Agricultural productivity growth, technical innovation and efficiency in Central Africa

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Abstract

This paper presents a comparative analysis of the trend and drivers of agricultural total factor productivity growth in countries of the Central African Economic and Monetary Community. Secondary data for Cameroon, Chad, Congo, and Gabon are gotten from the FAOSTAT database. Based on an aggregate quantity framework, we compute changes in agricultural productivity using the Färe-Primont productivity index, decomposing it into technical change, efficiency change, as well as several other measures of efficiency. Our results are line with prior studies in terms of the general trend of agricultural total factor productivity change in most African countries, but diverge in terms of the extent of estimates of average TFP growth (components), as well as in terms of the contributions of various components of TFP to TFP growth. We find evidence of agricultural productivity growth, technological progress, but efficiency declines, with strong distinctive patterns, in all four countries considered over the period 1980-2007. Both agricultural output and productivity growth was highest in Cameroon, with Chad strongly converging to Cameroon's level. Meanwhile, agricultural productivity stagnated in Gabon and Congo as high inefficiency attenuated prospects of growth in productivity that could have been triggered by technological innovation. Improvement in agricultural technologies was found to be the main driver of productivity growth in Central African agriculture, contrary to conventional wisdom that agricultural productivity growth in Africa is driven by efficiency growth.

Key words: Total factor productivity, Agricultural technology, Innovation, Structural transformation, Färe-Primont index, Efficiency, CEMAC

JEL codes: C43; O30; O47; O55; Q10

1 Introduction

Africa needs a green revolution. Increasing agricultural productivity in sub-Saharan Africa (SSA) is touted as one of the most effective means of simultaneously increasing food production and protecting the environment (Hourticq *et al.* 2013). This is crucial for most SSA countries where agricultural productivity (growth) has remained historically low and lagged behind all other regions of the world. A cliché has emerged that Africa has been bypassed by the green revolution that propelled agricultural and overall economic growth in Asia. This low performance is accompanied by marked spatial variation across the different countries (Fuglie 2011; Yu & Nin-Pratt 2011; Benin *et al.* 2011; Benin & Nin-Pratt 2016). While countries such as Egypt, Nigeria and South Africa feature among the top performers, countries of Central Africa severely lag behind. Africa's agricultural growth has nevertheless witnessed a rebound in recent years (Benin et al., 2011; Benin, 2016). Still, this recovery is largely attributed to catch-up with the agricultural growth levels recorded in the 1980's. In many instances, increase in agricultural output has been a result of increased farmed area and not due to more efficient farming practices (Dewbre & De Battisti 2007; Beintema & Stads 2017).

Countries of Central Africa remain the least performing in terms of agricultural total factor productivity (TFP) growth compared to all other sub-regions of Africa. Fuglie (2011) reports that while all the other sub-regions of Africa witnessed an overall positive average TFP growth between 1961 and 2008, Central Africa recorded a decline of 28% per year. In fact, apart from Cameroon that has enjoyed sustained growth in agricultural TFP since the sixties (except in the eighties) all other Central African countries fall in the 'no growth' category. Since the Maputo Declaration/CAADP of 2003, Central African countries have lagged behind in terms of the CAADP targets of 6% agricultural growth and the allocation of 10% of public spending to agriculture (Benin *et al*. 2011). Agricultural export earnings have severely deteriorated over the last two decades in the sub-region and Africa as a whole, with most of these countries winding up as net food importers (AfDB 2016).

Despite modest increase in agricultural research spending in SSA recorded after 2000, investments in agricultural research has been very low in most western and central African countries, estimated by Beintema and Stads (2017) to be less than 10m USD in 2014 (while Nigeria, South Africa and Kenya account for half of agricultural R&D investments made in 2014 in SSA). The latter further opine that despite significant empirical evidence on the productivity-enhancing effects of investment in agricultural innovations, arguably surpassing contributions from other forms of investments in agriculture (such as extension and training, subsidies, etc.), growth in public agricultural R&D spending in most Francophone African countries of Central and West Africa from 2000-2014 either stagnated or was negative[1], and below their agricultural output growth (far less than 1% of agricultural GDP). The well-developed literature on structural transformation pioneered by the works of Lewis (1954) shows how present-day high-income nations became industrialised thanks to improvements in their agricultural productivity, which led to a reduction in both agricultural share of GDP and in employment in agriculture. Barrett *et al.* (2017) re-present the conceptual framework or pathways linking improvements in agricultural productivity in Africa's agriculture that is required to induce economic progress, poverty reduction, and in turn reduce the environmental footprint of economic activities. Growth in agricultural productivity liberates excess labour hitherto employed in agriculture, and while agricultural output continues to increase significantly in absolute terms, its share in total gross domestic product (GDP) reduces, owing to more-than-proportionate increase in other output from other sectors of the economy.

[1] Mogues (2005) attributes the government underinvestment in agricultural R&D partly to the politically unprofitable nature of their returns which are mostly long-term.

Agriculture in Africa has been identified as pro-poor; the welfare impacts of agriculture are about twice the poverty reduction resulting from GDP growth induced by the non-agricultural sector (Ligon & Sadoulet 2007).

In spite of all these, the potential to increase agricultural productivity in the Congo Basin of Central Africa remains quite huge. The basin is one of the few areas in the world with the highest potentials of expanding production and increasing farm yields. Minimal interventions are sufficient to boost agricultural productivity while increasing resilience to climate risk. Central African countries have strong ability to unlock their agricultural potential in a sustainable manner (Hourticq *et al.* 2013; Megevand 2013) and increasing agricultural productivity is key to simultaneously achieving increased food availability and protecting the environment.

Increasing agricultural productivity in Africa has been underscored by the African Development Bank and development partners as one of the seven enablers needed to drive the Bank's High Five Agenda and quest to transform Africa's agriculture (Feed Africa Initiative). However, in order to better target agricultural policies aimed at increasing agricultural productivity in Central Africa, there is need to properly identify the main drivers of productivity growth in the region. Existing empirical evidence on the contribution of agricultural investments to agricultural productivity growth in Africa has two strands. One the one hand, innovations from R&D are portrayed as strong and sufficient drivers of agricultural productivity growth (Thirtle *et al.* 2003; Alene 2010). Meanwhile, other scholars argue that agricultural TFP growth observed in the past in Africa is mainly the result of efficiency improvements (Nkamleu 2004; Majiwa, 2015). As re-echoed by O'Donnell (2010, 2011a, 2012), reliable estimates of indexes that measure agricultural (total factor productivity) growth and its drivers are rare in the empirical literature. Despite the huge literature on agricultural TFP growth in SSA, conventional analytical frameworks often used limit the number the number of studies that accurately measure agricultural TFP growth and its components. This could misguide policy, and consequently hinder the effectiveness of agricultural programs and investments.

This study seeks to address the following questions: What is the trend and pattern of agricultural productivity growth in CEMAC countries? Which countries are more productive than the others? Was there technological progress (regress) and/or efficiency improvement (decline) in agriculture in these countries over the period under study? Do payoffs from investments in agricultural research and development outweigh returns to efforts made to improve efficiency or vice versa? The objectives of this study are to; (1) measure agricultural TFP and its growth, for CEMAC countries; (2) identify the main driver of agricultural TFP change in the Congo Basin, (3) examine prospects of catch-up and conditions necessary for this to occur.

2. Aggregate Quantity Framework for Productivity Analysis

The aggregate quantity framework proposed by O'Donnell (2012) has become probably the most popular approach over the past decade for measuring productivity growth and decomposing it into exhaustive economically meaningful components (especially via nonparametric techniques). The subsections that follow summarise this conceptual framework, establishing the relationship amongst well-known efficiency and productivity concepts.

2.1 Agricultural productivity change

Let $q_{it} \in \mathbb{R}_+^K$ and $x_{it} \in \mathbb{R}_+^J$ be vectors of input and output quantities for country *i* in year *t*. Corresponding input and output aggregates $X_{it} \equiv X(x_{it})$ and $Q_{it} \equiv Q(q_{it})$ Q can be derived based on chosen aggregator functions $X(.)$ and $Q(.)$; the latter must be monotonic and linearly homogenous in order to qualify for obtaining input and output quantity indexes (as well as TFP indexes) that satisfy required axioms of index numbers (see O'Donnell, 2010, 2011a, 2011b, 2012 for details).

