39	1.67	2.32	2.47
1997	0.91	0.95	1.41	1.67	2.37	2.49
1998	0.92	0.94	1.37	1.63	2.23	2.37
1999	0.93	0.94	1.32	1.61	2.13	2.25
2000	0.92	0.96	1.31	1.59	2.09	2.17
2001	0.90	0.95	1.33	1.57	2.09	2.19
2002	0.87	0.95	1.35	1.55	2.09	2.19
2003	0.85	0.95	1.34	1.54	2.08	2.18
2004	0.88	0.97	1.28	1.58	2.02	2.08
2005	0.93	0.93	1.19	1.62	1.93	2.08
2006	0.89	0.95	1.26	1.64	2.06	2.17
2007	0.94	0.93	1.21	1.63	1.97	2.12
Geomean	0.91	0.95	1.35	1.53	2.06	2.17
Growth (%)	0.16	-0.07	-0.67	0.36	-0.31	-0.24

Source: author’s calculation from Färe-Primont Indexes estimates

Note: dITE = input technical efficiency; dISE = input scale efficiency; dIME = input mix efficiency; dRISE = residual input scale efficiency and dISME = input scale mix efficiency. These definitions apply in preceding tables.

4.3 TFP change and its components by country

Examining TFP change of individual countries (Table 8) reveals that Kenya had the highest TFP change of 4.54 and an overall productive efficiency change of 4.03 while Burundi experienced the lowest TFP change of 0.66 and overall productive efficiency change of 0.59. Technical efficiency change varied across countries with most countries experiencing a maximum change of 1.00 while Zambia had the lowest change of 0.48. Twelve countries experienced maximum scale efficiency change while Togo (0.67) experienced the highest regress. OME change was at maximum (1.00) in a majority of countries and lowest in Mozambique (0.51). Most countries experienced positive change in ROSE and OSME; Kenya had the highest score of 4.03 in both ROSE and OSME while Burundi had the lowest score of 0.59 for both.

From the results it is apparent that countries with high TFP growth change also had high efficiency change and its components. The high TFP growth change has been attributed to particular decisions taken by some of these countries. For example agricultural development efforts in Tunisia since the 1980's placed heavy emphasis on the promotion of public and private investments in agriculture, the performance of the agricultural marketing system, the use of technology and the effectiveness of the agricultural extension service practices which seem to have sustained and enhanced productivity (Aoun 2004). Kenya being a coastal country, has had more favorable agricultural conditions allowing it to develop as a major exporter. Furthermore the country has a more established agro-processing and other complimentary manufacturing sectors (Diao et al. 2010). Countries such as Niger, Libya and Madagascar although experience less favorable agro ecological conditions characterized by poor/low rainfall and poor terrain (Diao et al. 2007), they had a high TFPE indicating a greater ability to respond to the unfavorable weather conditions when compared to countries with favorable coastal climates such as Ghana, Mozambique and Malawi.

Malawi for example had low technical, scale and output mix efficiency changes meaning that the country had gaps in getting to the frontier, operating at optimal scale and achieving an optimal combinations of outputs. This is very true of the country since it is widely a maize producer and during the 1980s and early 1990s, agricultural credit, input and extension policies were targeted at disseminating a fixed input package of hybrid maize and fertilizer to small-holder farmers at subsidized rates while ignoring other key crops such as cotton (Zeller et al. 1998). On the other hand Mozambique's low change in TFP and associated efficiencies can be attributed to both the civil war which destroyed its research infrastructure and reduced livestock stock and to the country's poor access to animal traction and improved technologies such as inorganic fertilizers (Guanziroli and Frischtak 2011). Gambia's low TFP, TFPE, scale and OME efficiency change provides evidence of sub optimal overall productive efficiency, scale of economies and mix of outputs. The literature indicates that low levels of efficiency are allocative which are attributed to imperfections in the labor and capital markets (Chavas et al. 2005).

It is noted that countries that had low output inefficiencies also had a corresponding low input efficiency (see Table 9). One common characteristic of Malawi and Zambia is that they widely used the subsidization programme which has never been efficient. Overall none of the countries surveyed had an appropriate mix of inputs except Nigeria and the former territory of Sudan. This is reflected in low RISE and ISME for most countries the lowest being that of Burundi.

