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Knowledge Economy Gaps, Policy Syndromes, and Catch-Up Strategies: Fresh South Korean Lessons to Africa

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Abstract Africa's overall knowledge index fell between 2000 and 2009. South Korea's economic miracle is largely due to a knowledge-based development strategy that holds valuable lessons for African countries in their current pursuit towards knowledge economies. Using updated data (1996–2010), this paper presents fresh South Korean lessons to Africa by assessing the knowledge economy (KE) gaps, deriving policy syndromes, and providing catch-up strategies. The 53 peripheral African countries are decomposed into fundamental characteristics of wealth, legal origins, regional proximity, oil-exporting, political stability, and landlockedness. The World Bank's four KE components are used: education, innovation, information and communication technology (ICT), and economic incentives and institutional regime. Absolute beta and sigma convergence techniques are employed as empirical strategies. With the exception of ICT for which catch-up is not very apparent, in increasing order, it is visible in innovation, economic incentives, education, and institutional regime. The speed of catch-up varies between 8.66 and 30.00 % per annum with respective time to full or 100 % catch-up of 34.64 and 10 years. Based on the trends and dynamics in the KE gaps, policy syndromes and compelling catch-up strategies are discussed. Issues standing on the way to KE in Africa are dissected with great acuteness before South Korean relevant solutions are provided to both scholars and firms. The paper is original in its provision of practical policy initiatives drawn from the Korean experience to African countries embarking on a transition to KE.

Keywords Knowledge economy · Catch-up · South Korea · Africa

JEL Classification O10 · O30 · O38 · O55 · O57

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Introduction

The phenomenon of globalization has become an ineluctable process whose challenges can be neglected only by sacrificing the prosperity of nations. It is increasingly relevant today that for nations to be competitive and integrated into or involved in the world economy, they have to play by competitive rules that come with embracing globalization. Twenty-first-century competition is centered on knowledge economy (KE), a golden rule that has emerged as a key theme in the Organization of Economic Cooperation and Development (OECD) and World Bank reports since the start of the third millennium (World Bank 2007; Weber 2011).

It is in this spirit that the dynamics of KE have been mastered by North America and Europe, who are inexorably charting the course of development in the international arena. In calculated steps, Latin America and Asia have been growingly asserting the need for KE in their pursuits of national and regional initiatives (Dahlman 2007; Chandra and Yokoyama 2011; Tchamyou 2014). The historic pattern formulated by Japan has set the course for China, Malaysia, and the Newly Industrialized Economies of Asia (Singapore, Taiwan, Hong Kong, and South Korea). These nations have been witnessing a remarkable march from post-industrialization era "product-based economies" to "knowledge-based economies." The East Asian Miracle has left many scholars and policy makers debating on the implications and lessons for Africa (Kim 2013). Among the Newly Industrialized Economies of Asia, South Korea[1] has increasingly been the object of comparison with African countries because it was far less developed than most countries in the continent in the aftermath of colonial independence (Tran 2011). Aware of the fact that twenty-first development is KE-centered and Africa's lagging global position in KE, Korea's KE experience is an important benchmark for development prospects in the continent, especially when its overall knowledge index fell between 2000 and 2009 (Anyanwu 2012).

While a substantial portion of the literature has focused on the emerging economies of Latin America and Asia, very scanty scholarly attention has been devoted to African countries (Dahlman 2007; Chavula 2010; Chandra and Yokoyama 2011). However, in recent years KE themes have been increasingly taking central stage in discussions on development in the continent (AfDB 2007; Amavilah 2009; Asongu 2013a; Andrés and Asongu 2013a, b; Nyarko 2013a; Andrés et al. 2014). Indeed, a recent stream of literature is consistent with the imperative for urgent policy measures needed to foster the drive towards African KE, inter alia, general discourses about KE in the continent (Rooney 2005; Lin 2006; Anyanwu 2012), education (Ford 2007; Amavilah 2009; Chavula 2010; Weber 2011; Wantchekon et al. 2014), information and communication technologies (African Partnership Forum 2008; Chavula 2010; Butcher 2011), innovation (Oyelaran-Oyeyinka and Gehl Sampath 2007; Anyanwu 2012; Carisle et al. 2013), institutional regime and economic incentives (Cogburn 2003; Letiche 2006; Saxegaard 2006; Nguena and Tsafack 2014; Andrés et al. 2014; Andrés and Asongu 2013a), intellectual capital and economic development (Wagiciengo and Belal 2012; Preece 2013), indigenous knowledge systems (Raseroka 2008; Lwoga et al. 2010), research and development (German and Stroud 2007; African Development Bank 2007; Sumberg 2005), intellectual property rights (Zerbe 2005; Lor and Britz 2005; Myburgh

[1] South Korea and Korea are used interchangeably throughout the paper.

2011; Andrés and Asongu 2013a, b; Andrés et al. 2014; Asongu 2013a), spatiality in knowledge production (Bidwell et al. 2011; Neimark 2012), and KE in the transformation of space (Moodley 2003; Maswera et al. 2008).

The above narratives are also predominantly motivated by the need for greater emphasize on KE-based research that focuses on strategies towards bridging the gaps between benchmark countries (AfDB 2007; Bizri 2009; Aubert 2005; Britz et al. 2006; Chavula 2010; Makinda 2007; Lightfoot 2011). To the best of our knowledge, there is yet no African KE study that has addressed this concern with respect to benchmark Newly Industrialized Asian countries. The present paper aims to investigate the gaps in KE between Africa and South Korea. Based on assessed gaps, we provide recommendations from resulting catch-up policy syndromes. The updated dataset (1996–2010) essential for fresh policy measures also enables us to examine if the impressive growth experienced by some African countries during the past decade has been accompanied by similar patterns of catch-up in KE dimensions relative to South Korea.

In line with Suh and Chen (2007), the dramatic economic prosperity experienced by South Korea since the 1960s that enabled it to emerge from a low-income country to a high-income industrialized nation could substantially be attributed to the accumulation of knowledge rather than to traditional factors of labor and capital in production. According to the narrative, Korea was able to achieve this knowledge-oriented prosperity by heavily investing in training and education, developing accessible and modern information infrastructure, using intensive research and development (R&D) to boost innovation, focusing on economic incentives, and a favorable institutional regime that were conducive to boosting knowledge-oriented investments. In this light, the country has been able to use KE as an engine for growth: an experience that could offer lessons for developing countries, especially frontier African nations that were at the same development threshold as the core country in the 1960s.

The Korea-Africa relationship is a relatively little studied nexus in contemporary development literature (Kim 2013). This is probably due to the skepticism about South Korea as a role model of development for other countries.[2] However recent evidence suggests that the core country can serve as a role model of development for other emerging countries, particularly in terms of KE (Lee 2009). By using the South Korean KE experience as a frontier model for peripheral African countries, the paper also extends studies on "achieving development success: strategies and lessons from the developing world" (Fosu 2013a; Lee 2013; Jomo and Wee 2013; Warr 2013; Thoburn 2013; Khan 2013; Singh 2013; Yao 2013; Santos-Paulino 2013; Asongu and Aminkeng 2013; Robinson 2013; Subramanian 2013; Lundahl and Petersson 2013; Fosu 2013b; Naudé 2013; De Mello 2013; Solimano 2013; Trejos 2013; Pozo et al. 2013; Cardoso 2013; Looney 2013; Baliamoune-Lutz 2013; Nyarko 2013b; Drine 2013). Within the framework of this study, the "frontier" KE country is South Korea because it represents best practices that African countries in the KE periphery should emulate in closing the KE gaps.

In light of the above, by positioning this paper on the important development concern of KE and the relatively little investigated Korean-African nexus, this study contributes to existing literature by addressing the following policy issues. First, the

[2] "There is some scepticism about Korea as role model of development as the Korean model involved a considerable degree of state activism, unacceptable in today's global environment" (Lee 2009, p. 1).

paper provides a KE diagnosis on the current growth situation and prospects of peripheral African countries by investigating the KE gaps in relation to a frontier country (South Korea) and providing compelling catch-up policies to bridge the KE gaps. Second, the study also presents a unique opportunity of examining whether the impressive growth experienced over the last decade by African countries has moved hand-in-hand with identical catch-up trends in KE, relative to South Korea. Third, in response to a growing strand of studies on the need for KE as the main axis of future development (Makinda 2007; Lightfoot 2011), a comparison with South Korea is ideal in understanding growth prospects of Africa. Accordingly, very practical policy lessons are offered to African countries already embarking on the route to KE. Fourth, the decomposition of peripheral countries into fundamental characteristics of income levels, legal origins, openness to sea, political stability, natural resources, and regional proximity enable comparative insights for more focused policy implications.

The intuition and theoretical motivations underpinning this KE catch-up are typically in line with cross-country income convergence literature substantially documented within the framework of neoclassical models of growth and recently extended to other fields of economic development (Swan 1956; Barro 1991; Mankiw et al. 1992; Solow 1956; Baumol 1986; Barro and Sala-i-Martin 1992, 1995; Narayan et al. 2011; Andrés and Asongu 2013a, b; Fung 2009; Mayer-Foulkes 2010; Bruno et al. 2012; Asongu 2013a, b, c, 2014a, b, c). In this light, the theoretical underpinnings have been used in the harmonization/timing/modeling of intellectual property rights (IPRs) on software piracy (Asongu 2013a; Andrés and Asongu 2013b), common measures in the fight against capital flight (Asongu 2013d; 2014d), as well as the health of currency areas and financial markets (Narayan et al. 2011; Bruno et al. 2012; Asongu 2013b, 2014b, c).

The World Bank's four dimensions of the Knowledge Economy Index (KEI) are employed, notably information and communication technology (ICT), innovation, economic incentives and institutional regime, and education. This employment of a plethora of KE dimensions is essentially motivated by the fact that existing literature has focused only on one or a few KEI components (Aubert 2005; Britz et al. 2006; AfDB 2007; Bizri 2009). The empirical evidence is based on 13 panels. Accordingly, because of the richness of the dataset, we are able to disaggregate countries into fundamental characteristics of KE based on income levels, legal origins, petroleum-exporting, openness to sea, political stability, and regional proximity. Three main issues are investigated between the homogenous panels and South Korea: KE gaps or evidence of catch-up, the speed or rate of catch-up, and the corresponding time needed for full catch-up. To ensure robustness in the assessments, both *sigma* and *beta* catch-up empirical strategies are employed. Based on the findings from the three concerns assessed, we are able to provide catch-up policies necessary to bridge the KE gaps.

Beside specific policy recommendations that would emerge from the catch-up estimations, we are comfortable that four main categories of policy implications would emerge from the proposed study. First, the presence or not of catch-up informs policy makers on the various KE gaps vis-à-vis South Korea. Second, decomposing Africa into fundamental characteristics (legal origins, income-levels… etc.), provides the analytical subtlety needed for more targeted policy implications. Third, the rate of convergence and time needed for full convergence inform policy makers about the urgency of measures needed for bridging the KE gaps. Fourth, common catch-up trends among fundamental characteristics are relevant in informing policy on the effectiveness

of current regional integration efforts in the investigated KE dimensions. In summary, the research question addressed by this inquiry is to what extent are African countries catching-up with South Korea in terms of KE dimensions?

The rest of the study is organized as follows. South Korea as a KE is presented first, then the importance of learning from success stories is highlighted. Data and methodology are discussed next, followed by the empirical analysis, discussion of results, and policy implications, and ends with a conclusion.