Following Jorgenson and Griliches (1967), O'Donnell defines the agricultural TFP of country *i* in year *t* as a ratio of year-t aggregate output to aggregate input.

$$TFP_{it} = {}^{Q_{it}}/_{X_{it}} \tag{1}$$

By extension, the associated index that measures agricultural productivity growth in year *t* relative to year *s* is given as

$$TFP_{\ s,t} = TFP_t/TFP_s = Q_{s,t}/X_{s,t} = \frac{Q_{it}/X_{it}}{Q_{is}/X_{is}} \tag{2}$$

Any productivity index thus constructed is *multiplicatively complete* à la O'Donnell since it is a ratio of aggregate output index to input index. As such, c*omplete* indexes can be decomposed into technical change and several components of efficiency change[2]. The class of multiplicatively complete indexes includes those that require both price and quantity data (for instance Fisher, Tornqvist, Lowe) and those that need only quantity data (Hicks-Moorsteen and Färe-Primont). O'Donnell (2010, 2012) argues that the oft-touted Malmquist index of Caves et al. (1982) does not satisfy the *multiplicative completeness* condition and so cannot qualify as an unbiased measure of TFP growth except under a set of very restrictive conditions (inverse homothethicity and constant returns to scale). By extension, the decomposition of the said index in the manner of Färe *et a*l. (1994) yields unreliable estimates of components of TFP growth. *Completeness* is required in order to obtain an economically meaningful decomposition of TFP change (O'Donnell 2012).

2.2 Components of agricultural TFP growth

Efficiency and productivity concepts that have useful economic interpretation in our analysis are presented. These concepts can be stated in terms of aggregate quantity ratios used to measure agricultural TFP (change). The aggregate quantity space in Figure 1 below maps agricultural input and output combinations for a multi-input multi-output producing country (an output orientation is assumed given the agricultural context). Point A is the input-output bundle of country A, meanwhile the curve passing through B, C, and D is the locus of (aggregate) inputs and outputs that are scalar multiples of x_t and q_t and is a *mix-restricted* production possibility set (input and output mixes are held fixed).

The overall agricultural productive performance of country *i* in year *t* can be measured by its TFP efficiency (TFPE), which is the ratio of observed year-t agricultural TFP to its maximum

[2] TFP can be defined additively as aggregate output minus aggregate input. This gives rise to TFP measures that are *additively complete* (for instance the Luenberger-Hicks-Moorsteen indicator).

TFP feasible using technology available in year *t*. In all, the following efficiency measures can be derived:

TFP efficiency $TFPE_t = slope\ OA/slope\ OE = \frac{TFP_t}{TFP_t^*} \leq 1$

Output-oriented technical efficiency $OTE_t = slope\ OA/slope\ OC = Q_t/\bar{Q}_t \leq 1$

Output-oriented scale efficiency $OSE_t = slope\ OC/slope\ OD = \frac{\bar{Q}_t/X_t}{\tilde{Q}_t/\tilde{X}_t} \leq 1$

Output-oriented mix efficiency $OME_t = slope\ OC/slope\ OV = \bar{Q}_t/\hat{Q}_t \leq 1$

Residual scale efficiency $ROSE_t = slope\ OV/slope\ OE = \frac{\hat{Q}_t/X_t}{TFP_t^*} \leq 1$

Residual mix efficiency $RME_t = slope\ OD/slope\ OE = \frac{\tilde{Q}_t/\tilde{X}_t}{TFP_t^*} \leq 1$

Where, $\bar{Q}_t$ is the maximum feasible aggregate output when using x_t to produce a scalar multiple of q_t; $\hat{Q}_t$, is the maximum feasible aggregate output when using x_t to produce any output vector; $\bar{X}_t$ and $\hat{X}_t$ are the corresponding input analogues of the output aggregates just defined; $\tilde{Q}_t$ and $\tilde{X}_t$ are the aggregate output (input) quantities when TFP is maximised subject to the proviso that the input and output vectors are scalar multiples of their respective input vectors (O'Donnell, 2011a).

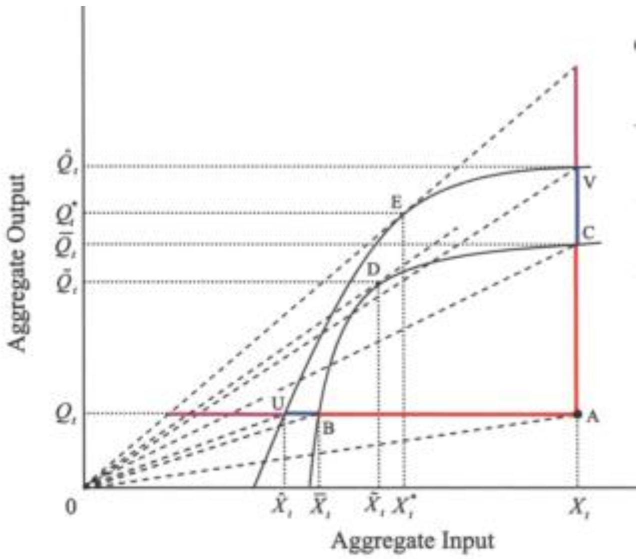

Figure 1: Output- and input-oriented efficiency measures for a multi-input multi-output producer. (Source: O'Donnell, 2012)

The output-oriented technical efficiency (OTE) level of country A is the ratio of his observed TFP at point A to his maximum possible TFP when the input and output mix are fixed (C). (Pure) output-oriented scale efficiency (OSE) is the ratio of his technically efficient TFP level on the restricted to TFP at the point of mix-invariant optimal scale -the point where the slope of the ray passing through the origin is tangent to the mix-restricted production frontier (point D). Relaxing the restrictions on input and output mix increases the number of input and output combinations available to the producer-country. This enables us to measure (pure) output-oriented mix efficiency as a ratio of a technically efficient TFP level on the mix-restricted frontier and a TFP level on the unrestricted frontier, holding the input mix fixed. The residual (output-oriented) scale efficiency ($ROSE_t$) and residual (output-oriented) mix efficiency (RME_t) as defined by O'Donnell (2011a, 2012).

2.3 The Färe-Primont TFP index

The main objective of this study is to empirically measure and compare agricultural productivity growth among countries of Central Africa (and over time), as well as identify the main driver. In the absence of data on input and output prices, the suite of possible productivity indexes available to us is restricted to those constructed using aggregator functions that to not require price information, are *complete,* and pass the transitivity test. So far, the Färe-Primont index proposed by O'Donnell (2011b) is the only qualified candidate (the Malmquist is not *complete* and the complete Hicks-Moorsteen is not transitive, making them unsuitable to multilateral and multi-temporal comparisons).

The Färe-Primont index satisfies all economically-meaningful axioms and tests of index number theory; it is temporally- and spatially-transitive and as such, is suitable for comparing agricultural productivity growth in more than two countries and/or over more than two time periods.

Consider the following Färe-Primont input and output aggregator functions

$$Q(q) = D_o(x_0, q, t_0) \tag{3}$$

$$X(x) = D_I(x, q_0, t_0) \tag{4}$$

Where $D_o(.)$ and $D_I(.)$ are Shephard (1953) output and input distance functions; x_0 *and* q_0 are representative quantity vectors, and t_0 is the representative time period. O'Donnell (2011) shows that plugging the distance-based aggregator functions from (3) and (4) in (1) and (2) yields the following Färe-Primont TFP index that measures change in agricultural TFP of country *j* in year *t*, relative to reference country *i* in base year *s*:

$$\text{Färe-Primont } TFP_{is,jt} = \frac{D_O(x_0,q_{jt},t_0)}{D_O(x_0,q_{is},t_0)}\frac{D_I(x_{is},q_0,t_0)}{D_I(x_{jt},q_0,t_0)} \tag{5}$$

Based on efficiency concepts defined in subsection above, equation (2) can be rewritten as

$$TFP_{is} = TFP_{is}^{*} \times TFPE_{is}$$

It follows that the Färe-Primont TFP index (5) can also be further decomposed into

$$TFP_{s,t} = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{TFPE_t}{TFPE_s}\right) \tag{6}$$

The right-hand-side component in the first bracket in equation (6) measures technological progress (technical change) over time; it compares maximum possible agricultural TFP that can be attained using year-*t* technology and that possible using year-*s* technology. The ratio in the second bracket measures overall efficiency change (TFPE). The latter can be further decomposed based on efficiency components presented in subsection 2.2 (see O'Donnell 2010, 2012). The decomposition of the Färe-Primont index is rather simple and does not require strong assumptions about technology structure or optimising behaviour of the economic agents.