Table 8: Mean TFP output change and its components: by country

Country	dTFP	dTFPE	dOTE	dOSE	dOME	dROSE	dOSME	dRME
Burundi	0.66	0.59	1.00	1.00	1.00	0.59	0.59	0.59
Cameroon	3.43	3.04	1.00	1.00	1.00	3.04	3.04	3.04
Côte d'Ivoire	2.92	2.59	1.00	1.00	0.87	2.97	2.59	2.59
Gabon	3.04	2.69	1.00	1.00	1.00	2.69	2.69	2.69
Gambia	1.23	1.09	1.00	0.73	1.00	1.09	1.09	1.51
Ghana	1.18	1.04	0.92	1.00	0.74	1.53	1.14	1.15
Kenya	4.54	4.03	1.00	1.00	1.00	4.03	4.03	4.03
Libya	2.82	2.50	1.00	1.00	1.00	2.50	2.50	2.50
Madagascar	2.79	2.47	1.00	0.99	1.00	2.47	2.47	2.50
Malawi	0.92	0.82	0.76	0.97	0.69	1.55	1.07	1.10
Mozambique	0.68	0.60	0.61	0.78	0.51	1.92	0.99	1.27
Niger	3.60	3.19	1.00	1.00	1.00	3.19	3.19	3.19
Nigeria	3.82	3.39	1.00	1.00	1.00	3.39	3.39	3.39
Sudan (former)	3.86	3.42	1.00	1.00	1.00	3.42	3.42	3.42
Togo	1.44	1.28	1.00	0.67	1.00	1.28	1.28	1.90
Tunisia	3.65	3.24	1.00	1.00	1.00	3.24	3.24	3.24
Tanzania	2.04	1.81	1.00	0.99	1.00	1.81	1.81	1.83
Zambia	1.93	1.71	0.48	0.99	0.97	3.65	3.55	3.61

Source: author's calculation from Färe-Primont output indexes estimates;

Table 9: Mean input change across countries

Country	ITE	ISE	IME	RISE	ISME
Burundi	1.00	1.00	0.75	0.78	0.59
Cameroon	1.00	1.00	1.65	1.84	3.04
Côte d'Ivoire	1.00	1.00	1.79	1.45	2.59
Gabon	1.00	1.00	1.94	1.39	2.69
Gambia	1.00	0.73	1.92	0.57	1.09
Ghana	0.92	1.00	0.77	1.48	1.14
Kenya	1.00	1.00	1.90	2.12	4.03
Libya	1.00	1.00	1.30	1.92	2.50
Madagascar	1.00	0.99	1.24	1.99	2.47
Malawi	0.75	0.99	0.88	1.24	1.09
Mozambique	0.55	0.87	0.66	1.68	1.10
Niger	1.00	1.00	1.56	2.04	3.19
Nigeria	1.00	1.00	1.96	1.73	3.39
Sudan (former)	1.00	1.00	1.95	1.76	3.42
Togo	1.00	0.67	1.16	1.10	1.28
Tunisia	1.00	1.00	1.70	1.90	3.24
Tanzania	1.00	0.99	0.93	1.94	1.81
Zambia	0.49	0.97	1.83	1.92	3.52

Source: author's calculation from Färe-Primont output levels estimates

4.4 Comparison of mean annual TFP and growth by country and over time

A direct comparison of country TFP over the years 1980-1989; 1990-1999; 2000-2007 and 1980 to 2007 is provided in Table 10. From the results Kenya is shown to have the highest TFP in 1980 with a score of 0.43 while Mozambique had the lowest with a score of 0.06 in the same year. The change in productivity between these two countries was (0.43/0.06=7.17) indicating that Kenya was seven times more productive than Mozambique in 1980. This is reflected in the fact that Kenya has continued to sustain a steady long term growth in agricultural TFP since the 1960s with its TFP increasing by 78% between 1960 and 2008 (Fuglie et al. 2012).

Examining the mean TFP change and its components indicates that, except for Burundi (-0.14%), Gambia (-0.21%), Madagascar (-0.02%), Malawi (-0.01%), Niger (-0.18%), former territory of Sudan (-0.04%) and Zambia (-0.11%) all of which had a decline in TFP in the 1980s, other counties had an increase in TFP with the highest increase realized by Tunisia (0.35%). The decline in the countries listed here may have been due to civil wars which have typically caused a diversion of public resources and discouraged foreign investments. This can be observed in countries such as Sri Lanka (Kumar et al. 2008). Secondly, bad weather including periodic droughts may have hampered agricultural production in these countries as shown in Table 4. In the 1990s most countries had registered a positive change in TFP except Burundi (-0.18%), Gambia (-0.1%), Ghana (0.09%), Kenya (-0.12%) and Madagascar (-0.13%). The decline in these countries in the 1990's is correlated with periods of civil unrest or microeconomic mismanagement experienced especially by Burundi, Gambia and Madagascar (Fuglie et al. 2012). In the 1990s Kenya experienced four major drought periods that may have affected production. On the other hand the country was going through political unrest caused by the multi-party political struggle hence the extent of the decline in productivity in agriculture (Kimuyu 2005). In the 2000s all countries experienced a positive change in TFP except Gabon, Gambia, Ghana, Madagascar and Mozambique which had declines of 0.01%, 0.03%, 0.04%, 0.11% and 0.13% respectively. Comparing 1980 and 2007 reveals an increase in TFP for all countries except Burundi, Gambia, Ghana and Madagascar which had declines of 0.49%, 0.36%, 0.03% and 0.28% respectively. The consistent decline in TFP in these countries may be due to the effect of civil war other than Ghana noted for its low technology capability.