South Korea as a Knowledge Economy and Learning from Success Stories

In line with recent literature (Suh and Chen 2007; Tchamyou 2014), the South Korean Republic has experienced one of the most spectacular growths in the twentieth century, starting as a low-income nation in the 1950s to an industrialized OECD economy by the turn of the century. While a development strategy that clearly articulated knowledge was not apparent, development of the economy critically hinged on interactions among the four dimensions of the World Bank's KEI, notably innovation, education, ICT, economic incentives and institutional regime. Characteristics of the development model included, inter alia, human resource development fortified with technological capacity building and intensive learning processes; proactive leadership by government in providing, sustaining, and fostering transformations; promotion of export- and import-substitution industries… etc. South Korea has often been used as a development model for Africa because it lagged behind most African countries even before the 1980s.[3]

Consistent with Lee (2009) and Lee and Kim (2009), Korea can be used as a model for African countries because it has achieved so far one of the most rapid economic prosperities in recent history: from below 91.62 USD in 1961 to over 22,000 USD in 2011.[4] According to the narrative, because of the skepticism over whether Korea could serve as a model for other developing nations, earlier literature focused on the mission of market versus government in catch-up processes (Amsden 1989; Chang 1994; World Bank 1993). This has been parallel to another stream of the literature contending that Korea has been catching-up by assimilating and adapting to seemingly obsolete technology from advanced countries (Utterback 1975; OECD 1992; Hobday 1995; Dahlman et al. 1985; Andrés and Asongu 2013a; Andrés et al. 2014).

Consistent with Andrés et al. (2014), the ongoing debate about the "East Asian miracle" has been on "governing the market" and/or "soft authoritarian" concepts. It is based on the fact that certain politico-economic conditions (especially in South Korea) have been conducive for the miracle. This narrative also sustains that some scholars advocate the miracle might have resulted from the low enforcement of IPRs at the early stages of development (Bezmen and Depken 2004). This is consistent with the recent

[3] For instance, "After the Korean war, South Korea was one of the world's poorest countries with only $64 per capita income. Economically, in the 1960s it lagged behind the Democratic Republic of the Congo (DRC) – currently holding elections marred by violence. Since then the country's fortunes have diverged spectacularly. South Korea now belongs to the rich man's club, the OECD development assistance committee (DAC). The DRC has gone backwards since independence and, out of 187 countries, ranked bottom in the 2011 Human Development Index" (Tran 2011).

[4] Source of per capita values: http://www.indexmundi.com/facts/korea/gdp-per-capita (accessed on 14/06/2015).

findings of Kim et al. (2012) who have concluded that the protection of patent is instrumental in innovation, with patentable innovation contributing to economic prosperity in developed, but not in developing countries (Kim et al. 2012). On the other hand, some authors have argued that there is nothing to be miraculous about the East Asian miracle (Lucas 1988, 1993). A recent strand of KE literature has been substantially devoted to analyzing this miracle in the context of Africa. Notably, the enforcement of IPRs through governance channels not being a sufficient condition for KE in the sub-Saharan Africa (SSA) and Middle East and North African (MENA) countries (Andrés et al. 2014), timelines for the fight against piracy (Asongu 2013a; Andrés and Asongu 2013b), and corruption as the greatest fuel to software piracy and hence deterrence to the potential for KE (Andrés and Asongu 2013a, b). In the catch-up literature specifically positioned on South Korea, Lee (2009) has debunked the skepticism surrounding the Korean experience as a model for other developing countries by arguing that capacity building, standard trade openness, and devaluation cannot result in sustained catch-up because they grease short-run and temporary booms for the most part. The study has analyzed the manner in which Korea made use of various access modes to knowledge and learning in order to boost technological capabilities. The author has concluded that the Korean lessons are transferable to other countries, thus confirming an earlier report that recommended the Korean model to other developing countries (Suh and Chen 2007). The present study is therefore a response to the above-recommended future research directions.

The paper is also an extension of studies on "achieving development success: strategies and lessons from the developing world" (Fosu 2012, 2013a) and learning from the past (Fosu 2010). The papers have focused on South Korea, Malaysia, Thailand, and Vietnam in East Asia and the Pacific (Lee 2013; Jomo and Wee 2013; Warr 2013; Thoburn 2013; Khan 2013); the emerging Asian giants of China and India (Singh 2013; Yao 2013; Santos-Paulino 2013; Asongu and Aminkeng 2013); sub-Saharan Africa with examples of Botswana, Mauritius, Ghana, and South Africa (Robinson 2013; Subramanian 2013; Lundahl and Petersson 2013; Fosu 2013b; Naudé 2013); Latin America and the Caribbean in which emphasis is placed on Brazil, Costa Rica, Chile, and the Dominican Republic (De Mello 2013; Solimano 2013; Trejos 2013; Pozo et al. 2013; Cardoso 2013); and the MENA region with analyses from Oman, Bahrain, Tunisia, and the United Arab Emirates (Looney 2013; Baliamoune-Lutz 2013; Nyarko 2013b; Drine 2013).

Starkly contrasting with the skeptical narrative on lessons for developing countries (Lucas 1988, 1993; Lee 2009), a common denominator to studies in the preceding paragraph is the position that compelling lessons could be conditionally drawn from other successful developing countries. In other words, every developing success story has a dimension. Consistent with Fosu (2013a), they portray a substantial diversity in development strategies, inter alia, the "disinterested-government" political economy of China; the high-sector and democratically based Indian development approaches; reforms in China and Ghana based on the "Washington-Consensus"; the strategies of diversification in Bahrain, the United Arab Emirates (UAE), and Oman; the optimal natural-resource management strategies of the UAE, Oman, Botswana, and Bahrain; the social-sector development programs underpinning progress in Tunisia and Costa Rica; the democratic political system of diversity management in India; and the dynamic orthodox-heterodox strategy in Vietnam and Malaysia.

Inspired by above narratives, this paper is positioned on the KE success story of South Korea with particular emphasis on Africa. The interesting narratives highlighted in the introduction can be summarized into one sentence: the need for greater emphasis on KE in Africa as a development strategy.

But before we engage the empirical analysis, it is worthwhile to briefly discuss on the one hand, the roles of foreign aid and technology transfer in South Korea's KE development and on the other hand, a broader global political economy underlying the line of inquiry, notably (i) some obstacles presented by advanced industrial nations like patent/licensing issues and (ii) the global unfavorable economic context for trade and exports from Africa.

According to estimates from the Korean government, the country received about 12.7 USD billion between 1945 and the mid-1990s (OECD 2008, p. 9). This helped mitigate poverty, spur economic development, and enhance the viability of KE strategies. This inference is consistent with the position by Asongu (2015) that South Korea's KE development was also substantially aid-driven.

Harnessing the potential for technology and science by South Korea has depended for the most part on foreign technologies (Pillay 2010, p. 73). According to the account, at the launch of the country's economy-wide development plan, apart from the availability of a massive labor force, she was not well endowed with factors needed for industrialization. Given that South Korean firms lagged substantially in terms of technological competence by world standards, she looked for foreign sources of technology immediately after the process of industrialization was launched in 1962. The technological capability process in South Korea has been characterized as one entailing the interplay between indigenous R&D efforts and imported technologies. It should be noted that (i) the underlying R&D efforts have substantially been the outcome of initiatives by research institutes instead of universities and (ii) the configuration of the country's system of innovation is fundamentally shaped by strategies of economic development.

There has been considerable disagreement in the legal protection of advance technology between developing and advanced industrialized countries since the 1960s. The debate has principally centered on the patent system, which less industrialized countries have been attempting to change in order to boost technology transfer to their economies. In many developing countries, the level of protection granted to patent holders was reduced at the Paris Convention while a new code of conduct on technology transfers was being amended (Van Wijk and Junne 1993, pp. 29–31).

According to Fofack (2014, p. 7), after more than 30 years of the neoliberal experiment, Africa is the only region of the developing world that would not attain the Millennium Development Goal (MDG) extreme poverty target of halving poverty by 2015 from 2010. The continent's contribution to world trade has dropped to below 1.5 % from over 3.8 % in the 1950s. These three decades of neoliberal experiment have been qualified as, inter alia, the lost decades and twentieth century's economic tragedy. Meanwhile, during the same period, in Asia and particularly in South Korea where the notion of "development state" did not change significantly with globalization of the dogma of neoliberalism, living standards have improved and poverty substantially mitigated. The April 15, 2015 publication of the World Bank Development Indicators has revealed that poverty has been decreasing in all regions of the world with the exception of sub-Saharan Africa (Asongu and Kodila-Tedika 2015). Accordingly, about 45 % of countries in the sub-region are off-track from attaining the MDG poverty target.

Data and Methodology

Data Highlights and Fundamental Characteristics

We examine 53 African countries with data from principal component analysis (PCA) and World Development Indicators for the period 1996–2010. The investigated interval begins from 1996 because government quality indicators essential for the institutional regime component of KE are not available before this year. The data ends in 2009/2010 to be consistent with studies documenting a drop in the overall KE index of Africa (Anyanwu 2012). The KE variables that are obtained from the former source are consistent with recent literature (Andrés et al. 2014; Andrés and Asongu 2013a, b). These KE variables include innovation, ICT, education, and economic incentives and institutional regime. We devote space to discussing the determination of fundamental characteristics in peripheral African countries. These include legal origins (English common law versus (vs) French civil law), income levels (low- vs middle-income), openness to sea (landlocked vs not landlocked), political stability (conflict-affected vs stability), regional proximity (sub-Saharan Africa vs North Africa), and natural resources (petroleum vs non-petroleum-exporting) countries. The fundamental characteristics are in accordance with recent KE literature (Andrés and Asongu 2013a).

First, the basis of legal origin has foundations on the substantially documented evidence of colonial legacy on openness, education and economic growth (Agbor 2011), institutional quality (La Porta et al. 1998, 1999), and adaptation to changes in economic conditions (Beck et al. 2003). Agbor (2011) has recently documented that in Africa, English common law countries have a better educational system and economic incentives that have given them an edge in economic prosperity over their French civil law counterparts. In terms of institutional quality (or regime), the edge of English common law documented in pioneering law-finance literature (La Porta et al. 1998, 1999) has been recently confirmed in the African continent (Asongu 2012a, b). The underlying intuition for this categorization is that informal rules, formal norms, and enforcement measures which potentially influence an institutional regime are necessary for KE. This narrative has a consensus that whereas French civil law places more emphasis on the power of the state, private property rights that are needed for KE is prioritized by English common law. The classification of countries in this dimension is in line with La Porta et al. (2008, p. 289).

Some practical issues could arise when assigning countries to the "conflict-affected" category. This is essentially because it is not easy to assign a country to this strand in exclusive and non-arbitrary manner. Some distinctions have to be made on the degree of significance and periodicity of instability because a country cannot be completely conflict free. Hence, this strand is presented in two groups. The first "civil war" group entails Burundi (1993–2005), Chad (2005–2010), Angola (1975–2002), Côte d'Ivoire (1999 coup d'état, 2002–2007 civil war, rekindled in 2011), Sierra Leone (1991–2002), Central African Republic (the wave of aborted coup d'états between 1996–2003 and the 2004–2007 Bush War), Congo Democratic Republic, Liberia (1999–2003), Sudan, and Somalia. On the second group, despite the absence of formal characteristics of civil war, we include Zimbabwe and Nigeria due to the seriousness of internal strife. From logic and common sense, severe conflict and political strife inhibit a favorable KE environment.

