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Who is Who in Knowledge Economy in Africa?

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Who is Who in Knowledge Economy in Africa?

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Abstract

This study assesses the knowledge economy (KE) performance of lagging African countries vis-à-vis their frontier counterparts with regard to the four dimensions of the World Bank's knowledge economy index (KEI). The empirical exercise is for the period 1996-2010. It consists of first establishing leading nations before suggesting policy initiatives that can be implemented by sampled countries depending on identified gaps that are provided with the sigma convergence estimation approach. The following are established frontier knowledge economy countries. (i) For the most part, North African countries are dominant in education. Tunisia is overwhelmingly dominant in 11 of the 15 years, followed by Libya which is a frontier country in two years while Cape Verde and Egypt lead in a single year each. (ii) With the exception of Morocco that is leading in the year 2009, Seychelles is overwhelmingly dominant in ICT. (iii) South Africa also indomitably leads in terms of innovation. (iv) While Botswana and Mauritius share dominance in institutional regime, economic incentives in terms of private domestic credit are most apparent in Angola (8 years), the Democratic Republic of Congo (3 years) and Tanzania, Sierra Leone and Malawi (each leading in one year).

JEL Classification: O10; O30; O38; O55; O57
Keywords: Knowledge economy; Benchmarks; Policy syndromes; Catch-up; Africa

1. Introduction

This study assesses the performance of lagging African countries vis-à-vis their frontier counterparts in relation to the four dimensions of the World Bank's knowledge economy index (KEI). Hence, the inquiry is motivated by the need to position African countries vis-à-vis their best performing counterparts in order to take stock of knowledge economy (KE) on the continent because most countries are in pursuit of knowledge-based economies (KBE).

It is now a widely held consensus that KE is key to development in the third millennium. The importance of the KBE has been central to development programs at the World Bank and the Organization for Economic Cooperation and Development (OECD) (see Tchamyou, 2016; Weber, 2011; World Bank, 2007). It is within this policy framework that the importance of KE has been well understood by North America and Europe: continents that have been determining the course of human and national progress at the international arena. Against this backdrop, countries in Asia and Latin America have been responding by tailoring national and regional development policies toward goals that clearly articulate the relevance of KE in contemporary development processes (Dahlman, 2007; Lee, 2009; Chandra & Yokoyama, 2011; Tran, 2012). Unfortunately, the overall KEI in Africa has been decreasing since the beginning of the third millennium (Anyanwu, 2012; Asongu, 2017a). After a critical survey of growth and development strategies for Africa's development, Babatunde (2012) has recommended that more focus should be placed on KE in Africa if the continent is to improve its lagging position.

This inquiry contributes to the existing literature by investigating how African countries are positioned in KE vis-à-vis their frontier or leading counterparts. First, for each dimension of KE and for a specific year, a frontier or leading country is selected as the corresponding benchmark nation. The retained benchmark country is one that reflects the highest value in the underlying KE dimension for the given year. Second, country-specific KE gaps are then assessed. Third, KE policies and strategies are implementable in the light of identified gaps ('policy syndrome' versus 'syndrome free' countries) are suggested[1]. The comparative approach to investigating KE gaps is broadly in accordance with recent KE literature which has emphasized the need for lagging countries to catch-up with their more advanced counterparts

[1] According Asongu (2017a, 2017b), a 'policy syndrome' refers to unappealing KE trends or high KE deviations between benchmark and frontier countries. Therefore wide dispersions in a given KE dimension implies 'policy syndromes' (PS) whereas a trend reflecting decreasing KE difference is qualified as a 'syndrome-free' (SF) tendency.

(Andrés et al., 2015; Nyarko, 2013a; Asongu, 2013a; Andrés & Asongu, 2013a, b; Lightfoot, 2011; Chavula, 2010; Amavilah, 2009; Bizri, 2009; AfDB, 2007; Makinda, 2007; Britz et al., 2006; Aubert, 2005). In the light of highlighted literature, the paper aims to answer the following research question: which countries are leading in knowledge economy in Africa?

The positioning of this study substantially steers clear of mainstream discourses in the African KE literature[2]. Furthermore, by employing the comparative methodology highlighted above, the inquiry complements an evolving stream of literature on achieving success in development by learning from other developing nations (Wa Gĩthĩnji & Adesida, 2011; Fosu, 2013a)[3].

This paper uses the four dimensions of the World Bank's KEI namely: innovation, education, economic incentives and institutional regime and information and communication technology (ICT). The rest of the study is structured as follows. The theoretical underpinnings and related literature are covered in Section 2. Section 3 presents the data and methodology. The empirical results are covered in Section 4 while Section 5 concludes with future research directions.

[2] To the best of our knowledge, the available literature has focused on, *inter alia*: broad narratives on KE (Lin, 2006; Rooney, 2005; Anyanwu, 2012); education (Ford, 2007; Wantchekon et al., 2014; Weber, 2011); information and communication technologies (Butcher, 2011); institutional regime and economic incentives (Letiche, 2006; Cogburn, 2003; Andrés & Asongu, 2013a; Saxegaard, 2006); innovation (Carisle et al., 2013; Oyelaran-Oyeyinka & Sampath, 2007); research and development (Sumberg, 2005; German & Stroud, 2007); intellectual capital and economic development (Wagiciengo & Belal, 2012; Preece, 2013); indigenous knowledge systems (Raseroka, 2008; Lwoga et al., 2010); intellectual property rights (Lor & Britz, 2005; Zerbe, 2005; Myburgh, 2011; Asongu, 2013a; Andrés et al., 2015; Andrés & Asongu, 2013a, 2013b); intellectual capital and knowledge acquisition in technological innovation and access to finance (Becheikh, 2013; Kamukama, 2013); the relationship between knowledge and project failures (Ika & Saint-Macary, 2014; Hashim, 2014; Ofori, 2014; Joseph et al., 2014); innovation and intellectual capital in firm performance and development (Makanyeza, & Dzvuke, 2015; Tarus & Sitienei, 2015); KE in space transformation (Moodley, 2003; Maswera et al., 2008); spatiality in the production of knowledge (Neimark, 2012; Bidwell et al., 2011) and catch-up in KE with respect to the East Asian miracle (Lucas, 1988, 1993; Andrés et al., 2015; Bezmen & Depken, 2004; Andrés & Asongu, 2013a, 2013b; Kim et al., 2012), the use of information and communication technology for entrepreneurship (Kuada, 2009, 2014, 2015; Afutu-Kotey et al., 2017, Asongu et al., 2017; Asongu & Nwachukwu, 2018), social change and development (Tony & Kwan, 2015; Asongu & Le Roux, 2017; Amankwah-Amoah, 2015, 2016; Amankwah-Amoah & Sarpong, 2016).

[3] Building on strategies from the past (Fosu, 2010), Fosu (2012, 2013a) has documented lessons with which to achieve development success. These lessons are derived from: (i) East Asia and the Pacific (Lee, 2013; Warr, 2013; Jomo & Wee, 2013; Khan, 2013; Thoburn, 2013); (ii) the emerging Asian giants of India and China (Singh, 2013; Santos-Paulino, 2013; Yao, 2013); (iii) sub-Saharan Africa (Robinson, 2013; Lundahl & Petersson, 2013; Subramanian, 2013; Naudé, 2013; Fosu, 2013b); (iv) the Middle East and North Africa (Nyarko, 2013b; Baliamoune-Lutz, 2013; Drine, 2013; Looney, 2013) and (v) Latin America and the Caribbean (Solimano, 2013; De Mello, 2013; Trejos, 2013; Cardoso, 2013; Pozo et al., 2013).