Table 11 examines average growth rates of TFP change and its components revealing that all the countries have experienced positive TFP growth over the twenty (28) years with Nigeria experiencing the highest growth of 2.31%. The high growth by Nigeria is attributed to change in technical efficiency and high OSME and RME. This corroborates the findings of Eboh et al. (2012) who found that Nigeria's growth in agricultural output has been mainly due to expansion of cultivated land.

Growth in efficiency change varied across countries with almost all the countries experiencing positive change except for Burundi, Gambia, Ghana, Kenya, Madagascar, Niger and Zambia which experienced declines of 3.39%, 2.60%, 1.1%, 0.01%, 2.15%, 0.07% and 0.61% respectively. In terms of scale efficiency change except for Ghana and Zambia which suffered a decline, Malawi and Mozambique registered positive values and the rest of the countries there was no change. In relation to mix efficiency, Gambia (0.92%) and Togo (0.48%) had negative growth while Malawi, Mozambique and Tanzania had positive values with no change for other countries. For residual scale efficiency Ghana (0.85%), Malawi (1.38%) and Mozambique (1.84%) experienced negative growth while the rest had no change. The growth in scale mix efficiency and residual mix efficiency change declined in Burundi, Gambia, Ghana, Kenya, Madagascar and Niger by 3.39%, 2.60%, 1.1%, 0.01%, 2.15% and 0.07% respectively while the rest had positive change. No change in input technical efficiency change is recorded (see Table 12) except for Ghana and Zambia both of which had negative growth of 0.95% and 0.99% respectively and for Malawi and Mozambique which had positive growth of 1.16% and 3.66% respectively. The change in scale efficiency was positive particularly for countries which subsidized their inputs such as Ghana, Malawi, Tanzania and Zambia. On the other hand input mix efficiency for most countries exhibited negative growth except Gabon, Libya, Tunisia and Zambia. This provides an indication that many countries have not been able to balance the combination of inputs correctly hence have negative growth. At the same time almost half the countries do not have the right mix of scale of operations and mix of inputs as indicated by the negative growth in scale mix efficiency. Thus policies that would encourage the appropriate combination of inputs and scale would address the productivity lag in these countries.

Table 10: Direct comparison of mean TFP: by country and time

Country	1980	1989	Change	1990	1999	Change	2000	2007	Change	Overall Change
Burundi	0.10	0.09	-0.14	0.08	0.06	-0.18	0.05	0.05	0.00	-0.49
Cameroon	0.28	0.36	0.29	0.36	0.39	0.07	0.38	0.45	0.18	0.64
Côte d'Ivoire	0.26	0.28	0.08	0.29	0.29	0.02	0.31	0.36	0.17	0.37
Gabon	0.26	0.29	0.11	0.30	0.36	0.19	0.36	0.35	-0.01	0.34
Gambia	0.17	0.13	-0.21	0.12	0.11	-0.10	0.11	0.11	-0.03	-0.36
Ghana	0.12	0.13	0.06	0.12	0.11	-0.09	0.12	0.11	-0.04	-0.03
Kenya	0.43	0.53	0.23	0.50	0.44	-0.12	0.42	0.57	0.35	0.32
Libya	0.23	0.27	0.16	0.26	0.34	0.29	0.34	0.40	0.18	0.71
Madagascar	0.33	0.32	-0.02	0.32	0.28	-0.13	0.26	0.24	-0.11	-0.28
Malawi	0.09	0.09	-0.01	0.09	0.09	0.11	0.11	0.12	0.16	0.39
Mozambique	0.06	0.06	0.01	0.05	0.10	0.86	0.10	0.08	-0.13	0.38
Niger	0.38	0.31	-0.18	0.32	0.41	0.28	0.43	0.49	0.13	0.30
Nigeria	0.30	0.32	0.08	0.33	0.47	0.45	0.46	0.57	0.23	0.91
Sudan (former)	0.33	0.32	-0.04	0.33	0.47	0.42	0.49	0.55	0.11	0.65
Togo	0.11	0.15	0.35	0.16	0.16	0.01	0.17	0.20	0.18	0.76
Tunisia	0.24	0.34	0.44	0.35	0.49	0.40	0.51	0.51	0.02	1.17
Tanzania	0.18	0.21	0.15	0.21	0.22	0.08	0.21	0.25	0.18	0.36
Zambia	0.19	0.17	-0.11	0.21	0.21	0.02	0.21	0.22	0.03	0.11