Third, in selecting petroleum-exporting countries, two issues arise. On the one hand, a country could qualify only for part of the investigated periodicity either because of a recent oil discovery or substantial decline in production. On the other hand, some countries (e.g., Botswana) have macroeconomic characteristics that are similar to those of oil-exporting countries. To tackle these constraints, we select only countries for which exports have been oil-dominated over the last decade and take a minimalistic approach in the categorization by adopting only oil-resource countries. These include Angola, Algeria, Chad, Cameroon, Congo Republic, Gabon, Equatorial Guinea, Nigeria, Libya, and Sudan.

Fourth, two main reasons motivate the dimension of wealth-effects with income levels. On the one hand, economic prosperity should come with higher opportunities for KE, and on the other hand, the wealth of African nations has been documented to be instrumental in institutional quality necessary for KE (Asongu 2012c). We use the Financial Development and Structure Database (FDSD) of the World Bank for the classification of wealth into low- and middle-income countries.

Fifth, the distinction between North and sub-Saharan African countries has two premises. On the one hand, proximity to Europe is likely to influence the drive towards KE. On the other hand, in accordance with Boyce and Ndikumana (2008), the distinction is consistent with the World Bank's regional classification in terms of policy implications.

Sixth, "openness to sea" should provide a relative KE advantage, such that landlocked countries incur higher costs to competition and openness, essential to KE. This is also in accordance with the institutional price of being landlocked (Arvis et al. 2007). Conversely, landlockedness could predispose certain countries to devote more efforts towards developing KE (e.g., Rwanda).

It is important to note that in the categorization of frontier KE African countries, some nations could qualify for more than one category. In contrast to Weeks (2012), we have not imposed any constrains on categorical priority such that a country may fall into as many categories as possible so long as it is consistent with the categorical features. Appendix 4 summarizes the categorization of peripheral African countries discussed above. Variables are defined in Appendix 1, the summary statistics presented in Appendix 2, and the correlation matrix displayed in Appendix 3.

Methodology

The first step in the empirical strategy consists of reducing the dimensions of the KE indicators with principal component analysis (PCA) discussed in "Principal Component Analysis" section below. The KE gaps are then assessed by means of sigma and absolute beta convergence strategies. Based on the latter estimations, we provide rates of catch-up and timelines for complete (full) catch-up. The former enables us to drive policy syndromes based on which catch-up strategies are recommended. While the methodology is highlighted here, it is discussed in detail concurrently with presentation of results to improve readability. For example, the computation of catch-up rates cannot easily be understood without corresponding estimated lagged values. But before we dive into the empirical analysis, it is worthwhile to justify the choice of the estimation strategies.

Borrowing from Asongu (2014a), there are substantial differences in ways in which convergence can be studied. Notably, convergence across economies versus (vs) convergence within an economy, convergence in terms of income vs. convergence in

terms of economic growth, TFP (total factor productivity) convergence vs. income convergence, stochastic convergence vs. deterministic convergence, sigma convergence vs. beta convergence, local or club-convergence vs. global convergence, and absolute (unconditional) vs. conditional convergence (Islam 2003).

There is some nexus between the highlighted definitions of convergence and the corresponding methodologies employed. This correspondence is not particularly unique since some have all employed beta convergence either conditionally or unconditionally (panel, time series, cross-sectional, informal and formal approaches). Most of the approaches have been oriented towards cross-economy per capita income convergence. In addition, the formal panel and cross-sectional approaches have been employed to investigate TFP and club convergence. The time series strategy has also been employed to assess both across- and within-economy convergence. The cross-sectional strategy has been used for sigma-convergence whereas the distribution measurement has been employed beyond the former and has assessed the whole shape of the distribution and intra-distribution dynamics.

The basic premise of income convergence is based on the assumption of decreasing returns which represent higher marginal productivity in capital-poor nations. Consistent with this narrative, poor countries would grow faster and a negative nexus between the subsequent growth rate and the initial income levels reflect the scenario. This form of convergence is beta convergence. However, as a draw-back of this approach, a negative beta from the initial growth levels is not necessarily synonymous to a reduction in dispersion. This shortcoming has given birth to the notion of sigma-convergence which is an assessment of cross-sectional standard deviations across time. While absolute beta convergence does not depend on country-specific characteristics, conditional beta convergence is contingent on these characteristics. Hence, the latter form of beta convergence has two critical shortcomings. On the one hand, the specification is substantially reliant on the conditionality of variables that are chosen for the model, which in certain situations may not reflect all the variables needed for the form of convergence to take place. On the other hand, the possibility of multiple equilibria since every nation could converge to its own long-term equilibrium or steady state (Asongu 2014a; Monfort 2008, pp. 4–5). In light of the above, the empirical strategies adopted in this paper are absolute beta convergence and sigma convergence. The absolute beta approach is based on yearly averages and means of fundamental characteristics for two reasons: enable comparison with sigma convergence and avoid misspecification in catch-up among peripheral countries. The latter point is very important because without usage of fundamental characteristics' means, the convergence could be among peripheral countries within a given homogenous panel and not with the core South Korean country. Hence, the empirical strategy may not address the problem statement.

Empirical Analysis

Principal Component Analysis

Consistent with recent literature (Tchamyou 2014; Asongu 2014e), constituent components of the World Bank's Knowledge Economy Index (KEI) may be correlated with each other. Hence, due to the high degree of substitution among the constituent

components, some information is redundant. We tackle the issue by using PCA in order to reduce the dimensions of the variables into a single indicator for each component.[5] The PCA is a widely employed empirical strategy that consists of reducing a set of highly correlated variables into a smaller set of uncorrelated indicators called principal components (PCs) that represent a significant variation in or information from the initial set of indicators. The criterion employed to retain a common factor is consistent with Kaiser (1974) and Jolliffe (2002) who have recommended stopping at factors with an eigenvalue greater than the mean (or one). This eigenvalue corresponds to the eigenvector that represents a significant proportion of the initial information.

Table 1 below shows PCA in KE components for African peripheral countries (panel A) and the South Korean frontier country (panel B). PCAs are needed for both frontier and peripheral countries to illustrate that based on the eigenvalues (reflecting the vectors), the KE dimensions are comparable. In panel A for instance, ICTex which is the first PC for ICT represents about 73 % of information in constituent elements (internet, mobile, and telephone) and has an eigenvalue of above one (2.190). This is comparable with a corresponding 80 % in panel B.

Knowledge Economy Gaps

Absolute Beta Convergence

Catch-Up Specification The two equations below are the standard procedures for estimating convergence (Fung 2009).

$$\ln\left(Y_{i,t}\right)-\ln\left(Y_{i,t-\tau}\right) = \beta\ln\left(Y_{i,t-\tau}\right) + \delta W_{i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$\ln\left(Y_{i,t}\right) = a\ln\left(Y_{i,t-\tau}\right) + \delta W_{i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (2)$$

Where $a=1+\beta$, $Y_{i,t}$ is the measure of a KE dimension in country i at period t. $W_{i,t}$ is a vector of determinants of KE, η_i is a country-specific effect, ξ_t is a time-specific constant, and $\varepsilon_{i,t}$ is an error term. In line with the exogenous growth theory, a statistically negative coefficient of β in Eq. (1) suggests that countries comparatively close to their equilibrium or steady-state in KE will experience a slowdown in KE, known as beta convergence (Narayan et al. 2011, p. 2773). In the same vein, consistent with Fung (2009, p. 59), if $0<|a|<1$ in Eq. (2), then $Y_{i,t}$ is stable dynamically around the path with a growth rate in trend the same as that of W_t and with a corresponding height relative to the level of W_t (Asongu 2014a). The proxies contained in $W_{i,t-\tau}$ and the individual-effect η_i measures the long-run level KE is converging to. Accordingly, the country-specific effect η_i measures other determinants of a country's equilibrium not captured by $W_{i,t-\tau}$. For convergence to take place, $W_{i,t}$ must be strictly exogenous. Unfortunately, it is not always the case and a means of correcting the problem between

[5] The proportions of common variations among KE components corresponding to the chosen eigenvalues (reflecting the eigenvectors) justify the high correlation among KE dimensions. Owing to space constraint, the underlying correlation analyses can be provided upon request.

Table 1 Principal component analysis (PCA) for KE indicators

Knowledge economy dimensions		Component matrix (loadings)						First PC	Eigen value	Indexes
Panel A: PCA for peripheral countries (Africa)										
Education	School enrolment	PSE		SSE		TSE		0.658	1.975	Educatex
		0.438		0.657		0.614				
Information and infrastructure	ICTs	Internet		Mobile		Telephone		0.730	2.190	ICTex
		0.614		0.584		0.531				
Innovation system	Innovation	STJA		Trademarks		Patents		0.917	2.753	Innovex
		0.567		0.572		0.592				
Economic incentive and institutional regime	Economic incentive	Private credit			Interest rate spread			0.656	1.313	Creditex
		−0.707			0.707					
	Institutional index	VA	PS	RQ	GE	RL	CC	0.773	4.642	Instireg
		0.383	0.374	0.403	0.429	0.443	0.413			
Panel B: PCA for the frontier country (South Korea)										
Education	School enrolment	PSE		SSE		TSE		0.688	2.065	Educatex
		−0.359		−0.675		0.645				
Information and infrastructure	ICTs	Internet		Mobile		Telephone		0.800	2.400	ICTex
		0.612		0.625		0.484				
Innovation system	Innovation	STJA		Trademarks		Patents		0.946	2.839	Innovex
		0.576		0.573		0.582				
Economic incentive and institutional regime	Economic Incentive	Private credit			Interest rate spread			0.682	1.365	Creditex
		0.707			0.707					
	Institutional index	VA	PS	RQ	GE	RL	CC	0.664	3.985	Instireg
		0.453	−0.064	0.487	0.460	0.458	0.364			

PC principal component; *PSE* primary school enrolment; *SSE* secondary school enrolment; *TSE* tertiary school enrolment, *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 non-resident); *VA* voice and accountability; *RL* rule of law; *RQ* regulation quality; *GE* government effectiveness; *PS* political stability; *CC* control of corruption; *Instireg* institutional regime, first PC of VA, PS, RQ, GE, RL, and CC; *Creditex* first PC of private domestic credit and interest rate spread

some potential correlation between the lagged endogenous variables and the individual-specific effect involves eliminating the latter by first differencing.

Hence, Eq. (2) becomes

$$\ln\left(Y_{i,t}\right)-\ln\left(Y_{i,t-\tau}\right) = a\left(\ln\left(Y_{i,t-\tau}\right)-\ln\left(Y_{i,t-2\tau}\right)\right) + \delta\left(W_{i,t-\tau}-W_{i,t-2\tau}\right) + \left(\xi_t-\xi_{t-\tau}\right) + \left(\varepsilon_{i,t}-\varepsilon_{i,t-\tau}\right) \quad (3)$$

A means of further dealing with the correlation between the lagged endogenous variable and the error term consists of regressing the equations in levels jointly with the equations in first difference in order to exploit all the orthogonality conditions. The process uses lagged differences of the regressors as instruments in the level equation and lagged levels of the regressors as instruments in the difference equation. Consistent with Bond et al. (2001, pp. 3–4),[6] we prefer the system GMM estimator (Arellano and Bover 1995; Blundell and Bond 1998) to the difference GMM specification (Arellano and Bond 1991). A *two-step* procedure is also preferred to a *one-step* specification because it accounts for heteroscedasticity.