If we consider that farmers within each country have a common technology and which is distinct from their counterparts in other countries, then it would be more appropriate to extend our analytical framework to a meta-frontier framework. However, without farm- or householdlevel data per country, it is difficult for us to construct the group frontiers and meta-frontier needed to compute the technology gap ratios.

2.4 Estimating and decomposing the Fare-Primont index using DEA

Data envelopment analysis (DEA) output-oriented linear programs written by O'Donnell (2010) are used to estimate the production technology/frontier, aggregate input and output, TFP and efficiency levels, and to decompose productivity growth into technical change and efficiency change (the latter is further decomposed into technical efficiency change, scale efficiency change and mix efficiency change) .

3 Data

This study focuses on countries of the Central African Economic and Monetary Community (CEMAC). This includes Cameroon, Chad, Central African Republic, Congo, Equatorial Guinea and Gabon. Country-level agricultural panel data was gotten mainly from the FAO statistics database (FAOSTAT). As previously noted by some authors (Heady *et al.* 2010; Coelli & Rao 2010), although time series data on production and a few conventional inputs are available for as far back as the sixties, data for certain input variables are only available over a limited period. This constrains the choice of countries, time span, and variables considered for our analysis. As such, countries with incomplete data were omitted from the analysis in order to have a balanced panel and enable more reliable comparison; Cameroon, Chad, Congo and Gabon were retained while the Central African Republic and Equatorial Guinea were excluded, largely due to irregularity and paucity of farm equipment data. The study period considered spans 1980-2007.

Output variables: Two output variables were considered- crop and livestock production. FAOSTAT data on the values of total crop and livestock production (gross value in 1000 international USD) were used.

Inputs

- Agricultural land: Agricultural land refers to total land used for agriculture. This comprises arable land, permanent crop and permanent pasture.
- Labour: This refers to the economically active population (both male and female) in agriculture during the reference period. This shows the number of workers in the agricultural sector (agricultural sector defined in terms of the characteristics of the economic unit in which the individual works, according to ILO classification standards: data on this variable was gotten from EconStats). Although this measure could overstate labour input as it does not account for disguised unemployment (Coelli & Rao 2004) it is the best available.
- Fertiliser: This refers to the total annual quantity of fertiliser used in agriculture over the period under consideration (measured in tons), that is the sum of total nitrogen (nutrient nitrogen N), total phosphate (nutrient phosphate P_2O_5), and total potash (nutrient potash K_2O), for all fertiliser products.
- Machinery and equipment (less tractors): Monetary value (USD) of machinery used in agriculture. The FAOSTAT database decomposes this into agricultural machinery, soil machinery and milking machinery. This input category thus includes equipment for animal feed, poultry incubators and brooders. It also includes dairy and milking machinery, as well as soil preparation tools such as ploughs, seeders and planters.

- Tractors (use in agriculture): For this variable, we relied on FAO data on actual number of wheel and crawler tractors in use in agriculture during the year under consideration (less pedestrian tractor).

Table 1 shows summary statistics for the input and output variables per country, over the study period. Overall, crop production increased throughout the sample period. The increase however was most significant in Cameroon (followed by Chad), where annual production was equal to the combined output value of all the other three countries (Chad, Congo, and Gabon). Increase in output was very timid in Congo and Gabon. In fact, crop production in Gabon never reached 200000 (1000 international USD) in any year throughout the sample period. However, output fluctuations were lower in Congo and Gabon compared to Cameroon and Chad. Meanwhile, Cameroon and Chad were (and continue to be) the main livestock producers in Central Africa (mainly cattle), accounting for more than 75% of livestock produced by all the CEMAC countries under study. As expected, total land area allocated for agriculture remained more or less constant throughout, indicating low land expansion and low conversion of forest land for crop and livestock production. Land use in agriculture in Chad was twice the combined total of Cameroon, Congo and Gabon throughout. This usually characterises extensive farming and dominance of livestock production (mainly through pastoral nomadism). Employment in agriculture, fertiliser use and farm machinery (excluding tractors) were highest in Cameroon, while Congo and Gabon recorded the highest numbers of tractor use, indicating higher agricultural mechanisation.

The input and output variables have different orders of magnitude and this could lead to numerical problems when solving the LP problems. To circumvent this issue, the data was rescaled before running the DEA so that the variables have unit means. By default, Cameroon in 1980 was set as the base observation. Annual agricultural total factor productivity levels and indexes measuring their growth was measured for each of the four countries, along with a decomposition of TFP change into technical change and efficiency change. The latter was further decomposed into its constituent elements (pure technical efficiency, scale efficiency, residual mix efficiency)[3].

[3] The empirical calculations were done using DPIN and R software.

Table 1: Descriptive statistics of production variables

Country	Stat	Crop production[a]	Livestock production[a]	Agricultural land[b]	Agricultural labour[c]	Machinery[d]	Tractors[e]	Fertiliser[f]
Cameroon	Mean	2089677.000	492487.800	9148.500	3185643.000	2802.893	523.679	38380.930
	SD	599602.600	116474.500	73.600	370102.000	2328.955	56.384	13380.470
	Min	1454995.000	295078.000	8930.000	2535000.000	550.000	472.000	12209.000
	Max	3625068.000	687377.200	9230.000	3626000.000	11443.000	700.000	75722.000
	CV	0.287	0.237	0.008	0.116	0.831	0.108	0.349
Chad	Mean	636015.100	487742.700	48524.900	2113929.000	299.357	168.036	10073.040
	SD	206894.200	164688.600	401.900	502586.000	179.945	5.828	5554.234
	Min	347758.500	240121.400	48150.000	1324000.000	59.000	160.000	900.000
	Max	1002259.000	730936.700	49530.000	2919000.000	840.000	175.000	17500.000
	CV	0.325	0.338	0.008	0.238	0.601	0.035	0.551
Congo	Mean	194065.000	48293.370	10539.800	463464.300	1080.464	694.964	2079.632
	SD	38261.700	15758.210	14.000	29602.900	1782.225	10.755	1677.288
	Min	143100.800	32204.510	10518.000	401000.000	118.000	670.000	26.000
	Max	275529.800	91311.590	10568.000	493000.000	9525.000	710.000	5000.000
	CV	0.197	0.326	0.001	0.064	1.649	0.015	0.807
Gabon	Mean	156761.700	61684.010	5156.900	204107.100	1052.000	851.786	1898.429
	SD	26471.400	8757.240	3.800	4779.100	717.680	69.071	2370.206
	Min	113558.900	50341.120	5152.000	192000.000	259.000	730.000	100.000
	Max	198439.300	74876.550	5160.000	210000.000	3816.000	950.000	8541.000
	CV	0.169	0.142	0.001	0.023	0.682	0.081	1.249
Total	Mean	769129.800	272552.000	18342.500	1491786.000	1308.679	559.616	13108.010
	SD	848977.000	240337.200	17617.400	1265453.000	1753.588	259.093	16701.000
	Min	113558.900	32204.510	5152.000	192000.000	59.000	160.000	26.000
	Max	3625068.000	730936.700	49530.000	3626000.000	11443.000	950.000	75722.000
	CV	1.104	0.882	0.960	0.848	1.340	0.463	1.274

[a] Gross value in 1000 international USD; [b] in 1000 ha; [c] number of persons; [d] in 1000 USD; [e] number in use; [f] measured in tons.