2. Intuition, theoretical underpinnings and KE literature

The intuition and theory underlying this inquiry on KE convergence is broadly consistent with the literature on income catch-up which has been considerably documented within the framework of neoclassical growth models and recently extended to other fields of economic development (Swan, 1956; Barro, 1991; Solow, 1956; Baumol, 1986; Mankiw et al., 1992; Barro & Sala-i-Martin, 1992, 1995; Fung, 2009; Mayer-Foulkes, 2010; Narayan et al., 2011; Andrés & Asongu, 2013a, 2013b; Bruno et al., 2012). In essence, the theoretical underpinnings of development catch-up have been recently extended to the harmonization of intellectual property rights against the piracy of software (Andrés & Asongu, 2013b) and financial market convergence (Bruno et al., 2012; Narayan et al., 2011).

Catch-up in KE between a frontier country and laggard countries can be expected for a multitude of reasons. Such convergence is made possible by the following conditions, *inter alia*: availability of skilled teachers and workers; students receiving training abroad and migration of experts from leading nations to peripheral countries (Kim & Nelson, 2000; Morrison et al., 2009; Mowery & Sampat, 2005). In essence, what is relevant today in the convergence phenomenon builds on the fact that basic and applied quest for know-how, together with KE dimensions, are important drivers of innovation and development (Morrison et al., 2009; Balconi et al., 2010). On the same line of thinking, Mazzoleni and Nelson (2007) have provided two principal justifications for which to expect KE catch-up. On the one hand, there is a changing nature of technology and science (see D'Este & Patel, 2007). On the other hand, globalization enhances cross-country diffusion of knowledge (see Asongu & Nwachukwu, 2017). In summary, there is a wealth of literature on KE catch-up in contemporary development processes (see Albuquerque, 2000; Esler & Nelson 1998; Jelili & Jellal, 2002; Wolff & Jellal, 2003; Murray & Stern, 2005; Mowery & Sampat 2005; Mazzoleni, 2008). In the paragraphs that follow, the literature review is aimed as articulating how this positioning of the study steers clear of prior exposition. Hence, for lack of space, less emphasis is placed on methodologies and the corresponding findings of the engaged studies are engaged when absolutely necessary.

The extant literature on KE can be briefly discussed in ten main strands, namely: general narratives on KE; KE in space transformation; spatiality in the production of know-how; intellectual property rights; research and development; intellectual capital and economic

progress; indigenous systems of knowledge; ICT; innovation, education and catch-up in KE with respect to the East Asian miracle (Tchamyou, 2016; Asongu, 2017b).

On the general narratives of KE in the first strand, it is important to mention Rooney (2005) who has analyzed the main discourses on knowledge, technology, society and the economy to establish that the understanding of KE and technocracy are restricted to a selected number of areas. Lin (2006) has rethought the linkage between growth and KE on the one hand and discussed some relevant areas that have been neglected on the other hand, notably: the relevance of knowledge in boosting inclusive growth and sustainability of the environment. Anyanwu (2012) has investigated the general state of knowledge in Africa to conclude that compared to other regions in the world, Africa has been lagging in terms of the overall knowledge index since the year 2000.

In the second category on KE in space transformation, Maswera et al. (2008) have examined the rate at which tourism corporations are improving their websites with electronic (e)-commerce in Africa to conclude that whereas the websites are informative, they are also not 'state of the art' when it comes to interactive facilities needed for electronic(e)-transactions. In the same stream, the relevance of e-business has been examined by Moodley (2003) in South Africa's apparel sector who has discussed challenges, opportunities and risks associated with e-business.

In the third strand on spatiality in knowledge production, Bidwell et al. (2001) have investigated the adaptability of rural heritages and needs of the community in the light of evolving technology. The authors provide valuable insights into the manner in which these communities can temporarily and spatially manage information flow. Within this same strand, Neimark (2012) has examined and discussed the political economy of bio-prospecting.

On intellectual property rights (IPRs) that are engaged in the fourth strand, a framework for the harmonization of IPRs has been documented by Asongu (2013a) and Andrés and Asongu (2013b, 2016) respectively at African and global levels. Contingent on IPRs instruments, corruption-control is a very effective tool in fighting software piracy, when compared to other good governance mechanisms (Andrés & Asongu, 2013a) and enforcing IPRs through formal institutions is not a sufficient condition for development of knowledge based economies in Africa (Andrés et al., 2015). Lor and Britz (2005) within this strand have assessed knowledge trends in conjunction with their effects on the flow of international information to outline three ethical

dimensions with which to elicit such information flows, namely: social justice, common good and human rights. Zerbe (2005) has examined the African Union Legislation on the protection of indigenous knowledge to establish that the legislation meets the requirements and needs of member countries in that, a good balance is defined between the rights of the local/indigenous population and monopoly rights. Within the same perspective, legal processes that are needed in digital knowledge related to plant-protection have been examined by Myburgh (2011). The author as a IPRs lawyer has discussed his/her perspective on contemporary changes in plant-based traditional knowledge.

German and Stroud (2007) in the fifth strand have attempted to comprehend the application of research and development in the light of typologies, lessons and consequences of approaches in learning. This stream is in accordance with the imperative to enhance research and development across the continent (Anyanwu, 2012; Chavula, 2010; African Development Bank, 2007), especially with regard to the lagging position of Africa in contribution to knowledge by means of scientific publications (Asongu & Nwachukwu, 2016a; Amankwah-Amoah, 2017).

Roseroka (2008) in the fifth strand on indigenous systems of knowledge, after assessing channels by which to safeguard indigenous knowledge, has presented comparative advantages of oral knowledge. Under the same canopy, Lwoga et al. (2010) have established that schemes of knowledge management that can be used to manage local know how when distinct features are accounted-for. The authors have arrived at the conclusions by applying approaches of knowledge management to local KE.

In the seventh strand on 'economic development and intellectual capital', information disclosure and lifelong learning have been on the agenda. After assessing the disclosure of intellectual capital, Wagiciengo and Belal (2012) have concluded that intellectual capital is evolving across corporations in Africa. Preece (2013) has investigated the importance of foreign aid in lifelong learning to establish that priorities at the international level are negatively affecting domestic governments' choices and externalities on lifelong learning.

Economic incentives and institutional regime make-up the eight strand. In this category, Cogburn (2003) has attempted to elicit the changes in the regime of international communications to provide relevant insights into valuable lessons and practices for other developing nations. Letiche (2006) has leaned on behavioral economics in order to understand success stories of

economic transitions. The author has then disclosed an interesting analysis of how nations with a plethora of traditions and customs (among others) go through such transitions. When compared to other governance indicators, corruption-control is a very effective weapon in the battle against software piracy is corruption-control (Andrés & Asongu, 2013a) and the use of good governance channels to enforce IPRs is not a sufficient condition for the development of KE in Africa (Andrés et al., 2015). The lack of financial access in the continent continues to represent a serious policy syndrome in the development of KE because, for the most part, mobilized deposits are not readily transformed into credit for economic operations because of information asymmetry between lenders and borrowers (Saxegaard, 2006; Fouda, 2009; Tchamyou & Asongu, 2017).

The ninth strand which is focused on innovation builds on the evolving relevance of innovation as a fundamental engine of industrial productivity and economic growth. The position is consistent with Oyelaran-Oyeyinka and Sampath (2007) in a study on 'innovation in African development'. Carisle et al. (2013) after assessing terrorism-related innovation have concluded that institutions have a fundamental mission to play in the enhancement of best practices, improvement of networks and knowledge transfer. In a nutshell, the relevance of innovation in contemporary African development is consistent with recent KE literature (Anyanwu, 2012; Tchamyou, 2016).