Since yearly intervals are not appropriate for investigating catch-up because short-run disturbances may loom substantially large, we use 3-year non-overlapping intervals (NOI). Hence, τ is set to 3. Therefore, in order to compute the implied catch-up rate, we calculate "$a/3$" or "$1+\beta/3$" because we have used 3 NOI to mitigate short-run disturbances. For convergence to take place, the following information criterion is needed: $0<|a|<1$ or $\beta<0$. We choose the former for simplicity.[7] With the absolute value of the lagged coefficient less than one but greater than zero ($0<|a|<1$), the existence of catch-up can be confirmed. A general interpretation consistent with the neoclassical growth model is as follows: past variations have a less proportionate incidence on future variations. Hence, with the left hand side of Eq. (3) decreasing with time, the country is approaching equilibrium or a steady-state. The Sargan over-identifying restrictions (OIR) test and second-order Arellano and Bond autocorrelation (AR(2)) test are used to assess the validity of the instruments and absence of autocorrelation in the residuals, respectively.

Presentation of Absolute Beta Catch-Up Results Three main issues are assessed in this section: (1) the presence of catch-up, (2) the speed of catch-up, and (3) the time required for full catch-up. Table 2 below summarizes the findings of Table 3. Owing to

[6] "We also demonstrate that more plausible results can be achieved using a system GMM estimator suggested by Arellano and Bover (1995) and Blundell and Bond (1998). The system estimator exploits an assumption about the initial conditions to obtain moment conditions that remain informative even for persistent series, and it has been shown to perform well in simulations. The necessary restrictions on the initial conditions are potentially consistent with standard growth frameworks, and appear to be both valid and highly informative in our empirical application. Hence we recommend this system GMM estimator for consideration in subsequent empirical growth research" Bond et al. (2001, pp. 3–4).

[7] To put our point into perspective, consistent with Asongu (2014a), the estimated lagged value of a standard dynamic GMM approach is a from which 1 is subtracted to obtain β ($\beta=a-1$). Under this scenario, the information criterion for *beta*-convergence is $\beta<0$. Hence, for simplicity, a could be reported, and the $0<|a|<1$ information criterion used to determine convergence. This is interpretation is in line with recent convergence literature (Prochniak and Witkowski 2012a, p. 20; Prochniak and Witkowski 2012b, p. 23; Asongu 2013a, 2014a).

Table 2 Summary of results

	Income levels		Legal origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
Panel A: education (Educatex)													
Catch-up (C)	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Rate of C (%)	16.33	–	18.33	–	–	15.00	12.00	16.66	14.33	16.33	14.66	–	17.83
Time to FC (years)	18.37	–	16.36	–	–	20.00	25.00	18.00	20.93	18.37	20.46	–	16.82
Panel B: information and communication technology (ICTex)													
Catch-up (C)	No	No	No	No	No	No	No	No	No	No	No	No	No
Rate of C (%)	–	–	–	–	–	–	–	–	–	–	–	–	–
Time to FC (years)	–	–	–	–	–	–	–	–	–	–	–	–	–
Panel C: innovation (Innovex)													
Catch-up (C)	No	No	No	No	Yes	No	Yes	No	Yes	No	No	No	No
Rate of C (%)	–	–	–	–	30.00	–	30.00	–	29.33	–	–	–	–
Time to FC (years)	–	–	–	–	10.00	–	10.00	–	10.22	–	–	–	–
Panel D: institutional regime (Instireg)													
Catch-up (C)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rate of C (%)	15.33	16.66	15.00	15.66	11.66	13.66	16.33	17.00	18.00	16.33	17.33	17.33	13.00
Time to FC (years)	19.56	18.00	20.00	19.15	25.72	21.96	18.37	17.64	16.66	18.37	17.31	17.31	23.07
Panel E: economic incentives (Creditex)													
Catch-up (C)	No	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Rate of C (%)	–	–	–	12.00	–	8.66	19.00	14.66	17.00	–	12.66	20.00	–
Time to FC (years)	–	–	–	25.00	–	34.64	15.78	20.46	17.64	–	23.69	15.00	–

Low low-income countries, *Middle* middle-income countries, *English* English common law countries, *French* French civil law countries, *Oil* petroleum-exporting countries, *NoOil* non-petroleum-exporting countries, *Closed* landlocked countries, *Open* countries open to the sea, *Conf* conflict-affected countries, *NoConf* countries not affected by conflicts, *SSA* sub-Saharan Africa, *NA* North Africa, *C* catch-up, *FC*, full catch-up

the shortcomings discussed in the methodology section on conditional beta catch-up, we only model absolute beta catch-up. Hence, absolute (or unconditional) convergence has been estimated with only the lagged difference of the dependent variable as independent variable. In other words, absolute catch-up is modeled without $W_{i,t}$.

To investigate the validity of the estimation and indeed the catch-up hypothesis, two tests have been performed to validate the models: the Sargan OIR and AR(2) tests. The latter assesses the null hypothesis of no autocorrelation in the residuals whereas the former investigates the null hypothesis for the absence of correlation between the error terms and the residuals. Hence, failure to reject the null hypotheses of both tests is essential for the validity of the models. Based on the findings presented in Table 3, the null of both tests are overwhelmingly rejected.

Before discussing the results, we devote some space to elucidating how the numbers in Table 2 have been obtained. For an estimated initial value of 0.49 that is consistent with the information criterion ($0<|a|<1$), the rate of catch-up is 16.33 % per annum (0.49/3) and the period needed to achieve full or 100 % catch-up is 18.37 years (300 %/16.33 %).

In the summary of the results presented in Table 2 below, the following could be established between African peripheral countries and the South Korean frontier country. First, with the exception of ICT where no catch-up is apparent, in increasing order it is visible in innovation, economic incentives, education, and institutional regime. Second, the essence of using fundamental characteristics is sound, since there is evidence of wealth-effects, legal-origin effects… etc., in KE catch-up patterns (e.g., education). The speed of convergence varies between 8.66 % per annum (non-oil in economic incentive dimension) and 30.00 % (innovation dimension) with respective time to full or 100 % convergence of 34.64 and 10 years.

We have already seen in the methodology section that beta convergence is a necessary but not a sufficient condition for sigma convergence. Hence, beta convergence is generally appreciated as catch-up, whereas sigma convergence is a reduction in cross-country dispersions necessary for convergence to really take place. To this end, we complement the absolute beta catch-up estimations above with tabular and graphical sigma convergence patterns for robustness purposes and greater subtlety in the analysis.

Sigma Convergence: Tabular and Graphical KE Dispersions

Table 4 below is a tabular representation of KE convergence between peripheral African countries and the frontier South Korean country in terms of education (panel A), ICT (panel B), innovation (panel C), institutional regime (panel D), and economic incentives (panel E). The sigma convergence approach consists of computing standard deviations across time between the peripheral fundamental characteristics and South Korea.

Figures 1, 2, 3, 4, and 5 below are based on Table 4. As will be discussed in "Policy Syndromes and Catch-Up Strategies" section below, both tabular and graphical representations are needed to fully calibrate "policy syndromes" for more targeted/focused policy implications/strategies.

It can be seen from Fig. 1 above that the gap between Korea and African countries was very substantial in 1996, with middle-income and low-income countries witnessing

Table 3 Dynamic system GMM

	Income Levels		Legal origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
Panel A: education (Educatex)													
Initial	*0.49***	−0.164	*0.55***	0.688	0.530	*0.45***	*0.36***	*0.50***	*0.43***	*0.49***	*0.44***	−6.575	*0.53***
	(*0.001*)	(0.876)	(*0.003*)	(0.240)	(0.608)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.000*)	(0.129)	(*0.022*)
AR(2)	(*0.745*)	(*0.837*)	(*0.330*)	(*0.228*)	(*0.480*)	(*0.177*)	(*0.307*)	(*0.281*)	(*0.303*)	(*0.252*)	(*0.229*)	n.a.	(*0.418*)
Sargan	(*0.996*)	(*0.995*)	(*0.992*)	(*0.988*)	(*0.987*)	(*0.998*)	(*0.999*)	(*0.992*)	(*0.999*)	(*0.993*)	(*0.995*)	(*1.000*)	(*0.990*)
Wald	*10.2***	0.024	*8.48***	1.377	0.262	*120***	*72.3***	*23.0***	*31.8***	*24.1***	*59.0***	*2.300*	*5.23***
	(*0.001*)	(0.876)	(0.003)	(0.240)	(0.608)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.129)	(0.022)
Panel B: information and communication technology (ICTex)													
Initial	0.536	0.973	0.797	0.668	0.743	0.686	0.522	0.785	0.549	0.763	0.619	1.227	0.736
	(0.166)	(0.448)	(0.244)	(0.295)	(0.444)	(0.175)	(0.128)	(0.337)	(0.183)	(0.277)	(0.129)	(0.493)	(0.487)
AR(2)	(*0.356*)	(*0.337*)	(*0.342*)	(*0.360*)	(*0.353*)	(*0.356*)	(*0.354*)	(*0.351*)	(*0.359*)	(*0.348*)	(*0.358*)	(*0.312*)	(*0.301*)
Sargan	(*0.981*)	(*0.982*)	(*0.988*)	(*0.988*)	(*0.963*)	(*0.978*)	(*0.982*)	(*0.986*)	(*0.980*)	(*0.972*)	(*0.981*)	(*0.982*)	(*0.965*)
Wald	1.914	0.575	1.357	1.092	0.584	1.838	2.313	0.921	1.766	1.177	2.299	0.468	0.483
	(0.166)	(0.448)	(0.244)	(0.295)	(0.444)	(0.175)	(0.128)	(0.337)	(0.183)	(0.277)	(0.129)	(0.493)	(0.487)
Panel C: innovation (Innovex)													
Initial	0.064	0.193	*1.22***	0.302	*0.90***	−0.162	*0.90***	0.338	*0.88***	0.318	0.319	0.211	2.845
	(0.540)	(0.902)	(*0.000*)	(0.551)	(*0.000*)	(0.885)	(*0.000*)	(0.708)	(*0.000*)	(0.736)	(0.747)	(0.867)	(0.564)
AR(2)	(*0.412*)	(*0.903*)	(*0.300*)	(*0.603*)	(*0.306*)	(*0.640*)	(*0.293*)	(*0.816*)	(*0.313*)	(*0.878*)	(*0.886*)	(*0.933*)	(*0.597*)
Sargan	(*0.998*)	(*0.994*)	(*0.992*)	(*0.994*)	(*0.985*)	(*0.999*)	(*0.985*)	(*0.996*)	(*0.985*)	(*0.997*)	(*0.991*)	(*0.996*)	(*0.995*)
Wald	0.374	0.014	*48.7***	0.354	*1503***	0.020	*322***	0.140	*10,797***	0.113	0.103	0.027	0.332
	(0.540)	(0.902)	(*0.000*)	(0.551)	(*0.000*)	(0.885)	(*0.000*)	(0.708)	(*0.000*)	(0.736)	(0.747)	(0.867)	(0.564)

Table 3 (continued)