4 Results

4.1 Trend of total factor productivity growth in CEMAC countries

Figures 2 presents the evolution of the Färe-Primont indexes that measure changes (growth) in agricultural total factor productivity in Central African countries relative to agricultural TFP in Cameroon in 1980[4]. Figure 2 shows that there was a gradual positive trend in the agricultural productivity growth in the Central African sub-region as whole (with TFP change ranging between 0.5 and 1). The TFP growth pattern shows a slight decline in Cameroon between 1980 and 1983, with growth immediately picking up in 1984, after which a positive trend continued. Chad observed a similar scenario, with TFP declining between 1983 and 1990, probably due to the pinch of the global economic crunch prevailing at that time. Not only was initial agricultural TFP growth very low in Gabon and Congo (in 1980), but in addition, growth stagnated at the very low levels (less than 20 per cent) for close to 3 decades. Cameroon and Chad on their part enjoyed increasingly steady growth in agricultural productivity.

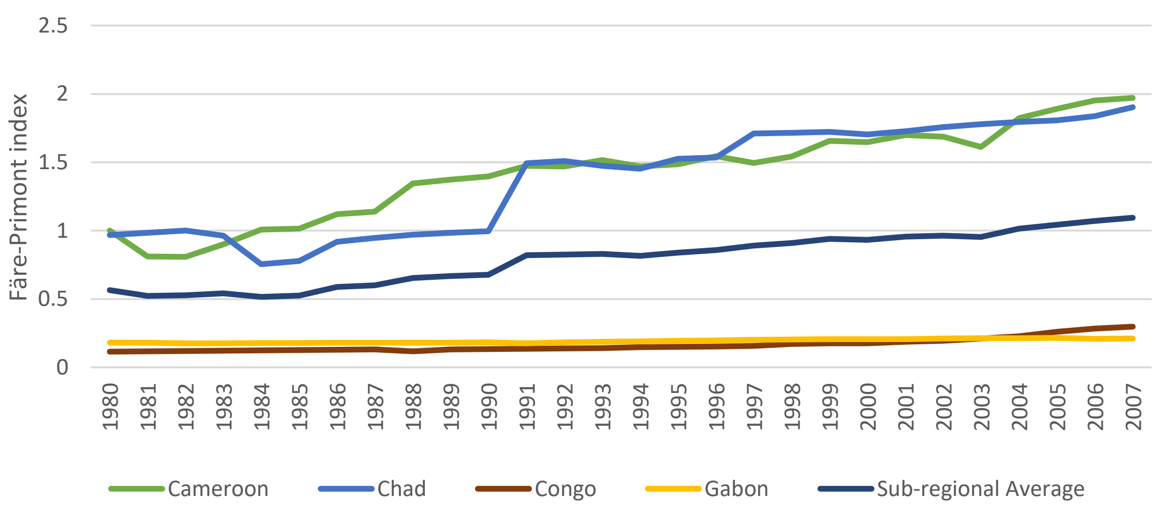

Figure 2: Evolution of agricultural TFP growth in CEMAC countries

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[4] We also computed the intransitive Hicks-Moorsteen (HM) and Malmquist TFP indexes and levels shown in Appendices 5 & 6. However, we do not discuss the results given that, by construction, the said indexes do not permit a direct inter-country or inter-year comparison of agricultural productivity. Their default results rather provide information on the main components of agricultural TFP for each year only, or of TFP growth (for instance, whether high TFP or TFP growth observed in a given year was due to technological improvement or efficiency (components)).

4.2 Multi-temporal and multilateral comparison of annual agricultural productivity growth in the CEMAC

Two types of agricultural TFP growth comparisons were done. First, for each country, its productivity in the first year (in 1980) was compared with its productivity in all other years (including the base year itself). That is TFP growth for country *j* measured using the TFP of country *j* in period *t*=1980 as reference year. This was based on the agricultural total factor productivity levels computed using Färe-Primont input and output aggregator functions as defined in equations (1), (3), (4), and (4)[5].

As shown in Table 2 below, average annual *absolute* growth (that is growth measured in terms of each country's productivity in the first year) was positive in all 4 countries for the period 1980-2007, although with distinct patterns. Agricultural productivity in Cameroon, Chad and Congo grew by 5 times that recorded in Gabon (42% on average per year as opposed to 7%). In fact, although all four countries seem to have enjoyed positive growth after 1990, productivity growth remained very timid in Gabon. Several years of productivity declines were recorded in Chad and Gabon mostly in the eighties (productivity fell by 3% in Gabon from 1982-1985, and in Chad by 21% in 1984/85 and 4% in 1986 and 1987) most likely due to the economic crisis. For similar reasons, Cameroon experienced productivity declines in her agriculture from 1981-1941 (20%) and in 1983 (10%). Meanwhile, absolute productivity growth in Congo has been very impressive since 2000, rising from 50% to 160% in 2007. Throughout the period under study (1980-2007), Congo did not record negative growth in any year. In fact, productivity growth in Congo peaked 160% in 2007. In general, agricultural productivity growth rates continued to increase in all four countries, as almost all of them recorded their highest growth rates in 2007 (apart from Gabon).

Next, a spatio-temporal comparison was done by comparing yearly agricultural productivity levels (as well as levels of productivity components and the various efficiency measures) of each country with Cameroon's agricultural productivity level in 1980 (that is, annual *relative* productivity growth, as well as growth in productivity and efficiency components, was measured using Cameroon 1980 as base period). As shown in column 2 of Appendices (1), (2), (3), and (4), agricultural productivity in 1980 was highest in Cameroon compared to the other CEMAC countries. In addition, while productivity in Chad was just 3% less than that of Cameroon, agricultural productivity in Congo and Gabon respectively was 11% and 18% that of Cameroon (that is 89% and 82% less than Cameroon). By 2007, the situation had not improved much for Gabon and Congo either. In fact, agricultural productivity in Congo in 2007 was barely 30% of Cameroon's productivity level in 1980 (TFP change relative to 1980 Cameroon = 0.299), while Gabonese farmers in 2007 were only 24% as productive as Cameroonian farmers were in 1980 (Gabon TFP index in 2007 = 0.21). Meanwhile, agricultural total factor productivity had almost doubled in Cameroon between 1980 and 2007 (Cameroon TFP index in 2007 = TFP in 2007 / TFP in 1980 = 1.97). Chad also enjoyed a similar increase in agricultural productivity over the period in question (TFP index in 2007 = 1.9).

The results in Table 2 show that by 2007, both Congo and Gabon did not show any prospects of converging to Cameroon's agricultural productivity level in 1980 (even despite output improvements consistently recorded by Congo). On average, annual productivity in Congo was only 16% Cameroon's productivity in 1980 (although recording the highest *absolute* growth in productivity). The case in Gabon was not much different either. Meanwhile, Chad's

[5] In a bid to limit the number of tables in the paper the results for annual country levels of TFP, efficiency (as well as its output-oriented components) and shifts in the frontier, were not presented. They are readily available from the authors upon request.

agricultural productivity (as well as efficiency) levels converged strongly to both Cameroon's in 1980. Gabon on the contrary failed to grow in *absolute* terms, and consequently could not converge towards Cameroon's 1980 agricultural productivity level. This is consistent with the paths observed in Figure 2 above.

Table 2: Average annual growth in TFP and in its components (1980-2007)

	Absolute growth[a]	*Relative* growth[b]							
	dTFP	dTFP	dTech	dEff	dOTE	dOSE	dOME	dROSE	dRME
Cameroon	1.42	1.42	1.47	0.97	1.00	1.00	1.00	0.97	0.97
Chad	1.43	1.38	1.47	0.93	1.00	1.00	1.00	0.93	0.93
Congo	1.42	0.16	1.47	0.11	1.00	0.93	1.00	0.11	0.12
Gabon	1.07	0.19	1.47	0.14	1.00	1.00	1.00	0.14	0.14

Notes: [a] values reflect growth in agricultural TFP levels for each country compared to the given country's level in 1980 (referred to here as average annual *absolute* growth).
[b] Changes shown here reflect values for each country relative to Cameroon in 1980 (referred to as average annual *relative* growth). dTFP = TFP change; dTech = technical change; dEff = efficiency change; dOTE = output-oriented (pure) technical efficiency change; dOME = output-oriented scale efficiency change; dOME = output-oriented mix efficiency change; dROSE = residual output-oriented scale efficiency change; dRME = residual mix efficiency change.

