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Policy Syndromes and
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to Africa**

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

Simplice A. Asongu*

Abstract

Africa's overall knowledge index fell between 2000 and 2009. South Korea's "economic miracle" was 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 knowledge economy (KE) gaps, deriving policy syndromes, and providing catch-up strategies. We decompose the 53 peripheral African countries based on several fundamental characteristics: wealth, legal origins, regional proximity, oil-exporting, political stability and state of "landlockedness". We use the World Bank's four KE components: education, innovation, information & communication technology (ICT, economic incentives and institutional regime). We employ absolute beta and sigma convergence techniques as empirical strategies. With the exception of ICT, for which "catch-up" is not very apparent, we observe African catch-up by categories (in increasing order) in innovation, economic incentives, education and institutional regime. The speed of catch-up varies between 8.66% and 30.00% per annum with full or 100% catch-up of between 34.64 years and 10 years. Based on the trends and dynamics in KE gaps, we discuss policy syndromes and compelling catch-up strategies. We dissect obstacles to KE in Africa before presenting relevant South Korean solutions.

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Keywords: Knowledge economy; Catch-up; South Korea; Africa

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Countries neglecting the challenges of inevitable globalization risk their prosperity. For nations to be competitive and integrated into the world economy, they must embrace globalization and must “play” by competitive-rules. North America and European countries have mastered transformation to a “Knowledge Economy” (KE), and these countries inexorably chart the course of international development. Latin America and Asia have increasingly asserted the need for KE in their pursuits of national and regional initiatives (Dahlman, 2007; Chandra & 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 the implications and lessons for Africa (Kim, 2013). In Asia, South Korea¹ has increasingly been the object of comparison with African countries. South Korea suffered from far less economic development than most African countries in the aftermath of colonial independence (Tran, 2011). Given that 21st century development is KE-centered, and that Africa’s global position in KE is lagging, Korea’s KE experience provides an important benchmark for African development, especially since Africa’s overall knowledge index fell between 2000 and 2009 (Anyanwu, 2012)².

While substantial literature has focused on the emerging economies of Latin America and Asia, scholars have devoted little attention to KE in African countries (Dahlman, 2007; Chavula, 2010; Chandra & Yokoyama, 2011). However, in recent years KE themes have increasingly taking central stage in discussions on development in the continent (AfDB, 2007; Amavilah, 2009; Asongu, 2013a; Andrés & Asongu, 2013ab; Nyarko, 2013a; Andrés et al., 2014). Indeed, a recent stream of literature reflects the need for urgent policy measures to foster African KE³.

¹ We use South Korea and Korea interchangeably throughout the paper.

² The knowledge index is a composite index entailing the: (i) education, (ii) innovation and (iii) information and communication technology (Anyanwu, 2012, p. 9).

³ It includes:

- 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 & communication technologies (African Partnership Forum, 2008 ; Chavula, 2010; Butcher, 2011);
- innovation (Oyelaran-Oyeyinka & Gehl Sampath, 2007; Anyanwu, 2012; Carisle et al., 2013);
- institutional regime & economic incentives (Cogburn, 2003; Letiche, 2006; Saxegaard, 2006; Nguena & Tsafack, 2014; Andrés et al., 2014; Andrés & Asongu, 2013a);
- intellectual capital & economic development (Wagiciengo & Belal, 2012; Preece, 2013);
- indigenous knowledge systems (Raseroka, 2008; Lwoga et al., 2010);
- research & development (German & Stroud, 2007; African Development Bank, 2007; Sumberg, 2005);
- intellectual property rights (Zerbe, 2005; Lor & Britz, 2005; Myburgh, 2011; Andrés & Asongu, 2013ab; 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).

These perspectives reflect the realization of the need for greater emphasis on KE-based research to bridge gaps between Africa and benchmark countries (AfDB, 2007; Bizri, 2009; Aubert, 2005; Britz et al., 2006; Chavula, 2010; Makinda, 2007; Lightfoot, 2011). To the best of our knowledge, no African KE study has yet compared Africa to benchmark Newly Industrialized Asian countries. This 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 syndromes⁴. An updated dataset (1996-2010)⁵, essential to analyze fresh policy measures, also enables us to examine if catch-up in KE dimensions relative to South Korea has accompanied the impressive growth in some African countries during the past decade.