	Income Levels		Legal origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
Panel D: institutional regime (Instireg)													
Initial	*0.46***	*0.50***	*0.45***	*0.47***	*0.35**	*0.41***	*0.49***	*0.51***	*0.54***	*0.49***	*0.52***	*0.52***	*0.39***
	(*0.000*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.062*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.007*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.002*)
AR(2)	(*0.355*)	(*0.254*)	(*0.349*)	(*0.330*)	(*0.497*)	(*0.413*)	(*0.341*)	(*0.291*)	(*0.259*)	(*0.296*)	(*0.279*)	(*0.281*)	(*0.413*)
Sargan	(*0.998*)	(*0.998*)	(*0.998*)	(*0.994*)	(*0.992*)	(*0.994*)	(*0.998*)	(*0.994*)	(*0.993*)	(*0.994*)	(*0.998*)	(*0.998*)	(*0.998*)
Wald	*92.9***	*25.7***	*110***	*514***	*3.46**	*12.03***	*569***	*149***	*7.05***	*243***	*63.0***	*20.6***	*9.19***
	(*0.000*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.062*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.007*)	(*0.000*)	(*0.000*)	(*0.000*)	(*0.002*)
Panel E: economic incentives (Creditex)													
Initial	*−2.2***	−0.47	−0.054	*0.36***	0.756	*0.26**	*0.57***	*0.44***	*0.51***	0.128	*0.38**	*0.60***	−0.928
	(*0.005*)	(0.649)	(0.902)	(*0.000*)	(0.514)	(*0.089*)	(*0.000*)	(*0.000*)	(*0.004*)	(0.707)	(*0.065*)	(*0.000*)	(0.384)
AR(2)	(*0.573*)	(*0.512*)	(*0.386*)	(*0.312*)	(*0.243*)	(*0.339*)	(*0.312*)	(*0.261*)	(*0.294*)	(*0.367*)	(*0.292*)	(*0.304*)	(*0.549*)
Sargan	(*0.995*)	(*0.999*)	(*0.999*)	(*0.998*)	(*0.989*)	(*0.996*)	(*0.998*)	(*0.989*)	(*0.992*)	(*0.997*)	(*0.997*)	(*0.993*)	(*1.000*)
Wald	*7.82***	0.206	0.015	*80.1***	0.424	*2.87**	*128***	*7.14***	*7.92***	0.140	*3.384**	*20.9***	0.755
	(*0.005*)	(0.649)	(0.902)	(*0.000*)	(0.514)	(*0.089*)	(*0.000*)	(*0.007*)	(*0.004*)	(0.707)	(*0.065*)	(*0.000*)	(0.384)

*, **, and *** indicate significance levels of 10, 5, and 1 %, respectively. The significance of italicized values is twofold. (1) The significance of estimated coefficients and the Wald statistics. (2) The failure to reject the null hypotheses of (a) no autocorrelation in the AR(2) tests and (b) the validity of the instruments in the Sargan OIR test. *P* values in brackets

Initial lagged dependent variable, *AR(2)* second-order autocorrelation test, *Sargan* Sargan overidentifying restrictions (OIR) test, *Low* low-income countries, *Middle* middle-income countries, *English* English common law countries, *French* French civil law countries. *Oil* petroleum-exporting countries, *NoOil* non-petroleum-exporting countries, *Closed* landlocked countries, *Open* countries open to the sea, *Conf* conflict-affected countries, *NoConf* countries not affected by conflicts, *SSA* sub-Saharan Africa, *NA* North Africa

Table 4 Tabular representation of KE dispersions

Years	Low. I	Mid. I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
Panel A: education (Educatex)													
1996	1.279	2.670	2.134	1.462	1.886	1.689	1.626	1.782	1.536	1.739	1.523	2.540	1.714
1997	0.567	2.469	1.900	1.289	0.468	1.653	0.593	1.826	0.573	1.653	1.215	2.429	1.518
1998	0.289	1.377	1.136	0.668	0.086	0.968	0.129	1.094	−1.563	0.968	0.492	1.333	0.772
1999	0.023	1.052	0.734	0.375	0.637	0.470	0.334	0.562	0.268	0.546	0.296	1.634	0.495
2000	0.483	0.379	0.390	0.438	0.370	0.078	0.341	0.009	0.254	0.111	0.222	0.994	0.132
2001	1.250	0.157	0.169	0.916	1.021	0.569	0.914	0.358	1.526	0.519	0.706	0.003	0.610
2002	1.272	0.373	0.437	0.522	1.045	0.715	0.965	0.230	–	0.485	0.803	0.660	0.485
2003	1.139	0.406	0.277	0.508	0.243	0.605	0.994	0.092	1.076	0.373	0.797	1.043	0.441
2004	1.078	0.287	0.308	0.636	0.331	0.577	0.931	0.326	1.026	0.484	0.797	0.632	0.542
2005	1.055	0.118	0.290	0.734	0.330	0.625	0.996	0.349	0.873	0.536	0.745	0.444	0.586
2006	1.099	0.067	0.362	0.822	0.856	0.661	1.014	0.422	1.205	0.646	0.776	0.080	0.669
2007	1.029	0.409	0.078	0.758	–	0.650	1.202	0.329	1.023	0.606	0.803	0.162	0.160
2008	0.995	0.461	0.078	0.712	0.867	0.582	1.138	0.138	1.099	0.482	0.722	0.319	0.612
2009	0.881	0.812	0.277	0.511	0.134	0.580	0.993	0.091	0.938	0.369	0.702	0.870	0.478
2010	0.818	0.072	0.414	0.548	0.428	0.566	0.755	0.263	0.686	0.491	0.525	0.766	0.540
Panel B: information and communication technology (ICTex)													
1996	1.488	1.804	1.714	1.542	1.559	1.625	1.514	1.661	1.484	1.657	1.598	1.787	1.616
1997	1.236	1.577	1.478	1.302	0.595	1.388	1.262	1.420	1.230	1.417	1.358	1.500	1.372
1998	1.035	1.422	1.318	1.112	1.088	1.213	1.067	1.241	−1.697	1.240	1.176	1.329	1.191
1999	0.309	0.167	0.034	0.200	0.195	0.093	0.263	0.052	0.315	0.052	0.138	0.097	0.112
2000	0.714	0.130	0.309	0.570	0.572	0.448	0.653	0.400	0.723	0.398	0.502	0.235	0.472
2001	0.898	0.216	0.430	0.727	0.747	0.584	0.830	0.530	0.914	0.527	0.651	0.328	0.615

Table 4 (continued)

Years	Low. I	Mid. I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
2002	0.980	0.219	0.469	0.782	0.790	0.634	0.909	0.567	0.991	0.568	0.711	0.290	0.664
2003	0.950	0.114	0.353	0.736	0.749	0.560	0.884	0.480	0.954	0.500	0.654	0.154	0.596
2004	0.850	0.158	0.129	0.571	0.563	0.379	0.788	0.260	0.845	0.310	0.502	0.238	0.415
2005	0.879	0.289	0.094	0.529	0.446	0.358	0.830	0.186	0.468	0.254	0.502	0.577	0.375
2006	0.647	0.682	0.259	0.230	0.054	0.049	0.608	0.173	0.604	0.092	0.209	1.088	0.050
2007	0.741	0.754	0.155	0.288	0.046	0.138	0.704	0.110	0.729	0.057	0.298	1.272	0.642
2008	0.805	0.918	0.160	0.241	0.034	0.119	0.770	0.179	0.779	0.112	0.310	1.636	0.090
2009	1.070	0.709	0.282	0.402	0.035	0.430	1.024	0.073	1.036	0.167	0.642	1.722	0.359
2010	1.101	0.928	0.199	0.479	0.027	0.297	1.106	0.119	1.019	0.080	0.536	1.856	0.249
Panel C: innovation (Innovex)													
1996	1.010	2.321	1.974	1.518	1.407	1.757	1.023	2.126	1.056	1.874	1.678	1.808	1.725
1997	0.950	2.629	2.166	1.036	1.020	1.897	0.862	1.975		1.789	1.897	1.249	1.789
1998	1.569	3.107	2.849	2.212	1.888	2.622	1.456	2.684		2.530	2.567	2.469	2.530
1999	0.927	2.482	2.028	1.381	1.073	1.915	0.803	1.834	0.910	1.818	1.646	1.881	1.705
2000	0.100	1.832	1.638	0.678	0.380	1.373	0.111	1.481	0.206	1.237	1.024	1.252	1.090
2001	0.005	1.842	1.675	1.174	0.283	2.269	0.005	1.842	0.077	1.824	1.675	1.174	1.475
2002	0.048	1.815	1.757	0.534	0.297	1.362	0.015	1.237	0.167	1.206	1.029	1.130	1.058
2003	0.258	1.501	1.394	0.262	0.053	1.067	0.349	0.929	0.267	0.916	0.691	0.888	0.747
2004	0.682	0.963	1.076	0.092	0.416	0.600	0.757	0.503	0.664	0.490	0.332	0.369	0.346
2005	1.150	0.662	0.756	0.482	0.815	0.248	1.253	0.159	0.895	0.136	0.053	0.041	0.018
2006	1.426	0.534	0.695	1.056	1.031	0.016	1.521	0.103	1.345	0.133	0.201	0.568	0.306
2007	1.706	0.391	0.596	1.110	1.399	0.296	1.769	0.388	1.633	0.405	0.601	0.421	0.748
2008	1.715	0.586	0.337	0.699		0.181		0.181		0.181	0.231	0.082	0.181

Table 4 (continued)

Years	Low. I	Mid. I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
2009	1.654	1.346	1.262	0.598		0.146		0.146		0.146	0.217	0.039	0.146
2010													
Panel D: institutional regime (Instireg)													
1996	1.570	2.279	2.269	1.609	0.464	2.267	2.337	1.729	0.180	2.273	1.843	2.097	1.877
1997													
1998	2.332	3.575	3.474	2.501	1.540	3.123	2.810	2.858	−3.127	3.249	2.808	3.117	2.844
1999													
2000	1.131	2.295	2.091	1.347	0.366	1.876	1.508	1.652	0.286	2.072	1.564	1.955	1.610
2001													
2002	1.041	0.070	0.152	0.819	1.648	0.355	0.794	0.496	2.369	0.148	0.642	0.140	0.583
2003	0.380	0.689	0.548	0.206	0.953	0.277	0.114	0.133	1.816	0.518	0.002	0.523	0.060
2004	0.660	0.359	0.288	0.528	1.255	0.023	0.368	0.187	2.087	0.210	0.307	0.257	0.240
2005	1.721	0.693	0.728	1.608	2.352	1.072	1.401	1.254	1.458	0.862	1.359	0.836	1.298
2006	0.057	0.943	1.020	0.009	0.755	0.592	0.261	0.393	1.302	0.759	0.319	0.624	0.355
2007	1.799	0.803	0.723	1.752	2.528	1.144	1.477	1.352	3.063	0.980	1.431	1.067	0.017
2008	0.141	0.923	0.972	0.071	0.846	0.542	0.244	0.319	1.411	0.714	0.267	0.522	0.297
2009	1.533	0.485	0.421	1.472	2.205	0.865	1.149	1.081	2.679	0.716	1.128	0.901	1.101
2010	1.905	0.993	0.804	1.925	2.692	1.280	1.491	1.545	3.029	1.164	1.528	1.539	1.529
Panel E: economic incentives (Creditex)													
1996	1.366	1.028	1.022	1.372	1.511	1.085	1.241	1.183	1.637	1.112	1.226	1.000	1.203
1997	1.530	1.160	1.246	1.444	0.767	1.252	1.502	1.262	1.626	1.278	1.366	1.189	1.345
1998	0.372	0.067	0.070	0.224	0.405	0.068	0.343	0.062	0.091	0.088	0.195	0.107	0.152
1999	0.907	0.507	0.607	0.794	1.043	0.585	0.872	0.625	1.140	0.621	0.753	0.406	0.707

Table 4 (continued)