Source: author's calculation from Färe-Primont output levels estimates

Table 11: TFP output growth rate (%) and its components: by country

Country	dTFP	dOTE	dOSE	dOME	ROSE	OSME	dRME
Burundi	-2.39	-3.39	0.00	0.00	0.00	-3.39	-3.39
Cameroon	1.76	0.77	0.00	0.00	0.00	0.77	0.77
Côte d'Ivoire	1.13	0.13	0.00	0.00	0.00	0.13	0.13
Gabon	1.04	0.04	0.00	0.00	0.00	0.04	0.04
Gambia	-1.60	-2.60	0.00	-0.92	0.00	-2.60	-2.60
Ghana	-0.10	-1.10	-1.00	0.17	-0.85	0.74	-0.10
Kenya	0.99	-0.01	0.00	0.00	0.00	-0.01	-0.01
Libya	1.92	0.92	0.00	0.00	0.00	0.92	0.92
Madagascar	-1.15	-2.15	0.00	0.00	0.00	-2.15	-2.15
Malawi	1.18	0.19	0.84	0.34	-1.38	0.73	-0.65
Mozambique	1.15	0.15	2.89	0.33	-1.84	-0.89	-2.73
Niger	0.93	-0.07	0.00	0.00	0.00	-0.07	-0.07
Nigeria	2.31	1.31	0.00	0.00	0.00	1.31	1.31
Sudan (former)	1.78	0.79	0.00	0.00	0.00	0.79	0.79
Togo	2.03	1.03	0.00	-0.48	0.00	1.03	1.03
Tunisia	2.77	1.78	0.00	0.00	0.00	1.78	1.78
Tanzania	1.11	0.11	0.00	0.49	0.00	0.11	0.11
Zambia	0.39	-0.61	-0.98	0.01	-0.05	0.42	0.37

Source: author’s calculation from Färe-Primont output levels estimates

Table 12: Mean input growth rate (%) across countries: 1980-2007

Country	dITE	dISE	dIME	dRISE	dISME
Burundi	0.00	0.00	-2.75	-0.64	-3.39
Cameroon	0.00	0.00	-0.07	0.84	0.77
Côte d'Ivoire	0.00	0.00	-0.79	0.92	0.13
Gabon	0.00	0.00	0.22	-0.18	0.04
Gambia	0.00	-0.92	-0.54	-2.06	-2.60
Ghana	-0.95	0.12	-0.13	-0.03	-0.15
Kenya	0.00	0.00	0.00	-0.01	-0.01
Libya	0.00	0.00	0.69	0.23	0.92
Madagascar	0.00	0.00	-2.33	0.18	-2.15
Malawi	1.16	0.02	-1.61	0.64	-0.97
Mozambique	3.66	-0.44	-4.52	1.02	-3.51
Niger	0.00	0.00	-0.10	0.04	-0.07
Nigeria	0.00	0.00	0.00	1.31	1.31
Sudan (former)	0.00	0.00	0.00	0.79	0.79
Togo	0.00	-0.48	-0.92	1.95	1.03
Tunisia	0.00	0.00	0.90	0.88	1.78
Tanzania	0.00	0.49	-0.50	0.61	0.11
Zambia	-0.99	0.03	0.36	0.02	0.38

Source: author’s calculation from Färe-Primont output levels estimates

4.5 Determinants of Efficiency

One of the major drawbacks of using DEA is its inability to provide tests of the significance of the input or output variables included in the model. To counter this drawback the bootstrap method was applied to provide a more robust non-parametric estimate of the confidence intervals for each country efficiency score. The estimated coefficients for the DEA double bootstrap are presented in the Table 13. The sign of the variables in the inefficiency model is important in explaining the observed level of TE of the surveyed countries. A negative sign implies that the variable has the effect of reducing technical inefficiency, while a positive coefficient has the effect of increasing inefficiency. It is observed that the results exhibit significance in all the variables except the rainfall variable. The coefficient of labor ratio was positive and statistically significant at 5% and 1% which indicates an increase in labor raises inefficiency as the excess labor may not be utilized well. This is not surprising considering that labor productivity in developing countries is normally low compared to developed countries. The decline in labor in developed countries is compensated by a shift to more intensive technologies such as increased use of fertilizer, manure and high yielding varieties which increases production (Okike 2001). However this is not the case for SSA where labor is still highly intensive and uptake of technology such as mechanization is still low. Deaton (1999), argues that the real prices for primary commodities which can have an effect on growth will not change as long as there is unlimited supply of labor at the level of subsistence wage and which will eventually fall in response to (local) technical progress.

The coefficient of the area under irrigation was negative and statistically significant at 1 % and 5%, an indication that when the area under irrigation increases inefficiency decreases. Irrigation is identified as a factor that not only influences technical efficiency but is also a measure of technical progress (Chen et al. 2008).

The coefficient of political instability was positive and statistically significant at 5% and 1% indicating that when political instability increases so does inefficiency. Many countries in Africa have experienced political instability and hence there is little reduction in inefficiency in the Agricultural sector. As noted by Kimuyu (2005) socioeconomic and political uncertainties have tended to increase discount factors, discouraging long term decision making in many African countries.