With regard to ICT in the tenth strand, the African Partnership Forum (2008) has concluded that ICT is playing a major role in reducing poverty and driving growth. According to the report, ICT is associated with improved governance, more income-generating opportunities, enhancement of efficiency, access to new services and markets and the possibility of more leverage for poorer factions of the population to voice their concerns. The discourse is in accordance with the evolving ICT-related literature (see Jonathan & Camilo, 2008; Chavula, 2010; Maurer, 2008; Aker & Mbiti, 2010; Butcher, 2011; Demonbynes & Thegeya, 2012; Merritt, 2010; Ondiege, 2010; Thacker, & Wright, 2012; Penard et al., 2012; Asongu & Nwachukwu, 2016b, c).

The eleventh strand is devoted to education. Ford (2007) has investigated digital age challenges for Africa. Amavilah (2009) has raised concerns on the low production value of doctoral dissertations in the continent: a position that has been confirmed by Asongu and Nwachukwu (2017) who have recommended the PhD by Publication route as a means towards innovation in and technology transfer to Africa. After assessing the relevance of education in KE,

Weber (2011) has concluded that education is important in diversifying the economy, preserving cultural integrity and ending illiteracy. The importance of education in boosting human capital externalities has been confirmed by Wantchekon et al. (2014).

The twelfth strands focuses on the literature of KE catch-up in the light of the East Asian Miracle. The debate on the East Asian Miracle has been substantially engaged in the literature (Utterback, 1975; Dahlman et al., 1985; Amsden 1989; Lucas, 1988, 1993; World Bank 1993; Chang 1994; Bezmen & Depken, 2004; Lee, 2009; Kim et al., 2012; Kim & Lee, 2009; OECD, 1992; Hobday, 1995; Andrés & Asongu, 2013a; Andrés et al., 2015). What is relevant for this inquiry is the evolution of recent KE literature in such catch-up processes. Asongu (2017b) has used South Korea as a benchmark or frontier in order to: (i) provide KE gaps between South Korea and fundamental characteristics of African development; (ii) derive policy syndromes based on the magnitude of investigated gaps and (iii) provide catch-up strategies inspired by successful KE strategies implemented by the frontier nation during its spectacular march towards economic prosperity.

3. Data and methodology

The study examines a sample of 53 African countries with data from the World Governance Indicators, the World Development Indicators and Principal Component Analysis (PCA) for the period 1996-2010. There are two main justifications for the adopted periodicity. (i) The periodicity begins from 1996 because data on good governance from the World Governance Indicators is only available from the year 1996. (ii) The periodicity ends in 2010 because it is in accordance with Anyanwu (2012) on the fall of the continent knowledge index. It is also important to justify the choice of the periodicity beyond the availability of data because the happenings of the period also justify the periodicity. Accordingly, the components of knowledge economy (institutions, human capital, ICT and innovation) were substantially installed across Africa during the investigated period. For instance, internet started penetrating Africa in 1998/1999 which coincided with the period during which most African countries deregulated their telecommunication sectors to enhance competition and involvement of the private sector. Moreover governance in Africa entered a new phase from 1998, when military intervention was discourage and investment in the private sector encouraged, which, enabled investments in innovation, education and ICT.

The World Bank's four components of the KEI are used, namely: innovation, education, ICT and economic incentives and institutional regime. These adopted variables are in accordance with recent African KE literature (see Tchamyou, 2016; Andrés et al., 2015; Amavilah et al., 2017). The definitions and sources of the variables are provided in Appendix 1, whereas the correlation matrix and summary statistics are provided in Appendix 3 and Appendix 2 respectively.

Consistent with recent literature on KE (see Asongu, 2017a), PCA is employed to reduce dimensions of KE. This is essentially because various components of each dimension of the KEI maybe highly correlated with one another. Hence, in the light of the potentially high degree of substitution between constituents of KE dimensions, we use the PCA to reduce sets of highly correlated variables into sets of uncorrelated variables known as principal components (PCs). These PCs denote a considerable proportion of differences in the original dataset. The Kaiser (1974) and Jolliffe (2002) criterion is employed to retain common factors. According to the criterion, after the PCA, only factor loadings which have eigenvalues that are greater than the mean or one should be retained. The retained eigenvalues therefore correspond to the eigenvectors that denote a significant difference in the original data. The same criterion for the retention of common factors has been used by Tchamyou (2016) and Andrés et al. (2015) in recent literature on KE.

The PCA findings presented in Table 1 discloses the retained common factors known as PCs or factor loadings. It is apparent from the table that the ICT index (*ICTex*) which is the first PC of internet penetration, mobile penetration and telephone penetration accounts for 73.00% of information in the constituent indicators and its eigenvalue is above one (or 2.190). In the same vein: (i) *Educatex* for education is the factor loading for Primary School Enrolment(PSE), Second School Enrolment (SSE) and Tertiary School Enrolment (TSE); (ii) *Innovex* for innovation is the retained PC for a combination of trademark applications, patent applications and scientific and technical journal articles published annually; (iii) *Creditex* on economic incentives summarizes private domestic credit and interest rate spread and (iv) *Instireg* is the first principal component of the six good governance variables, namely: political stability/no violence, voice and accountability, government effectiveness, regulation quality, corruption-control and the rule of law.

Table 1: Principal Component Analysis (PCA) for KE Indicators

Knowledge Economy dimensions		Component Matrix (Loadings)						First PC	Eigen Value	Indexes
Education	School Enrolment	PSE		SSE		TSE				
		0.438		0.657		0.614		0.658	1.975	Educatex
Information & Infrastructure	ICTs	Internet		Mobile		Telephone				
		0.614		0.584		0.531		0.730	2.190	ICTex
Innovation System	Innovation	STJA		Trademarks		Patents				
		0.567		0.572		0.592		0.917	2.753	Innovex
Economic Incentive & Institutional regime	Economic Incentive	Private Credit				Interest rate Spread				
		-0.707				0.707		0.656	1.313	Creditex
	Institutional index	VA	PS	RQ	GE	RL	CC			
		0.383	0.374	0.403	0.429	0.443	0.413	0.773	4.642	Instireg

P.C: Principal Component. PSE: Primary School Enrolment. SSE: Secondary School Enrolment. TSE: Tertiary School Enrolment. PC: Principal Component. ICTs: Information and Communication Technologies. Educatex is the first principal component of primary, secondary and tertiary school enrolments. ICTex: first principal component of mobile, telephone and internet subscriptions. STJA: Scientific and Technical Journal Articles. Innovex: first principal component of STJA, trademarks and patents (resident plus nonresident). VA: Voice & Accountability. RL: Rule of Law. R.Q: Regulation Quality. GE: Government Effectiveness. PS: Political Stability. CC: Control of Corruption. Instireg (Institutional regime): First PC of VA, PS, RQ, GE, RL & CC. Creditex: First PC of Private domestic Credit and Interest rate spread.

The study employs the *sigma* convergence approach to estimate KE gaps. It is not technically possible to employ the beta convergence approach because it is by definition consistent with a panel data structure. Furthermore, the beta estimation approach is also related with concerns of initial endowments and multiple equilibria (see Monfort, 2008, p. 4-5; Asongu, 2014a). The corresponding cross-sectional or sigma convergence technique is presented in Eq. (1) below:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(KE_i - \mu)^2}\ , \qquad (1)$$

where $\mu = \frac{1}{N}\sum_{i=1}^{N} KE_i$

The process for estimating *sigma* convergence disclosed in Eq. (1) consists of observing the trend of cross-country standard deviations across time. Convergence is conveyed by a decreasing tend or tendency.