In line with Suh & Chen (2007), we can largely attribute South Korea's dramatic economic prosperity since the 1960s—which enabled the country to emerge from a low-income country (LIC) to a high-income industrialized nation—to accumulation of knowledge rather than to traditional economic factors of labor and capital in production. 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 & development (R&D) to boost innovation, and
- Focusing on economic incentives and a favorable institutional regime conducive to knowledge-oriented investments.

In this light, Korea has been able to use KE as an engine for growth—an experience that could offer lessons for developing countries, especially frontier African nations at the same development threshold as Korea in the 1960s.

The Korea-Africa relationship has received little academic research attention (Kim, 2013), probably due to skepticism about South Korea as a role model of development for other countries⁶. However, recent evidence suggests that it 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 makes use of a number of studies on “achieving development success: strategies and lessons from the

⁴ In the context of this paper, we define policy syndromes as negative tendencies of dispersions in KE dimensions between African peripheral countries and the frontier South Korean economy.

⁵ Based on author's calculation.

⁶ “There is some skepticism 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).

developing world”⁷. For this study, the “frontier” KE country is South Korea because it represents best practices for African countries in the KE periphery to emulate to close KE gaps.

By positioning this paper on KE and the relatively little investigated Korean-African nexus, this study contributes to existing literature by addressing the following policy issues. First, the paper diagnoses KE prospects of peripheral African countries and KE gaps in relation to a frontier country (South Korea), and recommends catch-up policies to bridge KE gaps. Second, the study also examines whether the impressive growth experienced over the last decade by African countries has moved hand-in-hand with 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), comparison with South Korea is ideal in understanding growth prospects of Africa. Accordingly, we offer policy lessons to African countries already embarking on the route to KE. Fourth, looking at peripheral African countries by income levels, legal origins, access to sea, political stability, natural resources and regional proximity enable some insights for more focused policy implications.

The theoretical underpinnings for KE catch-up correspond with cross-country income convergence literature within the framework of neoclassical models of growth. Recently these studies have extended to other fields of economic development (Swan, 1956; Barro, 1991; Mankiw et al., 1992; Solow, 1956; Baumol, 1986; Barro & Sala-i-Martin, 1992, 1995; Narayan et al., 2011; Andrés & Asongu, 2013ab; Fung, 2009; Mayer-Foulkes, 2010; Bruno et al., 2012; Asongu, 2014abc, 2013abc). In this light, the theoretical underpinnings have been used in studying the harmonization/timing/modeling of intellectual property rights (IPRs) related to software piracy (Asongu, 2013a; Andrés & Asongu, 2013b), slowing capital flight (Asongu, 2014d, 2013d), as well as in currency areas and financial markets (Narayan et al., 2011; Bruno et al., 2012; Asongu, 2013b, 2014bc).

We employ the World Bank’s four dimensions of the Knowledge Economy Index (KEI): 1) information & communication technology (ICT), 2) innovation, 3) economic incentives & institutional regime, and 4) education. We specifically use this methodology using these diverse KE dimensions because existing literature has focused only on one or a few KEI components (Aubert, 2005; Britz et al., 2006; AfDB, 2007; Bizri, 2009). Empirical evidence stems from 13

⁷ Fosu, 2013a; Lee, 2013; Jomo & Wee, 2013; Warr, 2013; Thoburn, 2013; Khan, 2013; Singh, 2013; Yao, 2013; Santos-Paulino, 2013; Asongu & Aminkeng, 2013; Robinson, 2013; Subramanian, 2013; Lundahl & Petersson, 2013; Fosu, 2013b; Naudé, 2013; De Mello, 2013; Solimano, 2013; Trejos, 2013; Pozo et al., 2013; Cardoso, 2013; Looney, 2013; Balamoune-Lutz, 2013; Nyarko, 2013b & Drine, 2013.

panels or groupings of countries. Accordingly, because of the richness of the dataset⁸, we are able to disaggregate countries into fundamental characteristics of KE based on income levels, legal origins, oil exporting, access to seaports, political stability, and regional proximity. We investigate three main issues between the homogenous panels (or groupings of countries with similar characteristics) and South Korea: 1) KE gaps or evidence of catch-up: 2) the speed or rate of catch-up, and 3) the corresponding time needed for full catch-up. To ensure robustness in assessments, we employ both *sigma* and *beta* catch-up empirical strategies (see Methodology Annex 5)⁹. Based on the findings from the three issues assessed, we provide catch-up policies for African countries to bridge KE gaps.