The coefficient of rainfall was negative and statistically significant at 5% and 1% indicating that an increase in average rainfall increases inefficiency. Agriculture in Africa is mainly dependent on rainfall and different crops have different rainfall requirements. Most African regions have erratic weather conditions hence an increase in rainfall frequently leads to flooding. An important policy implication is the need for putting in place policies which improve rainfall use efficiency in rain-fed agricultural systems. Such measures should be aimed at decreasing water losses by soil evaporation, runoff, through-flow, deep drainage or competing weeds all of which make more water available for crop use (Turner 2004). Further, investment should be directed towards minimizing the potential damage from natural disasters such as flood control, better adaptation skills or drought resistant seeds in the areas susceptible to natural disasters (Wu et al. 2001).

The positive coefficient of tractors did not have the expected sign, a statistical significance of 5% indicated an increase in tractors would increase inefficiency. The possible explanation is that land in African is becoming highly fragmented hence the use of tractors does not generally increase efficiency. Further there is a very low utilization of tractors in Africa.

The positive coefficient of land per capita indicates that an increase in land raises inefficiency which is consistent with studies that have found a strong negative correlation between farm size on the one side, and factor inputs and yields per hectare on the other (Cornia 1985).

Table 13: Determinants of efficiency

Variable	theta2	BBlow05	BBup05	BBlow01	BBup01
Constant	-22.7903**	-23.7305	-20.4994	-26.8082	-20.0078
Labor ratio	19.5982**	19.59823	44.25395	19.59823	46.06218
Irrigation area	-6.4E-06**	-1.2E-05	-6.4E-06	-1.2E-05	-6.4E-06
Political instability	5.53327**	3.181669	7.530906	2.300251	8.89901
Rainfall	0.00123**	0.000469	0.001714	9.37E-05	0.001976
Tractors	3.63E-05*	3.29E-06	3.63E-05	-3.3E-06	5.34E-05
Per capita land	0.057039*	0.026822	0.09974	-0.00542	0.102921
Sigma Sq	8.67722**	6.230205	10.38265	4.361214	11.89806

Note: asterisks * and ** indicate significance at 5% and 1% confidence intervals respectively. The total number of iterations = 2000. A negative sign for parameters indicates the associated variable has a positive effect on technical efficiency, and vice versa.

4.6 Determinants of TFP

Using a Tobit model to estimate the determinant, TFP change was regressed against the following attributes: labor ratio, total area under irrigation, governance, rainfall, tractors and per capital land. The results are presented in Table 14. A positive coefficient implies a positive association with TFP while the reverse implies a negative association. All the coefficients were found to be significant. The coefficient of labor ratio was found to be negative and significant at 1% indicating growth in labor has a negative growth on TFP. Although a high labor ratio is known to yield an increase in TFP and output growth in the long-run (Izmirlioglu 2008) the growth in labor needs to be supported by a corresponding adoption of technologies in order to increase labor productivity. Growth in labor also implies freeing more labor to other productive sectors of the economy due to migration from rural to urban areas. However this is not the case in SSA where in a majority of countries livelihoods depend almost entirely on smallholder agriculture. Furthermore in these countries growth in manufacturing and agriculture has typically been low the two sectors that have the potential to enhance productivity growth compared to the service industry whose impact is difficult to quantify (Atolia 2008).

The coefficient of the amount of land under irrigation was significant at 1% and positively associated with TFP indicating an increase in area under irrigation increases TFP. Irrigation is a proxy of land quality hence it shows that an improvement in land quality enhances TFP.

The governance proxy was negative and significant at 1% indicating political instability is negatively associated with TFP growth.

Rainfall variable was significant at 1% and negatively associated with TFP growth, although the coefficient did not have the expected sign. The possible explanation is that African agriculture heavily depends on rainfall and given the inadequacy/uneven distribution of rainfall coupled with the effects of climate change experienced by many countries across the region, these factors are having a negative impact on the agricultural system (AGRA 2014). From the analysis of this results it is clear that in many countries when there was drought or flooding a corresponding drop in TFP was observed.

The coefficient for the variable tractors was negative and statistically significant and again did not have the expected sign.

Per capita land is negative and statistically significant at 1% indicating that an increase in land size reduced TFP growth. The reason is that the traditional African system of communal land tenure prevalent in many countries has been shown empirically to be inefficient particularly where land has scarcity value (Barrows and Roth 1990).

Table 14: Summary results of determinants of TFP

Variable	Coefficient	Std error	t-ratio
Constant	0.55293**	0.0278	19.86
Labor ratio	-0.35582**	0.0291	-12.25
Irrigation	0.1288D-06**	0.176D-07	7.30
Political instability	-0.04885**	0.0112	-4.35
Rainfall	-0.5112D-04**	0.1223D-04	-4.18
Tractors	-0.5979D-06**	0.2292D-06	-2.61
Per capita land	-0.00148**	0.0002	-6.29
Sigma	0.10903**	0.0034	31.749

Source: Limdep Estimates

Note: asterisks * and ** indicate significance at 5% and 1% confidence intervals respectively. A positive parameter sign indicates the associated variable has a positive effect on TFP and vice versa.