Years	Low. I	Mid. I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
2000	1.831	1.467	1.544	1.741	2.064	1.498	1.806	1.570	2.180	1.543	1.703	1.297	1.649
2001	0.192	0.610	0.496	0.317	0.039	0.533	0.205	0.499	0.055	0.492	0.346	0.760	0.401
2002	0.247	0.661	0.541	0.394	0.173	0.578	0.252	0.559	0.013	0.546	0.397	0.791	0.460
2003	0.438	0.810	0.740	0.539	0.305	0.763	0.438	0.721	0.130	0.726	0.567	0.954	0.630
2004	0.393	0.811	0.747	0.501	0.271	0.764	0.416	0.716	0.125	0.714	0.562	0.966	0.616
2005	0.303	0.786	0.681	0.434	0.188	0.692	0.342	0.664	0.457	0.655	0.506	0.849	0.553
2006	0.053	0.571	0.435	0.212	0.036	0.464	0.110	0.431	0.046	0.401	0.317	0.446	0.332
2007	0.002	0.662	0.529	0.135	0.059	0.444	0.104	0.426	0.084	0.441	0.315	0.522	0.531
2008	0.155	0.988	0.720	0.349	0.428	0.597	0.282	0.696	0.138	0.680	0.565	0.633	0.572
2009	1.112	2.025	1.768	1.293	1.517	1.607	1.278	1.705	1.147	1.712	1.594	1.586	1.593
2010													

Low. I low-income countries, *Mid. I* middle-income countries, *Eng* English common law countries, *Frch* French civil law countries, *Oil* petroleum-exporting countries, *NOil* non-petroleum-exporting countries. *LL* landlocked countries, *NLL* not landlocked countries, *Con* conflict-affected countries, *NCon* non-conflict-affected countries, *SSA* sub-Saharan Africa, *NA* North Africa, *S.K.* South Korea

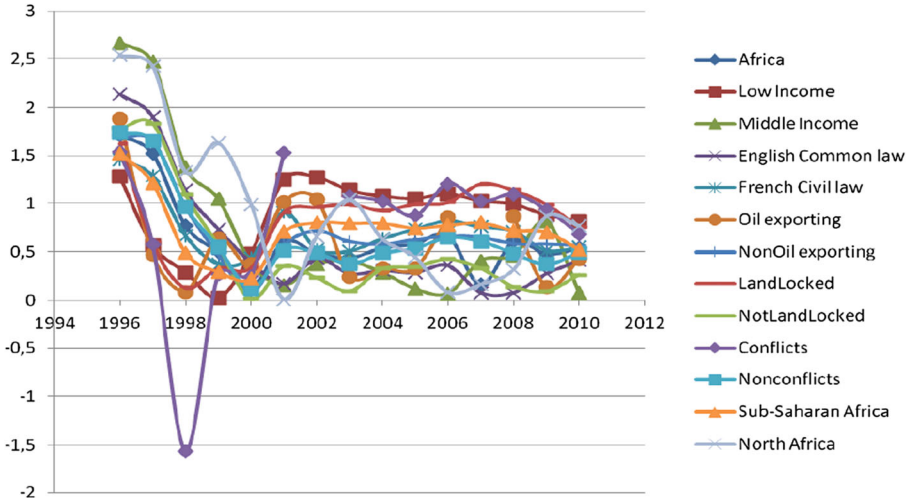

Fig. 1 Sigma convergence in education (x-axis for years and y-axis for education)

the highest and lowest gaps, respectively. It should be noted that a decreasing value in the y-axis depicts a more balanced development in KE between the peripheral fundamentals and the frontier country (South Korea). However, the gap decreased substantially up to the year 2000 in all fundamental characteristics. After this period, it has averagely remained stable, though fluctuating considerably in North Africa and oil-exporting countries. A reason for the increase in gap from the year 2000 can be explained from the KE strategies Korea adopted at the beginning of the millennium. Consistent with Suh and Chen (2007, p. 25), in 2000, Korea embarked on human resource development in its transition to intensive KE by greatly improving on education.

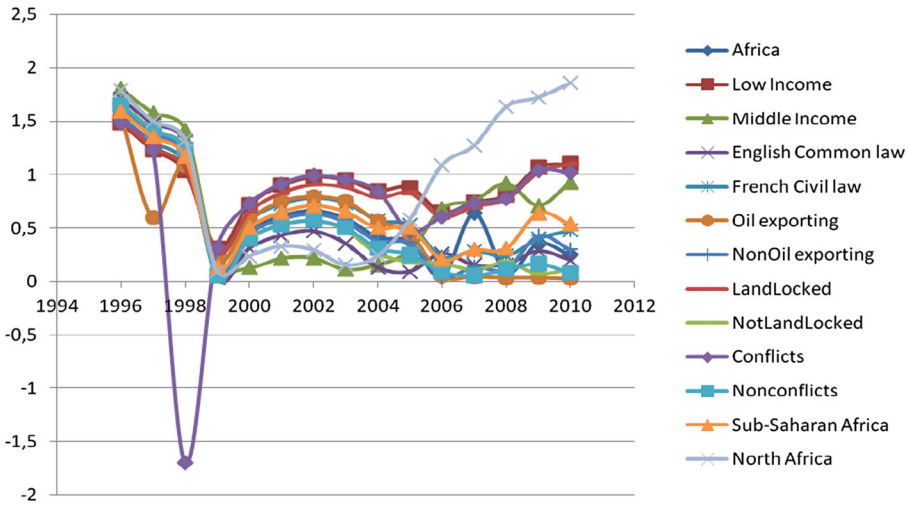

Fig. 2 Sigma convergence in ICT (x-axis for years and y-axis for ICT)

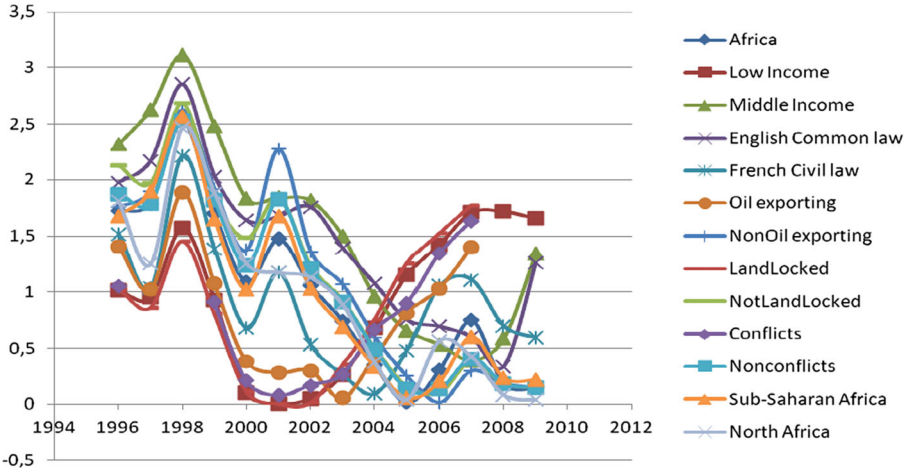

Fig. 3 Sigma convergence in innovation (x-axis for years and y-axis for innovation)

Figure 2 depicts the dispersions in ICT. The trends can be broadly summarized in three phases: a first phase between 1996 and 1999 entailing sharp declines in the dispersions; a second phase of gradual improvement and slow decline from 1999 to 2005, with a peak in 2002; and a third of phase of increases in the dispersions with mixed tendencies: sharp (North Africa, conflicts, low-income, landlocked) and gradual (non-conflicts, oil-exporting, not landlocked).

Dynamics in the dispersions of innovation depicted in Fig. 3 above generally display an oscillating pattern. First, a steep decline from 1996 to 1997, then a sharp rise

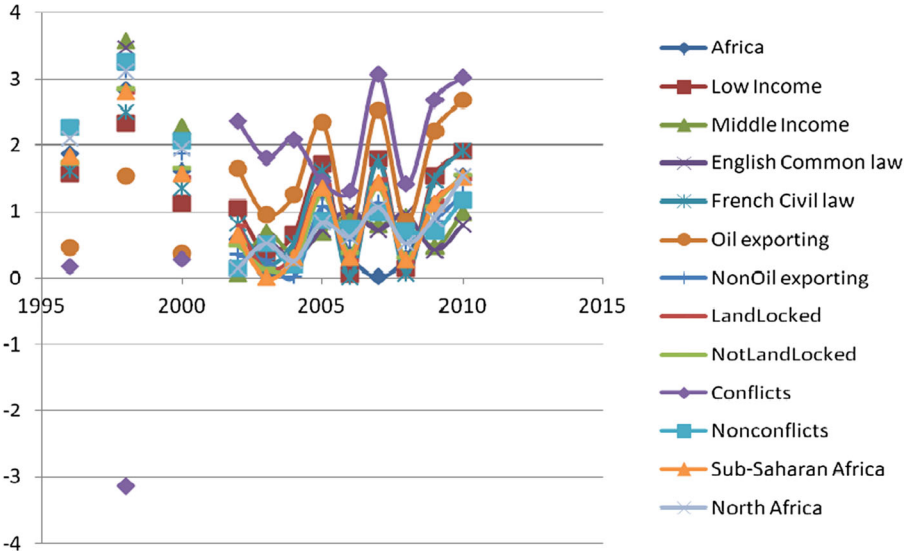

Fig. 4 Sigma convergence in institutional regime (x-axis for years and y-axis for institutional regime)

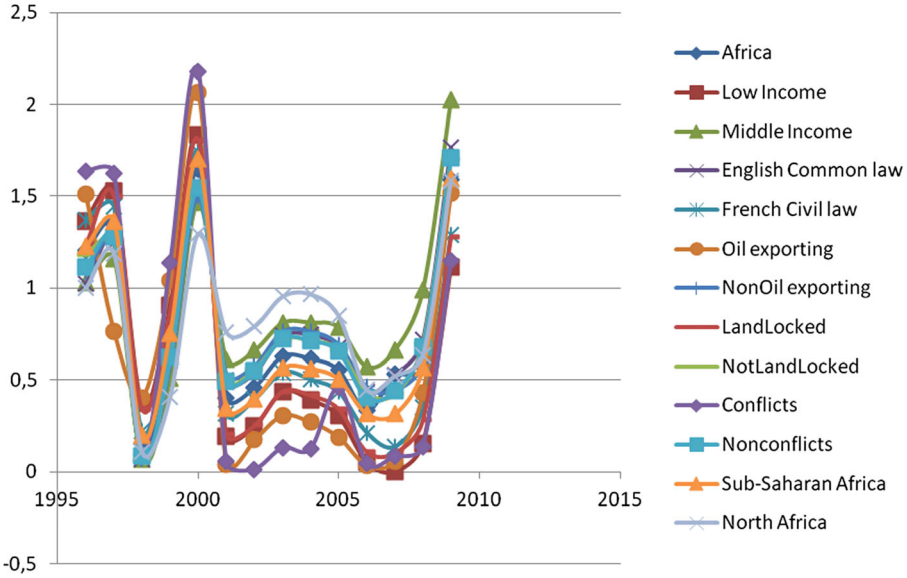

Fig. 5 Sigma convergence in economic incentives (x-axis for years and y-axis for economic incentives)

between 1997 and 1998, followed by another steep decline to the year 2000, after which two tendencies are observed: a first with some countries leveling-up for 2 years before witnessing another sharp rise to 2011 (oil exporting, conflicts, low-income, landlocked) and a second category of countries broadly experiencing sharp rises and decreases between 2000 and 2002 before displaying wave-like reductions in the dispersions.

Patterns of dispersions in institutional regime shown in Fig. 4 above are almost uniform across fundamental characteristics. The breaks in 1997, 1999, and 2001 are due to missing data. Generally, there are approximately eight wave-like patterns (or increases and reductions) in the dispersions. The last phase of these oscillations depicts a sharp increase in the dispersions: signaling a growing gap in the institutional dimension of KE between the frontier country and peripheral African countries.