Figure 3 and Table 3 confirm evidence in Figure 1 that growth in agricultural productivity levels in Cameroon and Chad was by far faster than in Congo and Gabon. TFP growth totals for the entire period show that by 2008, while agricultural TFP had grown by 40 times and 39 times Cameroon's level in 1980 (exceeding the average of the four countries), TFP basically stagnated in Congo and Gabon. Cumulative growth in these countries was only 25% the CEMAC average. The low cumulative growth in agricultural TFP only confirms the low annual growth in agricultural TFP in Congo and Gabon shown in Figure 2.

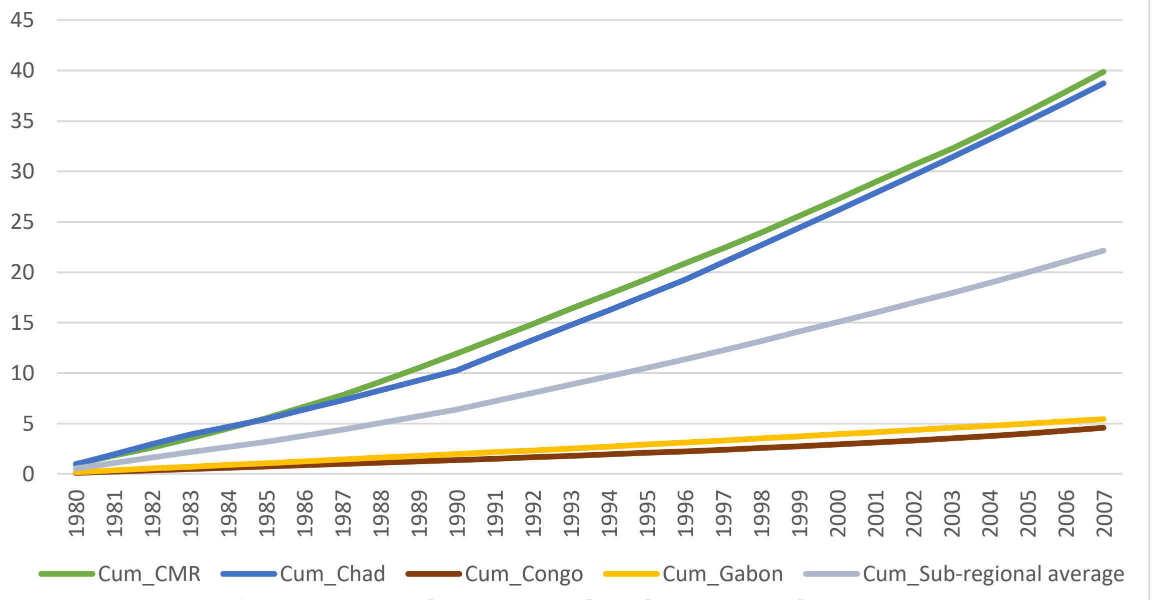

Figure 3: Cumulative agricultural TFP growth: 1980-2007

Table 3: Agricultural TFP level per country compared to Cameroon in 1980

Country	**TFP 1980**	**Cumulative TFP growth: 1980-2007**
Cameroon	1	39.86
Chad	0.98	38.72
Congo	0.12	4.59
Gabon	0.18	5.42
Four-country average	0.57	22.15

4.3 Decomposition of TFP change and efficiency change

Figure 4 below presents the contribution of technological change and efficiency change to growth in agricultural TFP, as well as the various (output-oriented) components of efficiency change. As observed in Figure 4 A1, B1, C1 and D1, technical progress remained the main driver of TFP growth in all four CEMAC countries, with its effect most remarkable in Gabon and Congo. Technological progress showed signs of improvement in all the countries (relative to Cameroon in 1980) while average efficiency levels (as well as efficiency growth measured both by multilateral and multi-temporal comparison) remained very low in Gabon and Congo (less than 15% in each of the two countries). Column 4 in Appendix (1) and (2) shows that in 1985, Chad was 76% efficient while overall efficiency in Cameroon was 100% (base). However, in 1991 and 1992, Chad had become fully efficient, and even overtaking Cameroon which dropped slightly (down to 97% in 1992). The same situation is observed between 1997 and 2003 during which Cameroon has inefficiency levels between 10 – 13 % while Chad remained fully efficient. Overall however, farmers in Cameroon and Chad seemed to operate very close to the frontier. Thus, as shown in Figures 4 and 5, the contribution of overall efficiency change to TFP change is far greater in Cameroon and Chad (40% and 39% respectively) than in Congo and Gabon where it is less than 10% in each of the countries (due to very high inefficiency in farming). On average, 93% of TFP growth in Congo and 91% in Gabon observed each year (throughout the sampled period), was achieved only thanks to technological progress (for example through increased use of tractors, especially in Gabon). The farmers themselves remained highly inefficient. As earlier noted, Figure 4 shows the average of annual contribution of efficiency change and technical change to growth in agricultural TFP. That is, the mean of the annual contributions of technical change and efficiency change to agricultural TFP for each year.