5. Summary and conclusion

The average annual TFP output value for all the eighteen (18) countries for the period 1980 to 2007 was 0.22. The maximum TFP (TFP*) given the technology for the same period was 0.48, while the technical factor productivity efficiency (TFPE) was 0.45. The pure technical efficiency estimate was 0.92, while scale efficiency was 0.94. The average output mix efficiency was 0.92 while residual scale, scale mix efficiency and residual mix efficiency were 0.54, 0.49 and 0.52 respectively. The output mix efficiency varied over the said period with a maximum of 0.96 and a low of 0.85; the low values of between 0.85 and 0.89 corresponded with the years of natural disasters especially floods, droughts or epidemics phenomenon that were experienced by many countries (see Table 4). The low residual scale, mix and residual mix efficiencies imply that the countries are not at the point of maximum productivity even though they appear to be approaching technically, scale and/or mix efficiency in their use of inputs.

Examining the average input efficiencies for the said period, as shown in Table 3, input technical efficiency was 0.91 and the input scale efficiency 0.95. The input mix efficiency was 0.69, the residual input scale efficiency 0.72 and the input scale mix efficiency 0.50. The average input mix efficiency ranged from 0.61 to 0.77 with the lowest score corresponding to the years of flooding or low rainfall years (see Table 4). This indicates difficulties were experienced in adjusting the input mixes to correspond with the changing production system. That is, since most crop inputs are applied at the beginning of the planting season there is limited flexibility to adjust with change in the weather patterns. The scale efficiency is noticeably higher than the other efficiencies. This is consistent with the findings of Thirtle et al. (1993) who show that TFP growth in many countries was largely driven by land expansion especially in the 1980s. This involved moving input resources such as fertilizer and improved varieties into more profitable crops and products for which prices had risen in recent years. TFP growth did not come from growth through technological change. Many countries during this period such as Nigeria, Ghana, Cameroon, Malawi and Kenya heavily subsidized their farmers to produce crops for exports such as coffee by providing added inputs. Hence the increase in output without necessarily an increase in TFP.

From these results it is evident that the overall technical efficiencies of both inputs and output are relatively high indicating that the eighteen African countries are doing well in these areas. However the variations that are apparent are shown to be due to differences in technical factor productivity and the mix efficiencies i.e. the output residual scale and scale mix efficiencies and all input mix efficiencies. This indicates that the discrepancy between TFP and the frontier TFP is in large part due to technical factor productivity efficiency driven by lower levels of output residual scale, mix and residual mix efficiencies. Thus while such countries have been able to maintain scale of operations (scale) and mix of products (mix), they have not been able to maintain technical efficiency change (being close to the frontier). Nor have these countries been able to derive economies of scale and scope and input-output mixes (scale mix efficiency) in their production processes thereby restricting the potential productivity growth.

From this study it is equally that TFP of agriculture in many African countries has been driven by efficiency change due to land expansion and increased use of inputs rather than from technical change. This is an important implication since expansion of land in the long run will no longer feasible especially in SSA where farm size is shrinking rapidly. However as much as the role of efficiency in productivity growth is being overtaken by technical change it is noted that in countries such as Zambia low efficiency is still experienced despite extensive in input distribution. The generally low scale mix efficiency in SSA countries also reveals an inability to balance optimally economies of scale and scope and input-output mixes in their production process. Policies that would improve the establishment of land quality through creation of irrigation facilities would therefore improve TFP. Improvement in political stability has also been identified as key to improvement in TFP.

Due to erratic weather conditions in many African countries, long run productivity improvement policies also need to be channeled towards strengthening of water resources including through conservation and harvesting of flood and rain water of labor productivity through more efficient use will also help raise productivity. Land intensification rather than expansion is equally a key to improving productivity through use of improved varieties of seed or livestock breeds and use of high quality inputs such as inorganic fertilizers.

6.0 References

AGRA (2014), 'Africa agriculture status report 2014: Climate change and smallholder agriculture in Sub-Saharan Africa', (Nairobi, Kenya).

Akudugu, Mamudu Abunga, Guo, Emelia, and Dadzie, Samuel Kwesi (2012), 'Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions?', *Journal of Biology, Agriculture and Healthcare,* 2 (3), 1-13.

Anonymous 'FAOSTAT 2013. http://faostat.fao.org/site/291/default.aspx'.

Aoun, A (2004), 'The performance of Tunisian Agriculture: an economic appraisal', *NEW MEDIT.,* 3, 4-7.