4. Empirical results

4.1 Derivation of frontier African KE countries

Frontier African countries with respect to a sampled year and knowledge economy dimension are presented in Table 2. The benchmark country reflects the highest value of the knowledge economy dimension for the given year. An obvious question arising from a curious scientific mind may be to know whether high values in PCs reflect higher values in knowledge economy. The intuition for this attribution is in accordance with Chinn and Ito (2002) on the positive correlation between more openness and higher values of the *de jure* (KAOPEN) measure of capital account openness. In essence, KAOPEN is defined as the first PC of four binary indicators of the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) and it takes higher values for financial regimes that are more open.

Table 2: Derivation of leading countries in KE (who is who?)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Educatex	Tunisia	Tunisia	Tunisia	Egypt	Tunisia	Tunisia	Libya	Libya	Tunisia	Tunisia	Tunisia	Tunisia	Tunisia	Tunisia	CV
ICTex	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Seych	Moroc	Seych
Innovex	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	S.A	---
Instireg	Botsw	---	Mauri	---	Mauri	---	Mauri	Botsw	Botsw	Botsw	Mauri	Mauri	Mauri	Mauri	Mauri
Creditex	Angola	Tanz	S.L	Angola	Angola	Angola	Angola	Angola	Angola	Angola	Malawi	DRC	DRC	DRC	---

Educatex: Education index. ICTex: Information & Communication Technology (ICT) index. Innovex: Innovation index. Instireg: Institutional Regime. Creditex: Economic Incentives. Botsw: Botswana. CV: Cape Verde. DRC: Democratic Republic of Congo. Mauri: Mauritius. Moroc: Morocco. Seych: Seychelles. S.L: Sierra Leone. S.A: South Africa. Tanz: Tanzania. (---): not available due to missing data.

The following findings are apparent from Table 2. (i) For the most part, North African countries are dominant in education. Tunisia is overwhelmingly dominant in 11 of the 15 years, followed by Libya which is a frontier country in two years while Cape Verde and Egypt each lead in a single year each. (ii) With the exception of Morocco that is leading in the year 2009, Seychelles is overwhelmingly dominant in ICT. (iii) South Africa also indomitably leads in terms of innovation. (iv) While Botswana and Mauritius share dominance in institutional regime, economic incentives in terms of private domestic credit are most apparent in Angola (8 years), the Democratic Republic of Congo (3 years) and Tanzania, Sierra Leone and Malawi (each leading in one periodic year).

4.2 Policy implications

In this section, we discuss policies that can be implemented in order to enable catch-up by lagging countries. It is important to emphasis that the relevance of the policies is contingent on established KE gaps by means of sigma convergence which are provided in graphs in the Appendix. Hence, the appendix is informative on guiding policy makers about the depth of KE gaps between frontier countries and each country, for a given year.

Innovation and quality education can be consolidated through four principal measures, *inter alia*: the imperative of more technical education in order to reduce the skewness of education towards general education; the promotion of R&D; the relevance of a lifelong learning culture and the need to constantly replace traditional/classical PhD programs with PhD by publication schemes. First, it is relevant to closely associate technical and vocational training (TVET)-related programs with initiatives that promote self-employment, notably, via: counseling, career guidance and entrepreneurship training. TVET training also has the advantage of facilitating post-conflict reconstruction and enabling the transition of economic operators from the informal to the formal economy. Moreover, TVET projects should be tailored to address needs in the labour market. Such qualitative schemes would necessitate collaborative frameworks between academic institutions and future employers. The schemes are very likely to provide employment prospects to a growing number of college/university graduates. Furthermore, cultural knowledge and practices like traditional crafts and arts are easily preserved when citizens are empowered with TVET programs. Other potential benefits from TVET include: benefits for girls and women as far as access to employment is concerned. An important stream of measures has been documented by the African Union (AU, 2006) in order to enable member states to improve on TVET schemes. The measures which are documented in page 5 of the report include: quality and relevance of national TVET programmes and systems; capacity building; equitable access to TVET for all; employment of network strategies; financing TVET and non-formal education.

Second, a strategy of lifelong learning in the continent is aptly summarised in the AU (2006) report on the promotion of quality education in Africa. "*To re-align education systems in Member States so that young people are provided with compulsory basic education which imparts key generic competencies, skills and attitudes that lead to a culture of lifelong learning and entrepreneurship in order to empower individuals to live in peace and harmony, engage in*

the world of work, alleviate poverty and pursue further learning" (p. 9). The related areas of priority are disclosed in Table 5 of the same AU report.

Third, given the comparatively low contribution to knowledge (through scientific publications) by African countries (see Pailey, 2016; Asongu, 2013b), which is substantially determined by the low production value of doctoral theses in the continent (see Amavilah, 2009), it is relevant for policies in higher education to be more conducive with the PhD by Publication route, as opposed to the traditional/classical course. In essence, doctoral dissertations that are based on published works offer more possibilities for technology transfer and innovation (see Asongu & Nwachukwu, 2017). This policy proposal is also motivated by the fact that the curricula in most African countries is outdated and not adapted to challenges of globalization in the 21st century (see Asongu & Nwachukwu, 2016a).

Fourth, it is important to promote R&D from cross-country settings, enhance research at the regional level on the one hand and on the other hand, tailor appropriate linkages between policy makers, researchers and industries. It is also vital for policy makers to adopt R&D initiatives of regional and cross-country nature the ease convergence between lagging African countries and frontier nations in terms of KE. The following could be encapsulated in the policy initiatives: (i) transnational R&D cooperation with the principal agenda of making R&D consistent with scientific output; (ii) emphasis on R&D projects that reflect both policy makers and local actors and (iii) refocus of research initiatives in order to tackle issues of exclusive development. It is important to note that this third point is vital as it indirectly articulates a recent World Bank report on attainment of the Millennium Development Goals (MDGs) which has shown that that poverty has been reducing in all regions of the world with the exception of Africa (see Asongu & Nwachukwu, 2016c). An eloquent example of an ongoing collaborative project that has been designed to boost cross-country research is a project by the Council for the Development of Social Science Research in Africa (CODESRIA) known as the 'African Diaspora Support to African Universities'. The initiative seeks to mobilize African researchers in the Diaspora so that they can contribute to *inter alia*: bridging teaching gaps; reinvigorating social sciences, consolidating PhD programs, strengthening African universities and mentoring young researchers. In a nutshell, the collaborative scheme seeks to improve connections between researchers in Africa and their counterparts in the Diaspora.

The engaged policy directions for education and innovation can be enhanced if they are implemented in conjunction with policy initiatives that are designed to improve ICT facilities and communication between researchers, policy makers and industries, by means of the underlying ICT facilities. The policy relevance of leveraging on ICT is consolidated by the potential for ICT penetration in Africa which is considerably higher than in other regions of the world which are experiencing saturation levels in ICT penetration (see Penard et al., 2012). Moreover, adopting low cost and universal ICT access schemes would go a long way to alleviating concerns about exclusive development we have highlighted above[4].