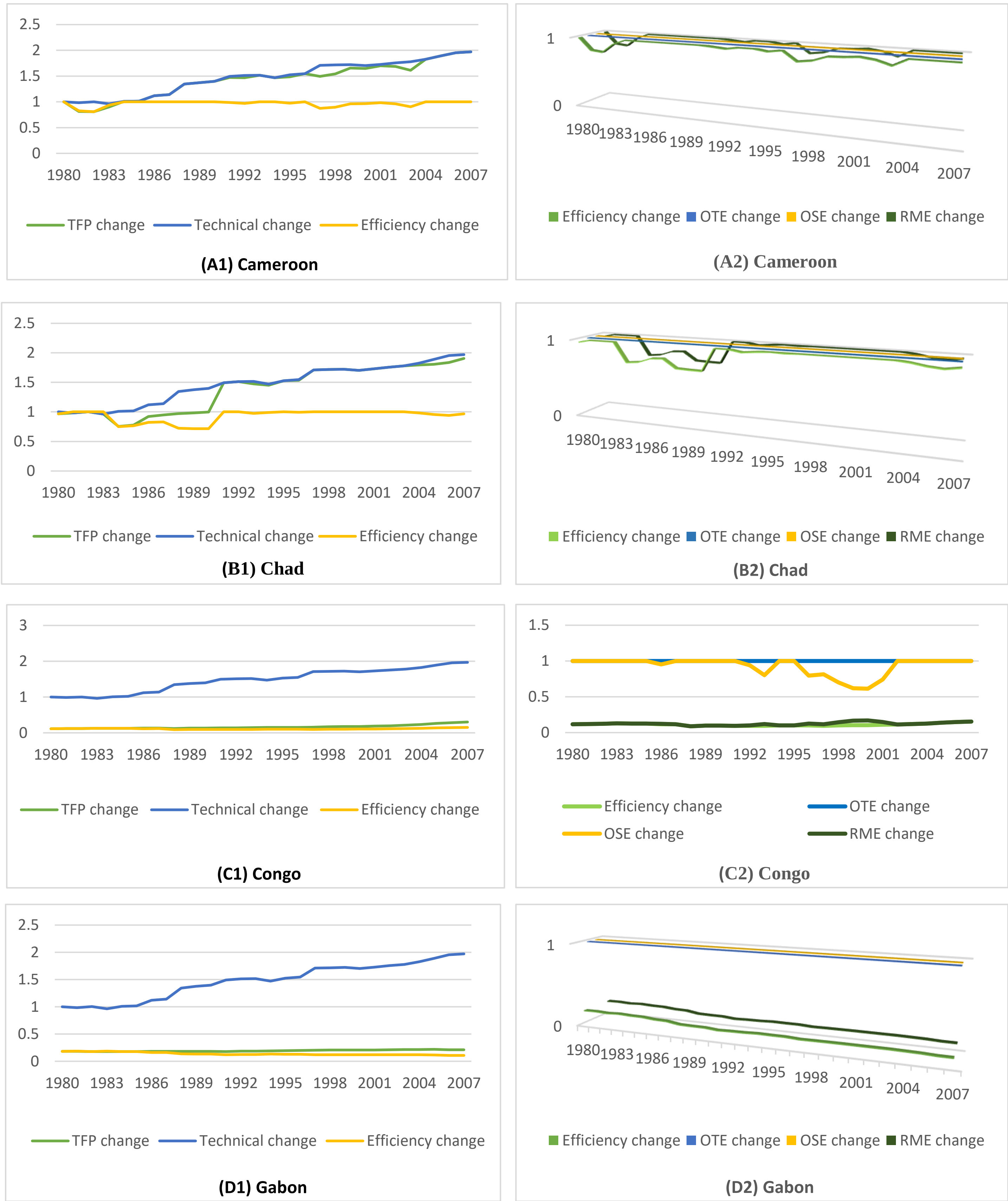

Figure 4: Components of TFP change (left panel) and output-oriented components of efficiency change (right panel)

From the decomposition of efficiency change as shown in Figure 4 above, it is observed that while pure technical efficiency change and scale efficiency change (and to a certain extent residual mix efficiency change) remained relatively constant in Cameroon, Chad and Gabon, changes in residual mix efficiency (RME) was the main cause of fluctuations and declines in overall efficiency in Cameroon and Chad. In addition, technical efficiency change and scale efficiency change was high in Congo and Gabon, while residual mix efficiency in these countries remain very low (13% on average). This implies that the marked low overall efficiency levels recorded in Congo and Gabon were mainly caused by high residual mix inefficiency.

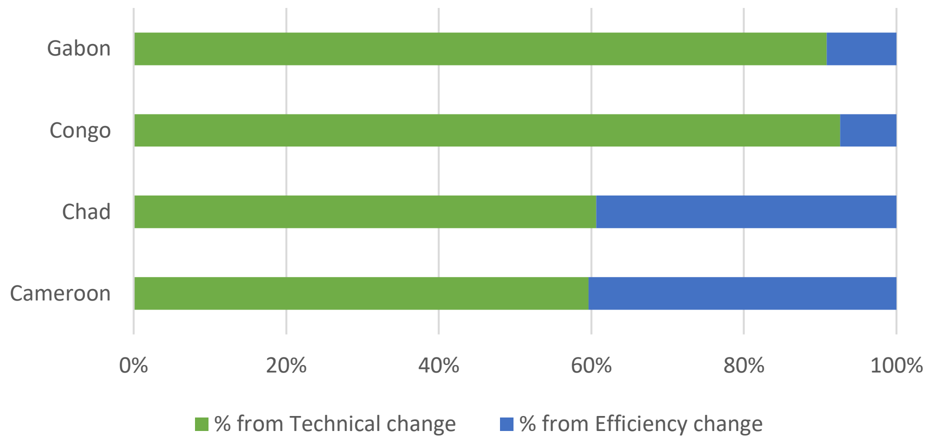

Figure 4: Proportion of annual growth in TFP from each component (1980-2007 average)

4.3 Discussion

This study attempts to bring out the big picture about the state of productivity growth in CEMAC countries of Central Africa, which is often examined only partially. Most empirical attempts to explain productivity in Central Africa almost always focus on Cameroon, and in most cases, only as part of a larger analysis attempting to span the whole of Africa (for instance Nkamleu 2004; Majiwa et al. 2015; Benin & Nin-Pratt 2016), or as global comparative analyses covering several countries in the various continents (for example Headey *et al.* 2010; Coelli & Rao 2003). This tends to mask spatial (and even temporal) variations is the sub-Region.

Our results are to some extent in line with prior studies notably in terms of the general trend of agricultural total factor productivity change in most African countries, although they diverge both in terms of the extent of estimates of average TFP growth (components), as well as in terms of the contributions of various components of TFP to TFP growth. For instance, while this study reports average annual TFP growth in Cameroon (1980-2007) to be 42%, Majiwa *et al.* (2015) report 240% growth in TFP (TFP change = 3.43), a rather very high estimate for Cameroon. In addition, there is wide disparity in estimates of efficiency change in Cameroon, as we obtain a mean of TFPE=1 while they report 3.04. However, our estimates of TFP growth are higher than those reported by Benin and Nin-Pratt (2016).

We also find that technical progress was positive in all four countries studied. While Nkamleu (2004) argues that Cameroon and most African countries did not experience technological progress between 1970 and 2001, and that growth in agriculture was largely due to efficiency improvements, our results instead show that contrary to this conclusion in most of the empirical literature, agricultural TFP growth in the CEMAC has largely been a result of technological progress. This is not very surprising, given the considerable amount of agricultural research and development (R&D) carried out in the sub-region by a consortium of international agricultural research centres located there (mostly CGIAR centres), local universities, national agricultural research scientists (NARS) and NGOs. In Gabon and Congo, high inefficiency attenuated prospects of growth in agricultural productivity that could have been triggered by technological innovation. However, caution must be taken in the interpretations, as the analytical framework used in this study differs from that used in many prior studies in on Africa. This is complicated by the differences in time periods considered as well as the choice of variables and their manner of construction.

5 Conclusion

Our results corroborate studies that point to a positive trend in agricultural TFP in Africa. We show that Cameroon remains the breadbasket of the CEMAC region. An interesting finding is the very remarkable improvement recorded by Chad over the years, with its agricultural productivity growth rising to compete with that of Cameroon over the period in question. Despite significant progress recorded by Congo, her very low initial agricultural productivity level made catch-up to Cameroon's 1980 level impossible. The situation in Gabon is most critical, as initial TFP in 1980, coupled with stagnation, only increased divergence between TFP growth in Gabon and benchmark peers like Chad and Cameroon. This was largely attributed to high inefficiency. This underscores the need for agricultural education and extension services to be beefed up in Congo and Gabon.

The role of agricultural R&D, particularly investments in, and the uptake of, agricultural technologies and other research output, is highlighted by our results. In all four countries, agricultural technologies are the main drivers or propellers of productivity growth (although to varying degrees). This reiterates the need for countries of Central Africa (and Africa as a whole) to fully commit to the CAADP targets in terms of requisite public investment in agricultural R&D. Without this requisite investment, improved agriculture and structural transformation that should leap Africa out of poverty will remain elusive.

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Appendix 1: Färe-Primont indexes of changes in agricultural total factor productivity and in its components: Cameroon (Cameroon 1980 = 1)

Year	TFP index	Technical change	TFPE index	OTE index	OSE index	OME index	ROSE index	RME index
1980	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	0.812	0.984	0.825	1.000	1.000	1.000	0.825	0.825
1982	0.810	1.002	0.808	1.000	1.000	1.000	0.808	0.808
1983	0.900	0.964	0.934	1.000	1.000	1.000	0.934	0.934
1984	1.008	1.008	1.000	1.000	1.000	1.000	1.000	1.000
1985	1.015	1.015	1.000	1.000	1.000	1.000	1.000	1.000
1986	1.120	1.120	1.000	1.000	1.000	1.000	1.000	1.000
1987	1.139	1.139	1.000	1.000	1.000	1.000	1.000	1.000
1988	1.344	1.344	1.000	1.000	1.000	1.000	1.000	1.000
1989	1.374	1.374	1.000	1.000	1.000	1.000	1.000	1.000
1990	1.396	1.396	1.000	1.000	1.000	1.000	1.000	1.000
1991	1.475	1.493	0.987	1.000	1.000	1.000	0.987	0.987
1992	1.469	1.510	0.972	1.000	1.000	1.000	0.972	0.972
1993	1.515	1.515	1.000	1.000	1.000	1.000	1.000	1.000
1994	1.469	1.469	1.000	1.000	1.000	1.000	1.000	1.000
1995	1.486	1.526	0.974	1.000	1.000	1.000	0.974	0.974
1996	1.545	1.545	1.000	1.000	1.000	1.000	1.000	1.000
1997	1.496	1.711	0.875	1.000	1.000	1.000	0.875	0.875
1998	1.542	1.716	0.898	1.000	1.000	1.000	0.898	0.898
1999	1.657	1.723	0.961	1.000	1.000	1.000	0.961	0.961
2000	1.649	1.703	0.968	1.000	1.000	1.000	0.968	0.968
2001	1.699	1.728	0.983	1.000	1.000	1.000	0.983	0.983
2002	1.687	1.757	0.961	1.000	1.000	1.000	0.961	0.961
2003	1.612	1.778	0.906	1.000	1.000	1.000	0.906	0.906
2004	1.824	1.824	1.000	1.000	1.000	1.000	1.000	1.000
2005	1.890	1.890	1.000	1.000	1.000	1.000	1.000	1.000
2006	1.953	1.953	1.000	1.000	1.000	1.000	1.000	1.000
2007	1.970	1.970	1.000	1.000	1.000	1.000	1.000	1.000