Atolia, Manoj (2008), 'Productivity-Enhancing Reforms, Private Capital Inflows, and Real Interest Rates in Africa', *Available at SSRN 1322170*.

Baiphethi, Mompati N and Jacobs, Peter T (2009), 'The contribution of subsistence farming to food security in South Africa', *Agrekon,* 48 (4), 459-82.

Barrows, Richard and Roth, Michael (1990), 'Land tenure and investment in African agriculture: Theory and evidence', *The Journal of Modern African Studies,* 28 (02), 265-97.

Chavas, Jean-Paul, Petrie, Ragan, and Roth, Michael (2005), 'Farm Household Production Efficiency: Evidence from The Gambia', *American Journal of Agricultural Economics,* 87 (1), 160-79.

Chen, Po-Chi, et al. (2008), 'Total factor productivity growth in China's agricultural sector', *China Economic Review,* 19 (4), 580-93.

Coelli, T. J. (1995), 'Recent developments in frontier modelling and efficiency measurement', *Australian Journal of Agricultural Economics,* 39 (3), 219-45.

--- (1996), 'Measurement of total factor productivity growth and biases in technological change in Western Australian agriculture', *Journal of Applied Econometrics,* 11 (1), 77-91.

Coelli, T. J. and Rao, D. S. Prasada (2005), 'Total factor productivity growth in agriculture: a Malmquist index analysis of 93 countries, 1980–2000', *Agricultural Economics,* 32, 115-34.

Comin, Diego (2006), 'Total factor productivity', *An Eponymous Dictionary of Economics. Elgar Publishers, Ltd*.

Cornia, Giovanni Andrea (1985), 'Farm size, land yields and the agricultural production function: An analysis for fifteen developing countries', *World Development,* 13 (4), 513-34.

Deaton, Angus (1999), 'Commodity prices and growth in Africa', *The Journal of Economic Perspectives,* 23-40.

Dercon, Stefan and Christiaensen, Luc (2011), 'Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia', *Journal of Development Economics,* 96 (2), 159-73.

Diao, Xinshen, Hazell, Peter, and Thurlow, James (2010), 'The role of agriculture in African development', *World Development,* 38 (10), 1375-83.

Diao, Xinshen, et al. (2007), *The role of agriculture in development: Implications for Sub-Saharan Africa* (153: Intl Food Policy Res Inst).

Druilhe, Zoé and Barreiro-Hurlé, Jesús (2012), 'Fertilizer subsidies in sub-Saharan Africa', (ESA Working paper).

Eboh, Eric, Oduh, Moses, and Ujah, Oliver (2012), 'Drivers and Sustainability of Agricultural Growth In Nigeria', *African Institute for Applied Economics Research Paper*, 8.

FAO (2012), 'Statistical Yearbook 2013: World Food and Agriculture', *FAO (Food and Agriculture Organziation of the United Nations), Rome*.

Fuglie, Keith Owen, Wang, Sun Ling, and Ball, V Eldon (2012), *Productivity growth in agriculture: an international perspective* (CABI).

Grifell-Tatjé, E. and Lovell, C. A. K. (1995), 'A note on the Malmquist productivity index', *Economics Letters*, 47 (2), 169-75.

Guanziroli, Carlos E. and Frischtak, Claudio (2011), 'Integrated productivity programme for agriculture in Mozambique: Final report', (The International Growth Centre, London School of Economic and Political Science, London).

IFPRI (2010), '2009 Annual Report'.

Irz, Xavier, et al. (2001), 'Agricultural Productivity Growth and Poverty Alleviation', *Development Policy Review*, 19 (4), 449-66.

Izmirlioglu, Yusuf (2008), 'The impact of population ageing on technological progress and TFP growth, with application to United States: 1950-2050'.

Jefferson, Philip N and O'Connell, Stephen A (2004), 'Rainfall shocks and economic performance in four African countries', *Worldwide Database on rainfall and drought severity, http://www. acad. swarthmore. edu/rain-econ/Framesets/HomePage. htm*.

Jin, Songqing, et al. (2010), 'Productivity, efficiency and technical change: measuring the performance of China's transforming agriculture', *Journal of Productivity Analysis*, 33 (3), 191-207.

Kimuyu, Peter (2005), 'Productivity performance in developing countries.', (Nairobi, Kenya: United Nations Industrial Development Organization (UNIDO)).

Kumar, Praduman, Mittal, Surabhi, and Hossain, Mahabub (2008), 'Agricultural growth accounting and total factor productivity in South Asia: A review and policy implications', *Agricultural Economics Research Review*, 21 (2), 145-72.

Lall, Sanjaya and Pietrobelli, Carlo (2002), *Failing to compete: Technology development and technology systems in Africa* (Edward Elgar Publishing).

Mallawaarachchi, Thilak, et al. (2009), 'Promoting productivity in the agriculture and food sector value chain: issues for R&D investment', *ABARE and BRS report to the Rural R&D Council, Canberra, December*.