Given that Africa's contribution to global trade has declined from 3.8 in the 1950s to about 1.5% in the contemporary era (see Fofack, 2014), economic policies should factor-in the perspective that the neoliberal experiment has not worked for Africa. Accordingly, while liberal policies promoted under the Washington Consensus have failed to deliver development to Africa on many fronts (Chang, 2008; Mshomba, 2011), it is at the same surprising that developed countries which are promoting such liberal economic policies employed protectionist policies when they were at their early stages of industrialisation. Even from a more contemporary perspective, some developed countries trading with Africa today are not implementing the neoliberal policies they advocate for. For instance, according to Stiglitz (2007), without subsidies, the USA will not be leading globally in the export of cotton. The same author maintains that because a cow is subsidised with two USD/day it may be better to be a cow in Europe than a human being in Africa where most inhabitants live with less than 2USD/day. This broadly implies that blindly adopting neoliberal policies of free market competition may not help drive development and knowledge economy that are needed to lift the continent out of poverty. It is also important to note that the European Union's agricultural plan is strategically designed to limit extensive or export-driven strategies by African countries in the agricultural sector. This is essentially because the principle of comparative advantage is not respected given that about half of the European Union's budget is allocated to subsidising agriculture and the agri-foods industry, which represent just about 6% of its GDP.

[4] There is an important body of ICT literature which has documented benefits in terms of economic prosperity and inclusive development (African Partnership Forum, 2008; Chavula, 2010; Butcher, 2011; Asongu, 2016).

5. Conclusion and future research directions.

This study has assessed the performance of African countries vis-à-vis frontier African countries in relation to the four dimensions of the World Bank's knowledge economy index (KEI). Hence the inquiry is motivated by the need to position African countries vis-à-vis their best performing counterparts in order to stock of knowledge economy (KE) in the continent. The empirical exercise which is for the period 1996-2010 first consists of establishing leading nations before suggesting policy initiatives that can be implemented by sampled countries depending on identified gaps that are provided with the sigma convergence estimation approach. Leading countries in relationship to specific knowledge economy components have been disclosed.

Future inquires can focus on the relevance of knowledge economy in unemployment and inclusive development. Both are glaring policy syndromes in the post-2015 sustainable development agenda. The African population has been projected to double by 2036 and represent about 20% of the population in the world by 2050 (see UN, 2009). Policy underlying knowledge-based economies may be critical in addressing the corresponding, poverty and unemployment accruing from the growing population.

Appendices

Appendix 1: Definition of variables

Variables	Signs	Variable definitions	Sources
		Panel A: Education	
Primary School Enrolment	PSE	School enrolment, primary (% of gross)	World Bank (WDI)
Secondary School Enrolment	SSE	School enrolment, secondary (% of gross)	World Bank (WDI)
Tertiary School Enrolment	TSE	School enrolment, tertiary (% of gross)	World Bank (WDI)
Education in KE	Educatex	First PC of PSE, SSE & TSE	PCA
		Panel B: Information & Infrastructure	
Internet Users	Internet	Internet users (per 100 people)	World Bank (WDI)
Mobile Cellular Subscriptions	Mobile	Mobile subscriptions (per 100 people)	World Bank (WDI)
Telephone lines	Tel	Telephone lines (per 100 people)	World Bank (WDI)
Information & Communication Technology (ICT) in KE	ICTex	First PC of Internet, Mobile & Tel	PCA
		Panel C: Economic Incentives & Institutional Regime	
Financial Activity (Credit)	Pcrbof	Private domestic credit from banks and other financial institutions	World Bank (FDSD)
Interest Rate Spreads	IRS	Lending rate minus deposit rate (%)	World Bank (WDI)
Economic Incentives in KE	Creditex	First PC of Pcrbof and IRS	PCA
Corruption-Control	CC	Control of Corruption (estimate): Captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests.	World Bank (WDI)
Rule of Law	RL	Rule of Law (estimate): Captures perceptions of the extent to which agents have confidence in and abide by the rules of society and in particular the quality of contract enforcement, property rights, the police, the courts, as well as the likelihood of crime and violence.	World Bank (WDI)
Regulation Quality	RQ	Regulation Quality (estimate): Measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	World Bank (WDI)
Political Stability/ No violence	PS	Political Stability/ No Violence (estimate): Measured as the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional and violent means, including domestic violence and terrorism.	World Bank (WDI)
Government Effectiveness	GE	Government Effectiveness (estimate):	World Bank (WDI)

		Measures the quality of public services, the quality and degree of independence from political pressures of the civil service, the quality of policy formulation and implementation, and the credibility of government's commitments to such policies.	
Voice & Accountability	VA	Voice and Accountability (estimate): Measures the extent to which a country's citizens are able to participate in selecting their government and to enjoy freedom of expression, freedom of association, and a free media.	World Bank (WDI)
Institutional Regime in KE	Instireg	First PC of CC, RL, RQ, PS, GE & VA	PCA
		Panel D: Innovation	
Scientific & Technical Publications	STJA	Number of Scientific & Technical Journal Articles	World Bank (WDI)
Trademark Applications	Trademark	Total Trademark Applications	World Bank (WDI)
Patent Applications	Patent	Total Residents + Nonresident Patent Applications	World Bank (WDI)
Innovation in KE	Innovex	First PC of STJA, Trademarks and Patents	World Bank (WDI)

WDI: World Bank Development Indicators. GDP: Gross Domestic Product. PC: Principal Component. PCA: Principal Component Analysis. Educatex is the first principal component of primary, secondary and tertiary school enrolments. ICTex: first principal component of mobile, telephone and internet subscriptions. Creditex: First PC of Private domestic credit and interest rate spread. P.C: Principal Component. VA: Voice & Accountability. RL: Rule of Law. R.Q: Regulation Quality. GE: Government Effectiveness. PS: Political Stability. CC: Control of Corruption. Instireg (Institutional regime): First PC of VA, PS, RQ, GE, RL & CC.

Appendix 2: Summary statistics

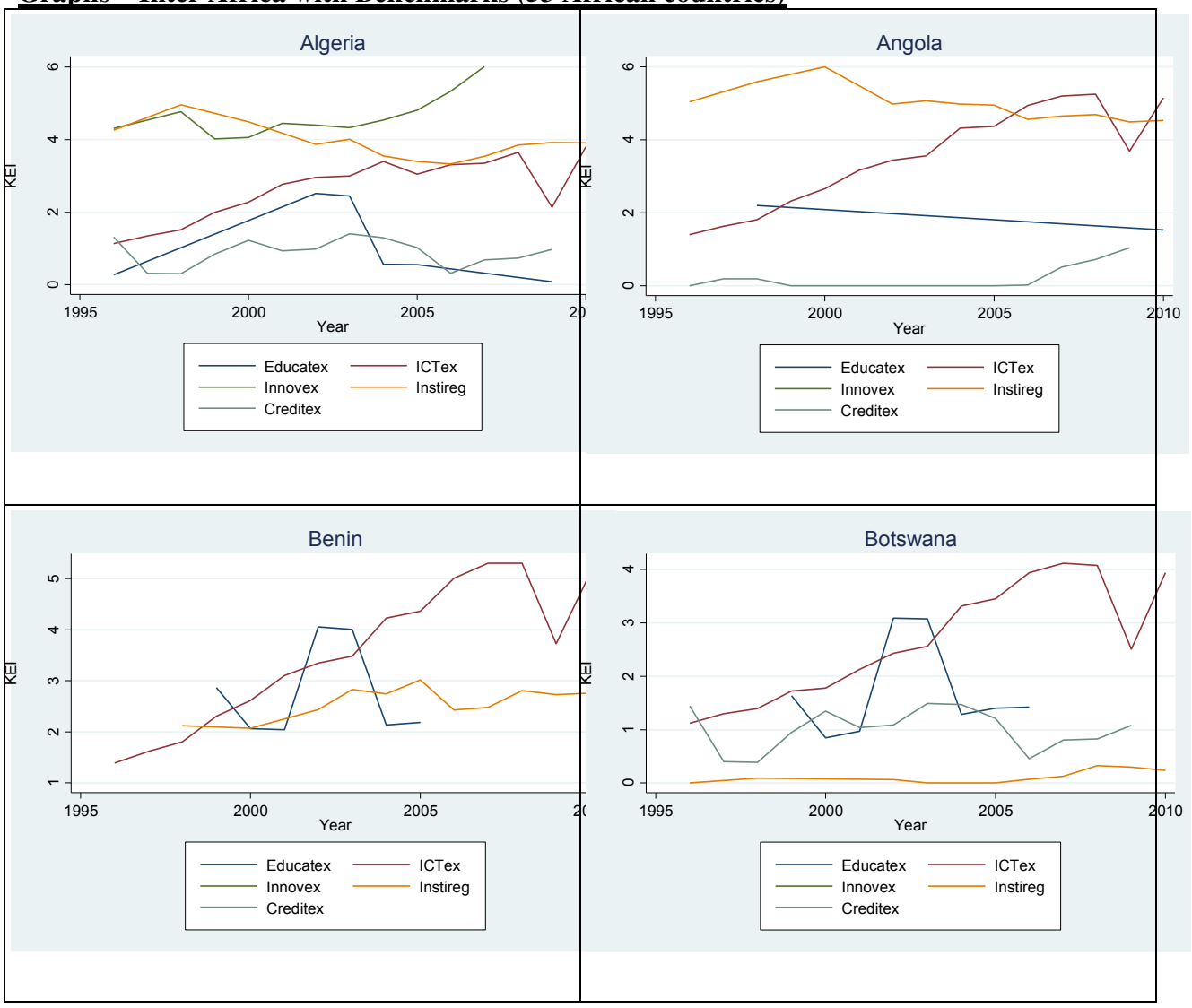
	Mean	S.D	Min	Max	Obs.
Educatex (Education)	-0.075	1.329	-2.116	5.562	320
ICTex (Information & Infrastructure)	0.008	1.480	-1.018	8.475	765
Creditex (Economic Incentive)	-0.083	0.893	-4.889	2.041	383
Instireg (Institutional Regime)	0.105	2.075	-5.399	5.233	598
Innovation (Innovex)	1.021	2.542	-0.770	8.859	102