In Fig. 5 above, the tendencies observed in economic incentive dispersions are broadly similar across fundamental characteristics. However, while the magnitude in elimination of dispersions are almost indistinguishable in the first (1996 to 2001) and third (2008 to 2010) phases, the second phase (2001 to 2008) is characterized by the following dispersion magnitudes, in increasing order: conflict, oil-exporting, landlocked, low-income, French civil law, sub-Saharan Africa, non-conflicts, English common law, Africa, middle-income, and North Africa.

One common factor in Figs. 1, 2, 3, 4, and 5 is an increasing gap in KE after the year 2000: an indication that compelling catch-up strategies are required to mitigate the growing gaps. In fact, the growing gaps are consistent with the Anyanwu (2012) finding that the African KEI has decreased between the years 2000 and 2009.

Table 5 "Policy syndrome" and "syndrome free" information criteria

	Policy syndrome (PS)										Syndrome free (SF)		
	→												
Educatex	Low. I	LL	NA	Con	Frch.	NOil	Africa	SSA	NCon	Oil	Eng.	NLL	Mid. I
ICTex	NA	Low. I	LL	Con	Mid. I	SSA	Frch	Africa	NOil	Eng	NLL	NCon	Oil
Innovex	LL	Low. I	Con	Oil	Mid. I	Eng	Frch	SSA	NOil	Africa	NCon	NLL	NA
Instireg	Con	Oil	Low. I	Frch.	NA	SSA	Africa	LL	NOil	NLL	NCon	Mid. I	Eng
Creditex	Mid. I	Eng	NCon	NLL	NOil	SSA	Africa	NA	Oil	Frch	LL	Con	Low. I
	Highest dispersions	←									Lowest dispersions		

Low. I low-income countries; *Mid. I* middle-income countries; *Eng* English common law countries; *Frch* French civil law countries; *Oil* petroleum-exporting countries; *NOil* non-petroleum-exporting countries; *LL* landlocked countries; *NLL* not landlocked countries; *Con* conflict-affected countries; *NCon* non-conflict-affected countries; *SSA* sub-Saharan Africa; *NA* North Africa; *S.K.* South Korea; *PC* principal component; *PSE* primary school enrolment; *SSE* secondary school enrolment; *TSE* tertiary school enrolment; *ICTs* information and communication technologies; *Educatex* 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 non-resident); *VA* voice and accountability; *RL* rule of law; *RQ* regulation quality; *GE* government effectiveness; *PS* political stability; *CC* control of corruption; *Instireg* institutional regime, first PC of VA, PS, RQ, GE, RL, and CC; *Creditex* first PC of private domestic credit and interest rate spread

Policy Syndromes and Catch-Up Strategies

Policy Syndromes

Fosu (2013c) defines policy syndromes as situations that are detrimental to growth: "administered redistribution," "state breakdown," "state controls," and "suboptimal inter temporal resource allocation" with the absence of syndromes qualified as "syndrome-free." The syndromes are thought to have substantially contributed to the poor post-independence growth of Africa. In the context of this paper, policy syndromes are negative tendencies of dispersions in KE dimensions between African peripheral countries and the frontier South Korean economy. Hence, increasing deviations for a given KE dimension denotes "policy syndromes" (PS) whereas a trend portraying diminishing dispersions is qualified as a "syndrome-free" (SF) tendency. While catch-up strategies discussed in this section are more relevant in PS scenarios, enhancing existing policies in SF events are essential to ensure a complete elimination of dispersions. This is essentially because SF situations are prone to become PS scenario given the history of wave-like trends in the KE dispersion patterns. Therefore, the catch-up strategies are essential both for preventing and curing dispersions in SF and PS scenarios, respectively. Hence, we devote space to specifically detailing the PS before discussing the catch-up strategies.

As we have already discussed in "Sigma Convergence: Tabular and Graphical KE Dispersions" section above, both tabular and graphical representations are needed to fully calibrate PS for more targeted/focused policy implications/strategies. Hence, Table 5 below depicting comparative PS and SF scenarios is obtained from both representations. While the left-hand-side of the table shows PS (or high dispersion panels), the right-hand-side presents SF (or low dispersion panels). Based on the patterns, it is consistently observed for the first three dimensions of KE that "landlockedness," "low income," and "political instability" are high PS fundamental characteristics. We discuss catch-up strategies relevant to the fundamental characteristics and degree of PS in the following section.

Catch-Up Strategies

The interesting questions motivating this section of whether other countries can adapt to the Korean model and catch-up have already been answered by Lee (2009) in the affirmative. Hence, consistent with Suh and Chen (2007), there are two important lessons from the experiences of Korea. In what follows, we first discuss broad policy implications before engaging how they are relevant to the derived policy syndromes. Therefore, while this may be a partial leap of logic relative to the quantitative analysis, it is to the best of our knowledge an appropriate way of presenting corresponding policy implications more comprehensively.

First, human capital is essential for the development of science and technology and economic prosperity. Second, market competition is the greatest motivator of privates business to engage in technology development. Thus, it is important to consolidate the capabilities of scientific research and ameliorate conditions for innovation.

Education and Innovation Strategies The lack of investment in education and brain drain have been recently documented as some of the issues standing on the way to consolidating the educational pillar of KE in Africa (Kamara et al. 2007; Ford 2007; Amavilah 2009; Chavula 2010; Weber 2011; Anyanwu 2012; Andrés et al. 2014; Tchamyou 2014). There is a background of depleting knowledge infrastructure, limited support for R&D, brain-drain, limited direct nexuses between science and industry, and outdated curricula. The continent is on a downward trend in KE (Anyanwu 2012) and risk losing the new economy unless bold measures are implemented to reinvigorate science and technology, innovation, and higher education (Kaiser 1974). We have established Africa's deficiency in innovation in "South Korea as a Knowledge Economy and Learning from Success Stories" section (Oyelaran-Oyeyinka and Gehl Sampath 2007; Anyanwu 2012; Carisle et al. 2013). What lessons does South Korea hold for the above issues?

First, African economies should take bold steps towards increasing college enrolment and the ratio of R&D/GDP. As shown by Lee (2009), such measures are effective and possible only in conjunction with substantial improvements in other institutional and policy environments, including the capacity and autonomy of government. Education consolidates a nation's ability to acquire new technology and knowledge. It also gives birth to the tacit knowledge of individuals which are essential in consolidating blocks of technological learning. In this light, African governments have to take full responsibility for the necessary measures needed to promote this core human resource development (Suh and Chen 2007; Tchamyou 2014). In essence, while Korea continues to import a substantial portion of its technology from more advanced nations, it has developed a solid indigenous R&D platform and allocates about 3 % of its GDP to R&D. Essentially, these strategies for technology and education best illustrate the disciplinary and practical dimensions that should motivate African countries in their efforts towards KE.

Second, in order for workers to cope with changing technological conditions, African governments need to provide technical and vocational trainings as well as take the necessary steps to encourage trainings at work places. The intuition behind this strategy is that as a nation becomes more advanced, a critical factor that comes with the prosperity is technological competence. For these strategies to be implemented, African government policy makers should nurture engineers and high-caliber scientists that are capable of handling prosperity on the frontiers of science and technology. In the Korean experience, industrialization and education complemented one another in accelerating and sustaining development. In essence, education produced technological learning and industrialization and the latest boosted the return rate on educational investment, which further promoted the demand for education (Suh and Chen 2007; Tchamyou 2014).

Third, consistent with the documented literature in the preceding sections (Bezmen and Depken 2004), the industrialization of Korea progressed from imitation to innovation. Hence, reverse engineering and less stringent property rights are essential to enable the copying of technology-intensive commodities. Peripheral African countries should therefore engage in informal channels of technology transfer at the initial stages of their industrialization. As documented by Suh and Chen (2007), the nexus between education and human development needs to be tailored into a lifelong learning strategy.

Based on the "policy syndromes," the increasing relevance of the strategies is as follows: (1) middle-income, not landlocked, English common law, oil-exporting, non-

conflict, SSA, Africa, non-oil-exporting, French civil law, conflict-affected, North Africa, landlocked, and low-income countries for the educational dimension and (2) North Africa, not landlocked non-conflict, Africa, non-oil-exporting, SSA, French civil law, English common law, middle-income, oil-exporting, conflict-affected, low income, and landlocked countries for the innovation dimension of KE.

ICT Catch-Up Strategies The plethora of African benefits in ICT catch-up has already been substantially covered in "South Korea as a Knowledge Economy and Learning from Success Stories" section (African Partnership Forum 2008; Chavula 2010; Butcher 2011). As we have also highlighted in the preceding section, reverse engineering of imported ICTs and less stringent IPRs on ICTs would be steps in the right direction towards enhancing the African base in ICTs. These would drive down the cost technological acquisition and mitigate the dependence on business operations.

Korea's ICT success has hinged on the exercise of soundly integrated approaches entailing an industrial policy, an active informatization policy and competitive and regulatory policies that are well enforced. The core country invested massively in internet equipment, telephone lines, and multimedia, inter alia. These investments have substantially contributed to its economic prosperity. Consistent with Suh and Chen (2007) and Tchamyou (2014), the policy was clearly articulated along three main areas highlighted in the first sentence of this paragraph, which entailed the following: R&D, venture capital, and human resources (an industrial policy); privatization and market liberalization (enforced competitive and regulatory policy); and setting-up of e-government, constructing an advanced infrastructure (an active information policy). In essence, combining the three areas of policy in a complementary mechanism has been the main cause for IT strategy success. Hence, it is a lesson that could inspire African countries because the well-tailored information infrastructure has been the basis for the exceptional development of Korea. In decreasing order, the relevance of above strategies applies to North Africa, low-income, landlocked, conflict-affected, middle-income, SSA, French civil law, Africa, non-oil-exporting, English common law, not landlocked, non-conflict, and oil-exporting countries.

Institutional Regime and Economic Incentive Catch-Up Strategies Good institutions are central to the emergence of African economies (Fosu 2013d). In "South Korea as a Knowledge Economy and Learning from Success Stories" section, we have seen that African countries are substantially lacking in this fourth pillar of KE (Cogburn 2003; Letiche 2006). The issues include, inter alia, poor institutions (Andrés et al. 2014), especially corruption in upholding IPRs (Andrés and Asongu 2013a); surplus banking liquidity; or absence of credit to finance investment needs (Saxegaard 2006; Nguena and Tsafack 2014).

Institutional Regime Poor institutions and capital flight repugnant to investment and economic prosperity have been substantially documented in African development literature (Boyce and Ndikumana 1998, 2001, 2003, 2008, 2011; Fofack and Ndikumana 2009). African institutions need to be market-focused by adopting a development strategy that completely liberates the competitive forces essential for the dynamics of KE. A market-oriented strategy requires the presence of competitive forces and therefore enhances competition. Hence, to fight capital flight, transparency of

financial markets, leveled playing fields for all market participants, government accountability, foreign investment regimes, and liberalized trade are essential components of the KE.

African governments' institutions should foster an industrialization strategy that is export-led. Accordingly, by adopting extensive development strategies, they would expose African corporations to global competition like Korean industries. This would ultimately compel domestic industries to invest substantially in innovation and technological assimilation in order to remain competitive.

One of the advantages of having a credible institutional regime is drawn from the manner in which the Korean Government solved the 1997 crisis (Tchamyou 2014). The lesson holds some potential for the mitigation of capital flight. African governments can learn from the special recognition in the long-term fiscal prudence of the Korean Government, which allowed it to put in place a plethora of post-1997 reforms. Measures such as recapitalization of financial institutions, removal of non-performing loans, provision of financial support to families with low-income and social programs like unemployment insurance, inter alia, entailed a lot of fiscal pressures on the state because the measures required a lot of public funds. Nonetheless, the Korean government was able to issue new bonds to finance the reforms and handle the public debt because of its history of financial credibility and fiscal prudence. African governments can learn from this and beware that their ability to emerge from a potential financial and/or economic crisis would depend on their institutional credibility.