Note: TFP = total factor productivity; TFPE = total factor productivity efficiency (overall efficiency); OTE = output-oriented technical efficiency; OSE = output-oriented scale efficiency; OME = output-oriented mix efficiency; ROSE = residual output-oriented scale efficiency; RME = residual mix efficiency.

Appendix 2: Färe-Primont indexes of changes in agricultural total factor productivity and in its components: Chad (Cameroon 1980 = 1)

Year	TFP index	Technical change	TFPE index	OTE index	OSE index	OME index	ROSE index	RME index
1980	0.969	1.000	0.969	1.000	1.000	1.000	0.969	0.969
1981	0.984	0.984	1.000	1.000	1.000	1.000	1.000	1.000
1982	1.002	1.002	1.000	1.000	1.000	1.000	1.000	1.000
1983	0.964	0.964	1.000	1.000	1.000	1.000	1.000	1.000
1984	0.755	1.008	0.749	1.000	1.000	1.000	0.749	0.749
1985	0.778	1.015	0.766	1.000	1.000	1.000	0.766	0.766
1986	0.920	1.120	0.821	1.000	1.000	1.000	0.821	0.821
1987	0.946	1.139	0.831	1.000	1.000	1.000	0.831	0.831
1988	0.971	1.344	0.722	1.000	1.000	1.000	0.722	0.722
1989	0.984	1.374	0.716	1.000	1.000	1.000	0.716	0.716
1990	0.997	1.396	0.714	1.000	1.000	1.000	0.714	0.714
1991	1.493	1.493	1.000	1.000	1.000	1.000	1.000	1.000
1992	1.510	1.510	1.000	1.000	1.000	1.000	1.000	1.000
1993	1.475	1.515	0.973	1.000	1.000	1.000	0.973	0.973
1994	1.453	1.469	0.989	1.000	1.000	1.000	0.989	0.989
1995	1.526	1.526	1.000	1.000	1.000	1.000	1.000	1.000
1996	1.535	1.545	0.994	1.000	1.000	1.000	0.994	0.994
1997	1.711	1.711	1.000	1.000	1.000	1.000	1.000	1.000
1998	1.716	1.716	1.000	1.000	1.000	1.000	1.000	1.000
1999	1.723	1.723	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.703	1.703	1.000	1.000	1.000	1.000	1.000	1.000
2001	1.728	1.728	1.000	1.000	1.000	1.000	1.000	1.000
2002	1.757	1.757	1.000	1.000	1.000	1.000	1.000	1.000
2003	1.778	1.778	1.000	1.000	1.000	1.000	1.000	1.000
2004	1.795	1.824	0.984	1.000	1.000	1.000	0.984	0.984
2005	1.806	1.890	0.956	1.000	1.000	1.000	0.956	0.956
2006	1.837	1.953	0.940	1.000	1.000	1.000	0.940	0.940
2007	1.903	1.970	0.966	1.000	1.000	1.000	0.966	0.966

Note: TFP = total factor productivity; TFPE = total factor productivity efficiency (overall efficiency); OTE = output-oriented technical efficiency; OSE = output-oriented scale efficiency; OME = output-oriented mix efficiency; ROSE = residual output-oriented scale efficiency; RME = residual mix efficiency.

Appendix 3: Färe-Primont indexes of changes in agricultural total factor productivity and in its components: Congo (Cameroon 1980 = 1)

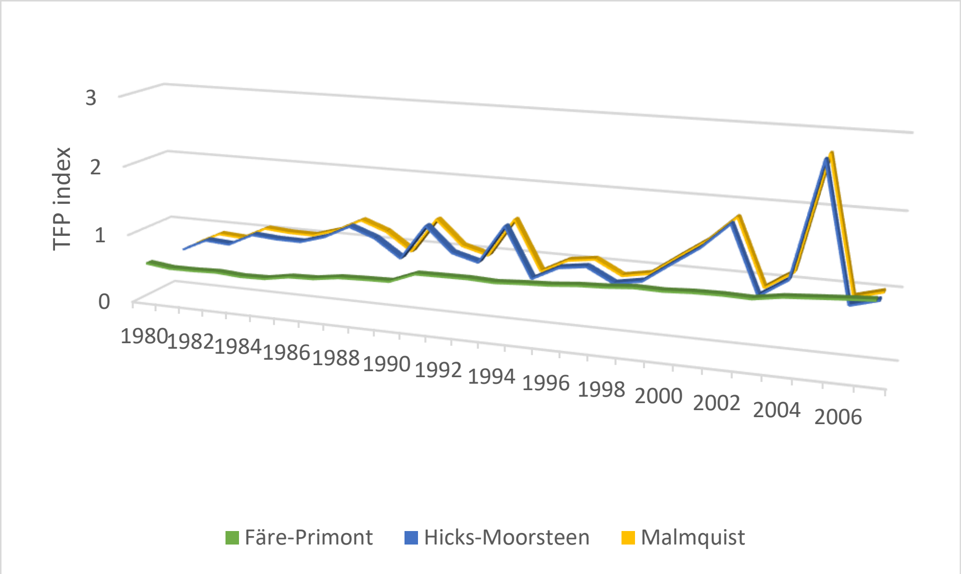
Year	TFP index	Technical change	TFPE index	OTE index	OSE index	OME index	ROSE index	RME index
1980	0.115	1.000	0.115	1.000	1.000	1.000	0.115	0.115
1981	0.118	0.984	0.120	1.000	1.000	1.000	0.120	0.120
1982	0.121	1.002	0.121	1.000	1.000	1.000	0.121	0.121
1983	0.122	0.964	0.127	1.000	1.000	1.000	0.127	0.127
1984	0.124	1.008	0.123	1.000	1.000	1.000	0.123	0.123
1985	0.127	1.015	0.125	1.000	1.000	1.000	0.125	0.125
1986	0.129	1.120	0.115	1.000	0.952	1.000	0.115	0.121
1987	0.133	1.139	0.116	1.000	1.000	1.000	0.116	0.116
1988	0.119	1.344	0.088	1.000	1.000	1.000	0.088	0.088
1989	0.131	1.374	0.095	1.000	1.000	1.000	0.095	0.095
1990	0.134	1.396	0.096	1.000	1.000	1.000	0.096	0.096
1991	0.137	1.493	0.092	1.000	1.000	1.000	0.092	0.092
1992	0.139	1.510	0.092	1.000	0.940	1.000	0.092	0.098
1993	0.142	1.515	0.094	1.000	0.802	1.000	0.094	0.117
1994	0.148	1.469	0.100	1.000	1.000	1.000	0.100	0.100
1995	0.151	1.526	0.099	1.000	1.000	1.000	0.099	0.099
1996	0.153	1.545	0.099	1.000	0.795	1.000	0.099	0.124
1997	0.159	1.711	0.093	1.000	0.815	1.000	0.093	0.114
1998	0.172	1.716	0.100	1.000	0.699	1.000	0.100	0.143
1999	0.176	1.723	0.102	1.000	0.617	1.000	0.102	0.166
2000	0.177	1.703	0.104	1.000	0.611	1.000	0.104	0.170
2001	0.188	1.728	0.109	1.000	0.739	1.000	0.109	0.147
2002	0.195	1.757	0.111	1.000	1.000	1.000	0.111	0.111
2003	0.211	1.778	0.119	1.000	1.000	1.000	0.119	0.119
2004	0.229	1.824	0.126	1.000	1.000	1.000	0.126	0.126
2005	0.262	1.890	0.139	1.000	1.000	1.000	0.139	0.139
2006	0.284	1.953	0.145	1.000	1.000	1.000	0.145	0.145
2007	0.299	1.970	0.152	1.000	1.000	1.000	0.152	0.152

Note: TFP = total factor productivity; TFPE = total factor productivity efficiency (overall efficiency); OTE = output-oriented technical efficiency; OSE = output-oriented scale efficiency; OME = output-oriented mix efficiency; ROSE = residual output-oriented scale efficiency; RME = residual mix efficiency.