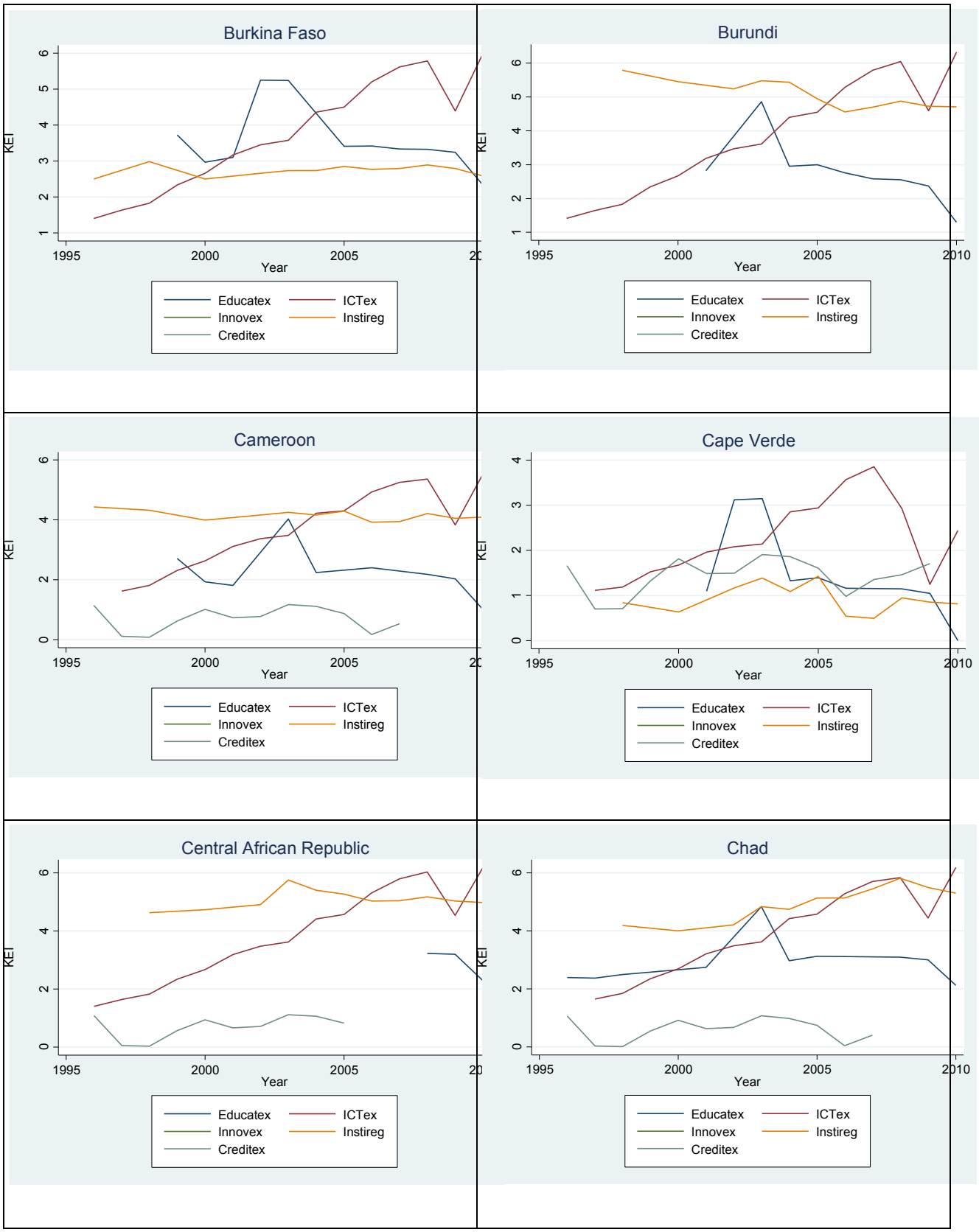
Appendix 3: Correlation Analysis

Education				ICT				Innovation				Eco Incentive			Institutional Regime							
PSE	SSE	TSE	Educatex	Inter	Mob	Tel	ICTex	STJA	TM	Pat	Innovex	Pcrd	IRS	Creditex	CC	RL	RQ	PS	GE	VA	Instireg	
1.00	0.42	0.27	0.64	0.24	0.27	0.25	0.30	0.10	0.07	0.07	0.11	0.16	0.08	-0.01	0.16	0.23	0.21	0.24	0.25	0.22	0.24	PSE
	1.00	0.74	0.91	0.57	0.59	0.82	0.75	0.43	0.57	0.61	0.74	0.62	-0.36	-0.62	0.55	0.55	0.35	0.43	0.59	0.35	0.55	SSE
		1.00	0.84	0.46	0.40	0.59	0.57	0.57	0.50	0.69	0.83	0.61	-0.27	-0.51	0.21	0.29	0.14	0.10	0.35	-0.05	0.21	TSE
			1.00	0.58	0.51	0.69	0.69	0.48	0.43	0.53	0.65	0.63	-0.24	-0.54	0.41	0.46	0.31	0.29	0.51	0.17	0.43	Educatex
				1.00	0.72	0.58	0.90	0.24	0.27	0.18	0.27	0.45	0.01	-0.42	0.28	0.33	0.21	0.25	0.36	0.18	0.32	Inter
					1.00	0.47	0.86	0.26	0.38	0.47	0.54	0.45	-0.10	-0.46	0.25	0.30	0.25	0.29	0.31	0.16	0.29	Mob
						1.00	0.78	0.27	0.36	0.41	0.51	0.56	-0.12	-0.54	0.50	0.57	0.33	0.43	0.56	0.33	0.53	Tel
							1.00	0.39	0.50	0.39	0.50	0.56	-0.08	-0.55	0.39	0.45	0.30	0.37	0.46	0.25	0.43	ICTex
								1.00	0.83	0.90	0.96	0.78	-0.09	-0.77	0.21	0.23	0.29	0.01	0.36	0.15	0.26	STJA
									1.00	0.91	0.93	0.89	-0.31	-0.89	0.32	0.26	0.41	0.01	0.50	0.33	0.35	TM
										1.00	0.97	0.86	-0.34	-0.91	0.47	0.42	0.54	0.27	0.61	0.57	0.55	Pat
											1.00	0.93	-0.39	-0.94	0.49	0.46	0.60	0.28	0.71	0.50	0.57	Innovex
												1.00	-0.31	-0.96	0.53	0.51	0.51	0.27	0.64	0.39	0.55	Pcrd
													1.00	0.54	-0.23	-0.25	-0.32	-0.15	-0.21	-0.16	-0.26	IRS
														1.00	-0.56	-0.54	-0.52	-0.30	-0.68	-0.51	-0.60	Creditex
															1.00	0.87	0.72	0.68	0.83	0.66	0.88	CC
																1.00	0.81	0.79	0.88	0.72	0.95	RL
																	1.00	0.63	0.81	0.70	0.86	RQ
																		1.00	0.64	0.65	0.80	PS
																			1.00	0.68	0.92	GE
																				1.00	0.82	VA
																					1.00	Instireg