Then there is the thorny issue of corrupt political elites in Africa (Garoupa and Jellal 2007; Jellal and Bouzahzah 2013). Narratives of the Korean model have been consistent on the position that an effective government is crucial for the success of the KE strategy in order to achieve the long-term development objectives. The pivotal role of the Korean Government has been very remarkable through the development process. The government has been visionary in ensuring effective leadership that enabled a conducive macroeconomic environment for KE: training of the population, mass education, domestic R&D initiatives, access to modern infrastructure, assimilation of foreign technologies, inter alia. Hence, consistent with Tran (2011), the leader Park was able to adopt a pragmatic approach to elite corruption. Instead of cracking down on them (and some business men) as was urged by the USA, he expropriated their shares in banks and obliged them to invest in industries that encouraged import-substitution. The lesson from this experience is for African governments to be more pragmatic in their approaches to fighting corruption in the continent: a massive industry that accounts for about 25 % of its GDP (Asongu 2014d).

Overall, based on the policy syndromes presented in Table 5 above, the importance of the policy recommendations apply to the following African peripheral fundamental characteristics in increasing relevance: English common-law, middle-income, non-conflict, not landlocked, non-oil-exporting, landlocked, Africa, SSA, North Africa, French civil law, low-income, oil-exporting, and conflict-affected countries.

Economic Incentives The extensive or export-led development model as we have seen would expose African industries to more competition. While the outward-looking strategy would induce intensive R&D programs, fiscal incentives from governments are essential for the success. In the same vein, protectionist measures are only necessary

at the initial stages of development in a given industry and should be eventually curtailed. If not, it would encourage complacency in innovation due to the absence of exposure to competitive forces.

Incentives to private credit should be provided by African governments to curtail the substantially documented surplus liquidity issues (Saxegaard 2006; Nguena and Tsafack 2014). This would stimulate private sector development and respond to the growing stream of literature on the need for investment in the continent (Anyanwu 2007, 2009) from recent African business literature (Rolfe and Woodward 2004; Bartels et al. 2009, 2014; Tuomi 2011; Darley 2012; Tchamyou 2014). Moreover, as established by Suh and Chen (2007), small- and medium-size enterprises, a sector with more risk or greater capital requirements, were aided by the research institutes of governments which furnished them with new know-how in terms of collaborative R&D as well as novel spinoff "government backed firms."

Based on the information criteria for "policy syndrome" and "syndrome free" fundamental characteristics presented in Table 5, the above strategies in increasing relevance apply to low-income, conflict-affected, landlocked, French civil law, oil-exporting, North Africa, Africa, SSA, non-oil-exporting, not-landlocked, not conflict-affected, English common law, and middle-income countries.

Conclusion

Africa's overall knowledge index fell between 2000 and 2009. South Korea's economic miracle is largely due to a knowledge-based development strategy that holds valuable lessons for African countries in their current pursuit towards knowledge economies. Using updated data (1996–2010), this paper presents fresh South Korean lessons to Africa by assessing the knowledge economy (KE) gaps, deriving policy syndromes and providing catch-up strategies. The 53 peripheral African countries are decomposed into fundamental characteristics of wealth, legal origins, regional proximity, oil-exporting, political stability, and landlockedness. The World Bank's four KE components are used: education, innovation, information and communication technology (ICT), and economic incentives and institutional regime. Absolute beta and sigma convergence techniques are employed as empirical strategies. With the exception of ICT for which catch-up is not very apparent, in increasing order it is visible in innovation, economic incentives, education, and institutional regime. The speed of catch-up varies between 8.66 and 30.00 % per annum with respective time to full or 100 % catch-up of 34.64 and 10 years. Based on the trends and dynamics in the KE gaps, policy syndromes and compelling catch-up strategies are discussed. Issues standing on the way to KE in Africa are dissected with great acuteness before South Korean relevant solutions are provided. The paper is original in its provision of practical policy initiatives drawn from the Korean experience to African countries embarking on a transition to KE. Policy implications have been discussed.

We devote some space to discussing catch-up horizons, cautions, and caveats. First, while we have presented catch-up rates and timelines needed for full catch-up, we have essentially used this dimension of the analysis for insights into potential catch-up horizons in the absence of multiple equilibria. While the absolute beta-convergence procedure may have less draw-backs than the conditional beta-convergence approach (which has not been implemented for reasons already discussed in the methodology section), multiple equilibria remain a caveat even in the absence of conditioning information set. For the above reasons, we have based the "policy syndrome" and "syndrome free" information criteria on sigma convergence dynamics because absolute beta catch-up is a necessary but not a sufficient condition for sigma convergence.

Second, we cannot ensure reliability and consistency of the original data with those reduced by PCA for two main reasons. First, since there are 15 underlying variables in the paper, it should represent a very substantial work load. Second, the KE indexes are not necessarily suppose to reflect their underlying constituents. For instance, *Educatex* which is the educational index could also be defined as the combined knowledge acquired during primary, secondary, and tertiary schooling. Hence, it may represent only those who have successfully enrolled in the three levels of education. Therefore, *Educatex* would not necessarily reflect the three levels of education independently.

Third, while the graphs in Figs. 1, 2, 3, 4, and 5 overlap and make the dispersions less visible, these figures have been essentially meant to provide some feeling on the trends in KE dispersions. The policy syndromes presented in Table 5 summarize the plethora of graphs in Figs. 1, 2, 3, 4, and 5.

Fourth, while researchers have become distrustful of results based on system GMM (Roodman 2007, 2008, 2009; Bazzi and Clemens 2010; Clemens et al. 2012), the absolute beta convergence estimations that are GMM-oriented are essentially employed in the paper to ascertain sigma catch-up estimations. Hence, the policy syndromes and resulting catch-up strategies have been based on sigma estimations.

Fifth, while comparing South Korea's recent era of development (data from 1996–2010) with that of Africa may be considered as misleading since South Korea's comparable period of development for many of Africa's developing countries was in the period before 1996, most of the comparative KE data for the period before 1996 is not available. Moreover, the mobile phone revolution in Africa has recently shown that certain phases of traditional development processes can be skipped. Hence, contemporary KE lessons from South Korea are as relevant as historic lessons to contemporary African nations. This evidently leaves room for further research. Moreover, as cautioned by Kim (1997) and Kim and Kim (2014), future inquiries on country-specific studies would improve extant literature.

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Appendix 1

Table 6 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, and TSE	PCA
Panel B: information and 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 and communication technology (ICT) in KE	ICTex	First PC of internet, mobile, and tel	PCA
Panel C: economic incentives and 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)

Table 6 (continued)

Variables	Signs	Variable definitions	Sources
Political stability/no violence	PS	Political stability/no violence (estimate): measured as the perceptions of the likelihood that the government will be destabilized or over thrown by unconstitutional and violent means, including domestic violence and terrorism	World Bank (WDI)
Government effectiveness	GE	Government Effectiveness (estimate): 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	World Bank (WDI)
Voice and 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, and VA	PCA
Panel D: innovation			
Scientific and technical publications	STJA	Number of scientific and technical journal articles	World Bank (WDI)
Trademark applications	Trademark	Total trademark applications	World Bank (WDI)
Patent applications	Patent	Total residents + non-resident 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* 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; *VA* voice and accountability; *RL* rule of law; *RQ* regulation quality; *GE* government effectiveness; *PS* political stability; *CC* control of corruption; *Instireg* institutional regime, first PC of VA, PS, RQ, GE, RL, and CC

Appendix 2

Table 7 Summary statistics

	Mean	S.D.	Min	Max	Obs.
Educatex (education)	−0.075	1.329	−2.116	5.562	320
ICTex (information and 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
Innovex (innovation)	1.021	2.542	−0.770	8.859	102

Appendix 3

Table 8 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

Table 8 (continued)

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	0.68	0.92	GE
																				1.00	0.82	VA
																					1.00	Instireg

ICT information and communication technology, *Eco* economic, *PSE* primary school enrolment; *SSE* secondary school enrolment, *TSE* tertiary school enrolment, *Educatex* education index (first principal component of PSE, SSE, and TSE), *Inter* internet penetration; *Mob* mobile phone penetration, *Tel* telephone subscriptions, *ICTex* ICT index (first principal component of internet, mobile, and tel), *STJA* scientific and technical journal articles, *TM* trademark applications, *Pat* patent applications, *Innovex* innovation index (first principal component of STJA, TM, and Pat), *Pcrd* private domestic credit, *IRS* interest rate spread, *Creditex* economic incentive index (first principal component of Pcrd and IRS), *CC* corruption-control, *RL* rule of law, *RQ* regulation quality, *PS* political stability, *GE* government effectiveness, *VA* voice and accountability. *Instireg* institutional regime index (first principal component of CC, RL, RQ, PS, GE, and VA)

Appendix 4

Table 9 Categorization of countries

Category	Panels	Countries	Number
Income levels	Middle income	Algeria, Angola, Botswana, Cameroon, Cape Verde, Côte d'Ivoire, Egypt, Equatorial Guinea, Gabon, Lesotho, Libya, Mauritius, Morocco, Namibia, Nigeria, Sao Tome and Principe, Senegal, Seychelles, South Africa, Sudan, Swaziland, Tunisia	22
	Low income	Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Djibouti, Eritrea, Ethiopia, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Sierra Leone, Somalia, Tanzania, Togo, Uganda, Zambia, Zimbabwe	31
Legal origins	English common law	Botswana, The Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mauritius, Namibia, Nigeria, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe	20
	French civil law	Algeria, Angola, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Guinea, Guinea-Bissau, Libya, Madagascar, Mali, Mauritania, Morocco, Mozambique, Niger, Rwanda, Sao Tomé and Principe, Senegal, Togo, Tunisia	33
Regions	Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Chad, Central African Republic, Comoros, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Rwanda, Sao Tomé and Principe, Seychelles, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe	47
	North Africa	Algeria, Egypt, Libya, Mauritania, Morocco, Tunisia	6
Resources	Petroleum exporting	Algeria, Angola, Cameroon, Chad, Congo Republic, Equatorial Guinea, Gabon, Libya, Nigeria, Sudan	10
	Non-petroleum exporting	Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Central African Republic, Comoros, Congo Democratic Republic, Côte d'Ivoire, Djibouti, Eritrea, Ethiopia, Egypt, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Senegal, Sierra Leone, Somalia, Rwanda, Sao Tomé and Principe, Seychelles, South Africa, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe	43
Stability	Conflict	Angola, Burundi, Chad, Central African Republic, Congo Democratic Republic, Côte d'Ivoire, Liberia, Nigeria, Sierra Leone, Somalia, Sudan, Zimbabwe	12
	Non-conflict	Algeria, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Comoros, Congo Republic, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-	41

Table 9 (continued)

Category	Panels	Countries	Number
		Bissau, Kenya, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Senegal, Rwanda, Sao Tomé and Principe, Seychelles, South Africa, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia	
Openness to sea	Landlocked	Botswana, Burkina Faso, Burundi, Chad, Central African Republic, Ethiopia, Lesotho, Malawi, Mali, Niger, Rwanda, Swaziland, Uganda, Zambia, Zimbabwe	15
	Not landlocked	Algeria, Angola, Benin, Cameroon, Cape Verde, Comoros, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Sao Tomé and Principe, Seychelles, South Africa, Tanzania, Togo, Tunisia	38

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