Appendix 4: Färe-Primont indexes of changes in agricultural total factor productivity and in its components: Gabon (Cameroon 1980 = 1)

Year	TFP index	Technical change	TFPE index	OTE index	OSE index	OME index	ROSE index	RME index
1980	0.182	1.000	0.182	1.000	1.000	1.000	0.182	0.182
1981	0.181	0.984	0.184	1.000	1.000	1.000	0.184	0.184
1982	0.177	1.002	0.177	1.000	1.000	1.000	0.177	0.177
1983	0.178	0.964	0.184	1.000	1.000	1.000	0.184	0.184
1984	0.179	1.008	0.177	1.000	1.000	1.000	0.177	0.177
1985	0.178	1.015	0.176	1.000	1.000	1.000	0.176	0.176
1986	0.181	1.120	0.162	1.000	1.000	1.000	0.162	0.162
1987	0.181	1.139	0.159	1.000	1.000	1.000	0.159	0.159
1988	0.181	1.344	0.135	1.000	1.000	1.000	0.135	0.135
1989	0.181	1.374	0.132	1.000	1.000	1.000	0.132	0.132
1990	0.183	1.396	0.131	1.000	1.000	1.000	0.131	0.131
1991	0.175	1.493	0.118	1.000	1.000	1.000	0.118	0.118
1992	0.184	1.510	0.122	1.000	1.000	1.000	0.122	0.122
1993	0.187	1.515	0.124	1.000	1.000	1.000	0.124	0.124
1994	0.192	1.469	0.130	1.000	1.000	1.000	0.130	0.130
1995	0.196	1.526	0.128	1.000	1.000	1.000	0.128	0.128
1996	0.198	1.545	0.128	1.000	1.000	1.000	0.128	0.128
1997	0.203	1.711	0.118	1.000	1.000	1.000	0.118	0.118
1998	0.206	1.716	0.120	1.000	1.000	1.000	0.120	0.120
1999	0.208	1.723	0.121	1.000	1.000	1.000	0.121	0.121
2000	0.206	1.703	0.121	1.000	1.000	1.000	0.121	0.121
2001	0.208	1.728	0.120	1.000	1.000	1.000	0.120	0.120
2002	0.211	1.757	0.120	1.000	1.000	1.000	0.120	0.120
2003	0.214	1.778	0.120	1.000	1.000	1.000	0.120	0.120
2004	0.215	1.824	0.118	1.000	1.000	1.000	0.118	0.118
2005	0.217	1.890	0.115	1.000	1.000	1.000	0.115	0.115
2006	0.210	1.953	0.108	1.000	1.000	1.000	0.108	0.108
2007	0.211	1.970	0.107	1.000	1.000	1.000	0.107	0.107

Note: TFP = total factor productivity; TFPE = total factor productivity efficiency (overall efficiency); OTE = output-oriented technical efficiency; OSE = output-oriented scale efficiency; OME = output-oriented mix efficiency; ROSE = residual output-oriented scale efficiency; RME = residual mix efficiency.



Appendix 5: Transitive and intransitive indexes of agricultural TFP growth in the CEMAC

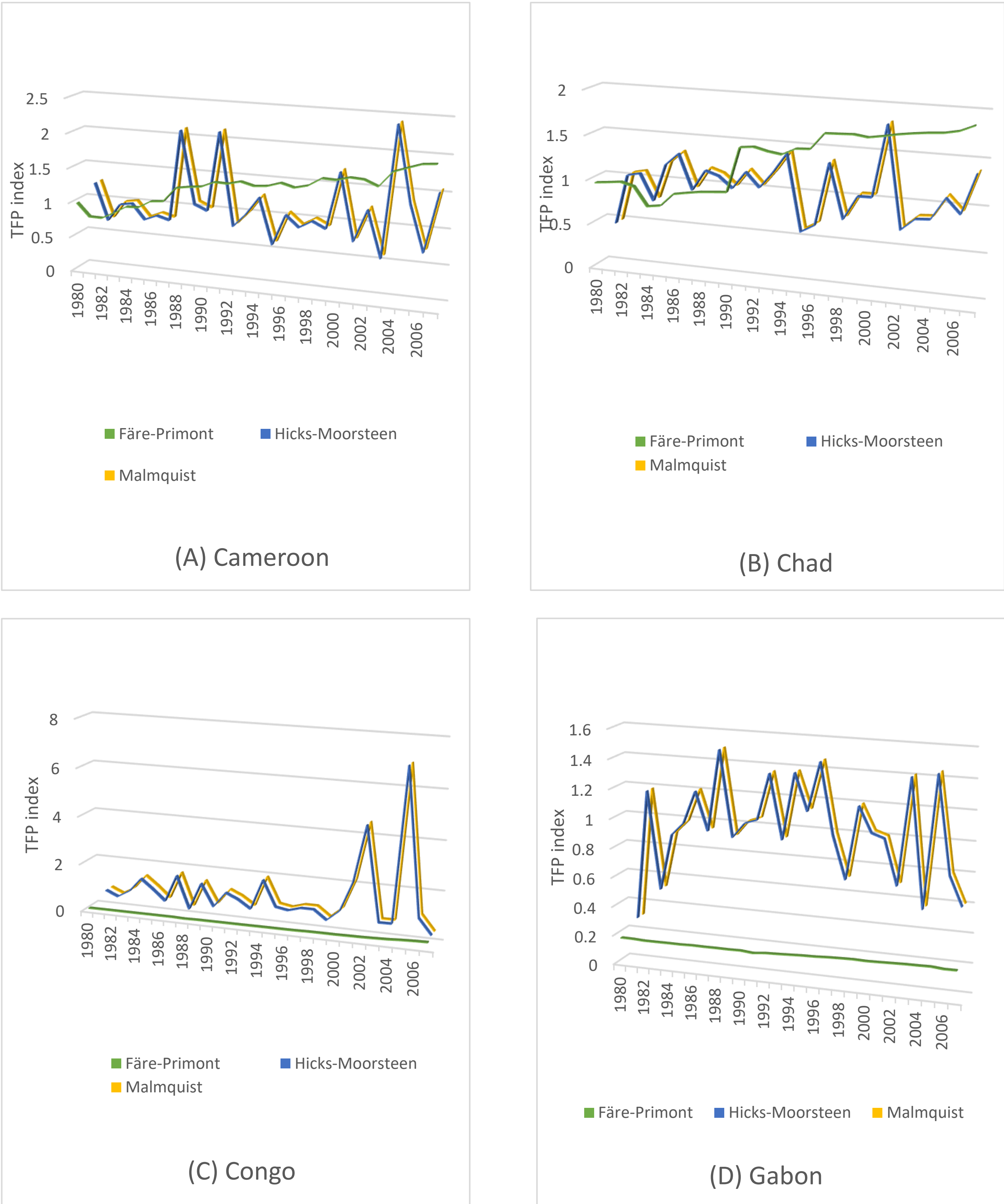


Figure 6: Transitive and intransitive indexes of TFP growth per country