ICT: Information & Communication Technology. Eco: Economic. PSE : Primary School Enrolment. SSE: Secondary School Enrolment. TSE: Tertiary School Enrolment. Educatex: Edication index (first principal component of PSE, SSE & TSE). Inter: Internet Penetration. Mob: Mobile Phone Penetration. Tel: Telephone Subscriptions. ICTex: ICT index (first principal component of Inter, Mob & Tel). STJA: Scientific & Technical Journal Articles. TM: Trademark Applications. Pat: Patent Applications. Innovex: Innovation index (first principal component of STJA, TM & Pat). Pcrd: Private Domestic Credit. IRS: Interest Rate Spread. Creditex: Economic Incentive index (first principal component of Pcrd & IRS). CC: Corruption-Control. RL: Rule of Law. RQ: Regulation Quality. PS: Political Stability. GE: Government Effectiveness. VA: Voice & Accountability. Instireg: Institutional Regime index (first principal component of CC, RL, RQ, PS, GE & VA).

Graphs – Inter Africa with Benchmarks (53 African countries)

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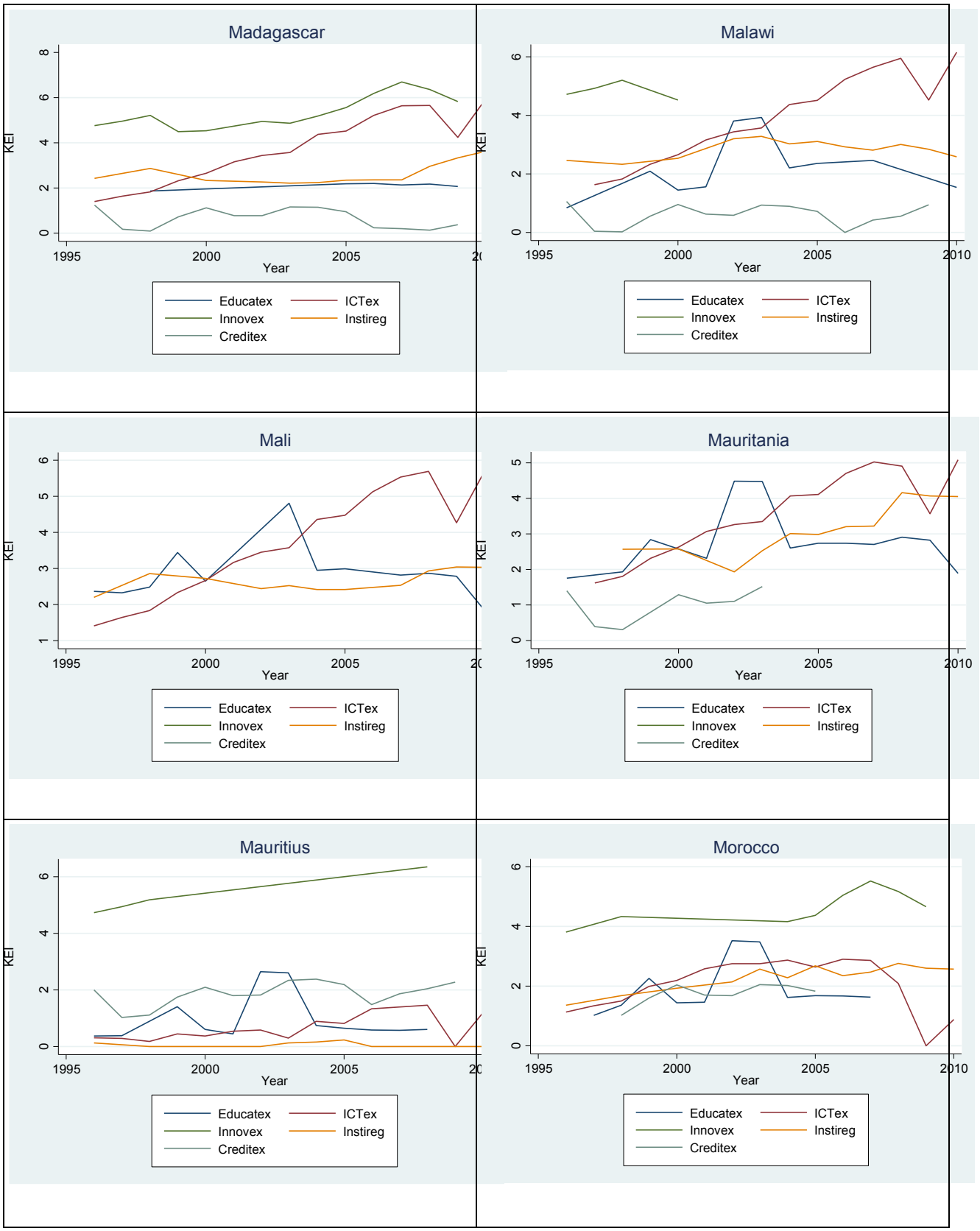
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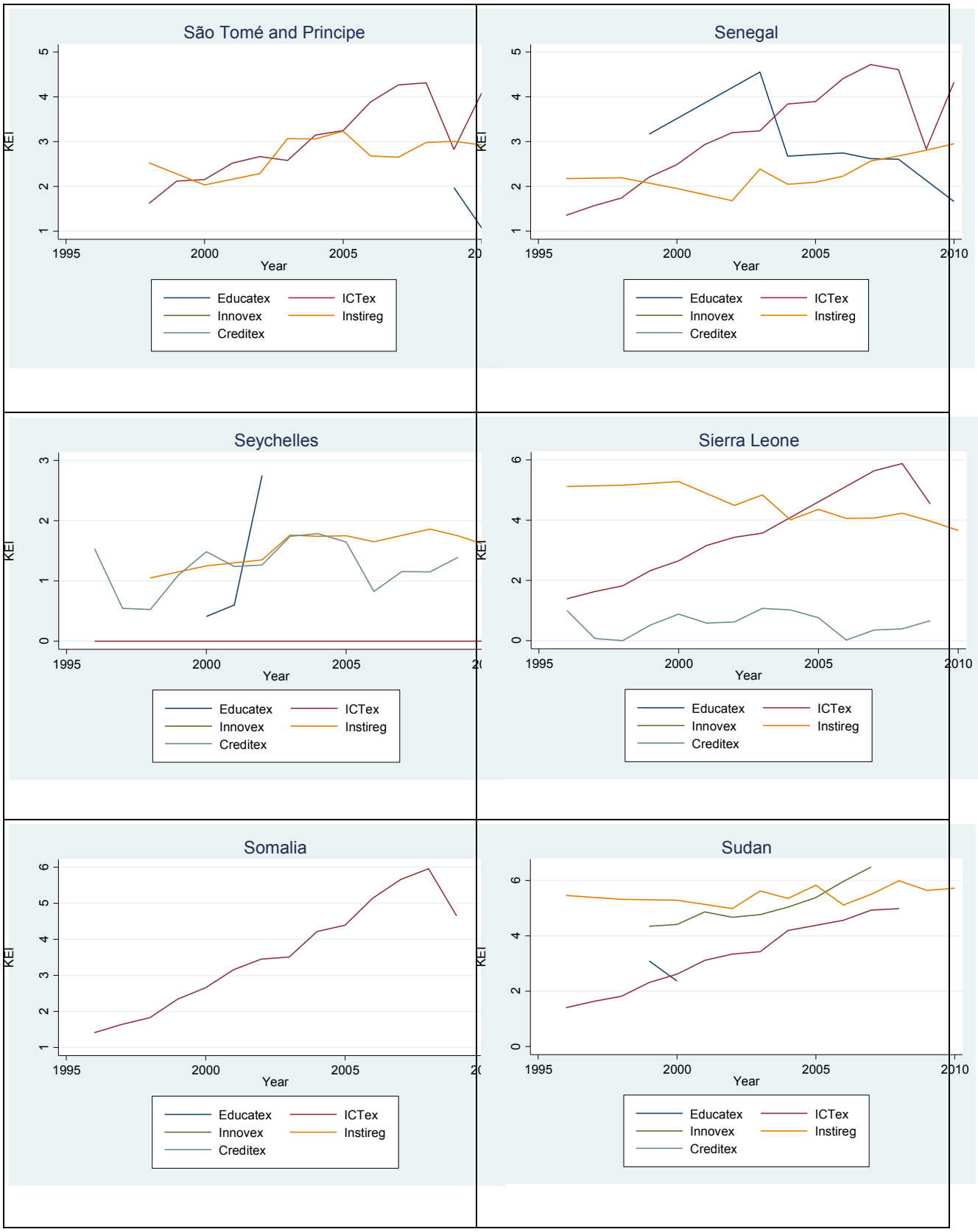
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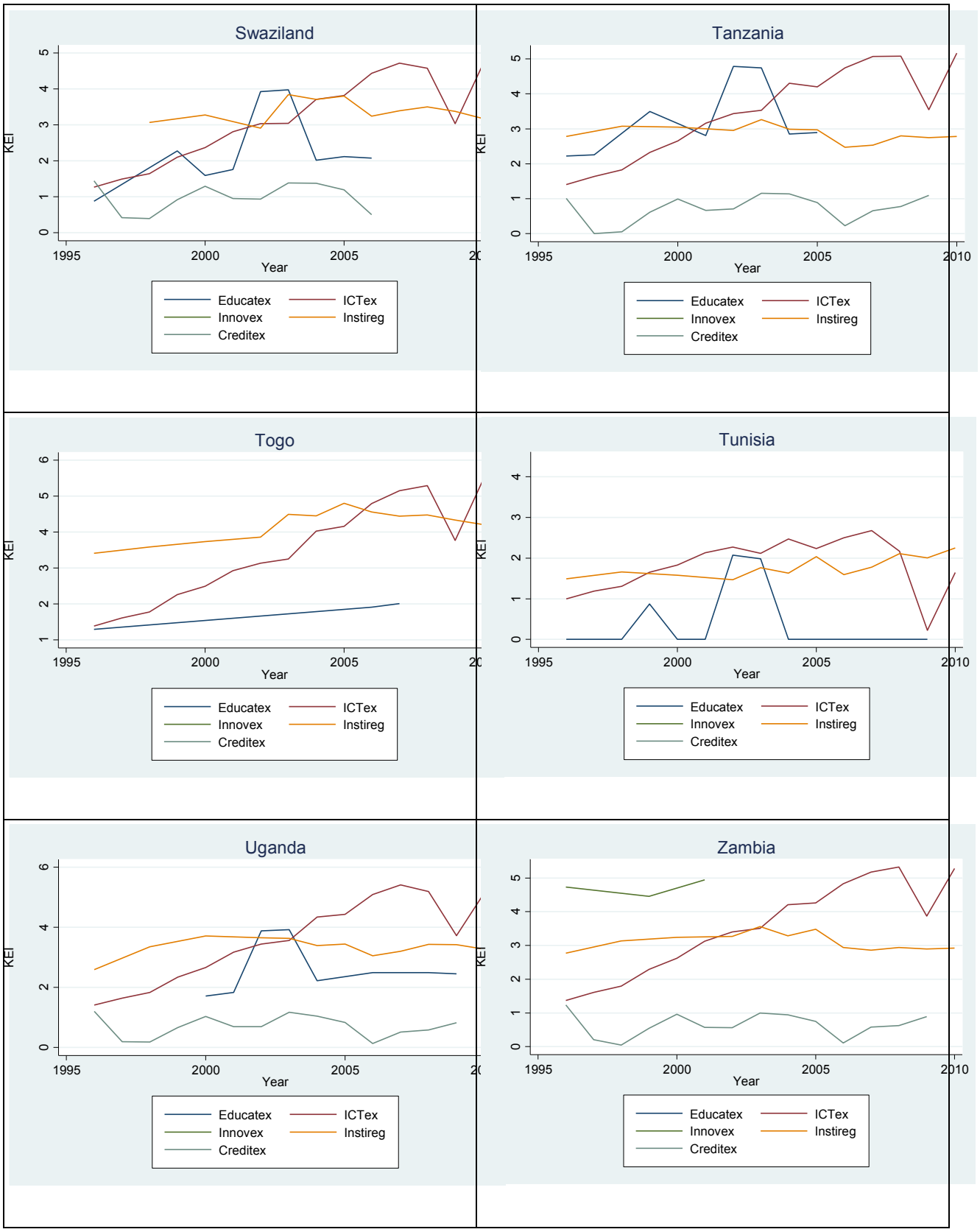
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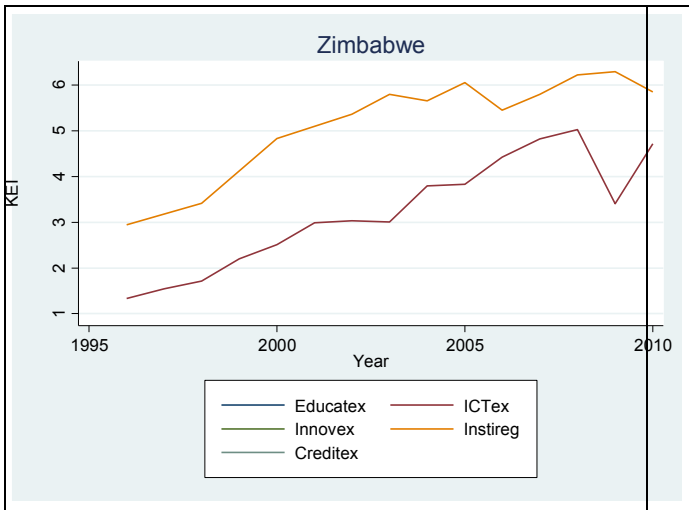
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