Misselhorn, Alison, et al. (2012), 'A vision for attaining food security', *Current Opinion in Environmental Sustainability*, 4 (1), 7-17.

Mitchell, TD, et al. (2004), 'A comprehensive set of climate scenarios for Europe and the globe: the observed record (1900-2000) and 16 scenarios (2000-2100).(eds', *University of East Anglia*, 30.

Moir, Brian (2011), *Global food security: facts, issues and implications* (ABARES).

Mustapha, Nik Hashim Nik, Hashim, Nik Mohd Hazrul, and Yacob, Ridzuan (2013), 'Technical Components of Total Factor Productivity Growth in Malaysian Manufacturing Industry', *Applied Mathematics*, 4, 1251.

Nin Pratt, Alejandro and Yu, Bingxin (2008), 'An updated look at the recovery of agricultural productivity in sub-Saharan Africa', *International Food Policy Research Institute*.

O'Donnell, C. J. (2011), 'The sources of productivity change in the manufacturing sectors of the US economy', (School of Economics, University of Queensland, Australia).
--- (2012), 'Nonparametric estimates of the components of productivity and profitability change in US agriculture', *American Journal of Agricultural Economics*, aas023.
O'Donnell, C. J. (2010), 'Measuring and decomposing agricultural productivity and profitability change', *Australian Journal of Agricultural and Resource Economics*, 54 (4), 527-60.
Odhiambo, Walter, Nyangito, Hezron O, and Nzuma, Jonathan (2004), *Sources and determinants of agricultural growth and productivity in Kenya* (Kenya Institute for Public Policy Research and Analysis).
Okike, I (2001), *Agricultural intensification and efficiency in the West African savannahs: Evidence from northern Nigeria* (ILRI (aka ILCA and ILRAD)).
Place, Frank (2009), 'Land Tenure and Agricultural Productivity in Africa: A Comparative Analysis of the Economics Literature and Recent Policy Strategies and Reforms', *World Development*, 37 (8), 1326-36.
Pratt, Alejandro Nin and Yu, Bingxin (2008), *An updated look at the recovery of agricultural productivity in Sub-Saharan Africa* (Intl Food Policy Res Inst).
Rahman, Sanzidur and Salim, Ruhul (2013), 'Six decades of total factor productivity change and sources of growth in Bangladesh agriculture (1948–2008)', *Journal of Agricultural Economics*, 64 (2), 275-94.
Rao, D.S.P. (1993), 'Intercountry comparisons of agricultural output and productivity', (FAO, Rome.).
Shekania, B and Mwangi, WM (1996), *Adoption of recommended maize technologies in Mbeya Region of the southern highlands of Tanzania* (CIMMYT).
Simar, Léopold and Wilson, Paul W. (2007), 'Estimation and inference in two-stage, semi-parametric models of production processes', *Journal of Econometrics*, 136 (1), 31-64.
Thirtle, Colin, von Bach, Helmke Sartorius, and van Zyl, Johan (1993), 'Total factor productivity in South African agriculture, 1947 ‐ 91', *Development Southern Africa*, 10 (3), 301-18.
Thirtle, Colin, et al. (2003), 'Multi-factor agricultural productivity, efficiency and convergence in Botswana, 1981–1996', *Journal of Development Economics*, 71 (2), 605-24.
Tozer, Peter R and Villano, Renato (2013), 'Decomposing Productivity and Efficiency among Western Australian Grain Producers', *Journal of Agricultural and Resource Economics*, 38 (3), 312-26.
Turner, Neil C. (2004), 'Agronomic options for improving rainfall-use efficiency of crops in dryland farming systems', *Journal of Experimental Botany*, 55 (407), 2413-25.
UNEP (2013), 'Ecosystem-based approaches key to tackling challenge of African food security amidst changing climate.', (Nairobi, Kenya).
Van Biesebroeck, Johannes (2007), 'Robustness of productivity estimates', *The Journal of Industrial Economics*, 55 (3), 529-69.
Von Braun, Joachim, Hill, Ruth Elaine, and Pandya-Lorch, Rajul (2009), *The Poorest and Hungry: Assessments, Analyses, and Actions: an IFPRI 2020 Book* (Intl Food Policy Res Inst).
Von Grebmer, Klaus, et al. (2012), *2012 Global hunger index: the challenge of hunger: Ensuring sustainable food security under land, water, and energy stresses* (70: Intl Food Policy Res Inst).

Wu, Shunxiang, et al. (2001), 'Productivity growth and its components in Chinese agriculture after reforms', *Review of Development Economics,* 5 (3), 375-91.
Zeller, Manfred, Diagne, Aliou, and Mataya, Charles (1998), 'Market access by smallholder farmers in Malawi: implications for technology adoption, agricultural productivity and crop income', *Agricultural Economics,* 19 (1–2), 219-29.