Beside specific policy recommendations, four main categories of policy implications emerge. 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 origin, income-level, etc.—helps refine policy implications. Third, rate of KE convergence, which allows us to calculate the time needed for full KE convergence, informs policymakers about the urgency of measures needed to bridge KE gaps. Fourth, catch-up trends can inform policies related to current regional integration efforts in the KE dimensions.

We organize the rest of the study as follows: Section 2 presents South Korea as a Knowledge Economy (KE), and highlights success stories; we discuss data in Section 3 (with in-depth Methodology covered in Annex 5); Section 4 covers the empirical analysis, discussion of results, and policy implications; we conclude with Section 5.

⁸ Emphasis on author's calculation based on World Bank Development Indicators.

⁹ Sigma and beta catch-up are reductions in cross-country differences in a given variable. Whereas sigma catch-up is cross-sectional (many countries in one year) reduction of the underlying difference across years, beta catch-up is based on panel data (many countries in many years).

II. SOUTH KOREA AS A KNOWLEDGE ECONOMY AND LEARNING FROM SUCCESS STORIES

In line with recent literature (Suh & Chen, 2007; Tchamyou, 2014), the South Korean republic has experienced one of the most spectacular growth stories of the 20th century, starting as a low-income nation in the 1950s and becoming an industrialized OECD economy by 2000. The combined interaction of the four dimensions of the World Bank's KEI—innovation, education, ICT, economic incentives & institutional regime—were clearly critical components of Korea's success, although Korea may not have always specifically addressed knowledge components in its early development strategies. Characteristics of Korea's development model included: human resource development fortified with technological capacity building and intensive learning; proactive leadership by government in providing, sustaining, and fostering transformation; and promotion of export and import-substitution industries, among others. Development experts have often used South Korea as a development model for Africa because Korea lagged behind most African countries before the 1980s¹⁰.

Consistent with Lee (2009) and Lee & Kim (2009), Korea can serve as a model for African countries because it achieved economic prosperity more rapidly than any country in recent history—from below 91.62 USD per capita GDP in 1961 to over 22,000 USD in 2011¹¹. According to the narrative, because of skepticism over whether Korea could serve as a model for other developing nations, earlier literature focused on the mission of market versus government in the catch-up processes (Amsden 1989; Chang 1994; World Bank 1993). This perspective paralleled 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 & Asongu, 2013a; Andrés et al., 2014).

Consistent with Andrés et al. (2014), the ongoing debate about the “East Asian miracle” has surrounded “governing the market” and “soft authoritarian” concepts. One theory asserts that certain politico-economic conditions, especially in South Korea, have been conducive for “the miracle”. Some scholars advocate the miracle might have resulted from low Korean enforcement of Intellectual Property Rights (IPRs) at the early stages of development (Bezmen & Depken, 2004). This is consistent with recent findings by Kim et al. (2012) concluding 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).

¹⁰ 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).

¹¹ Source of per capita values: <http://www.indexmundi.com/facts/korea/gdp-per-capita> (Accessed: 14/06/2015).

On the other hand, some authors have argued that there is nothing “miraculous” about the East Asian miracle (Lucas, 1988, 1993)¹². The recent strand of KE literature is devoted to analyzing East Asian economic success in the context of Africa implies that enforcement of IPRs is not a sufficient condition for KE in Sub-Saharan Africa (SSA) and in Middle East & North African (MENA) countries (Andrés et al., 2014). Discouragement of piracy is necessary (Asongu, 2013a; Andrés & Asongu, 2013b), and corruption fuels at least software piracy, which deters the potential for KE (Andrés & Asongu, 2013ab).

In the catch-up literature specifically focusing on South Korea, Lee (2009) has debunked skepticism surrounding Korea as a model for other developing countries by arguing that capacity building, trade openness, and devaluation alone tend to support only short-run and temporary economic “booms”. The study has analyzed Korea use of various knowledge and learning access modes to boost technological capabilities. The author concluded that Korean lessons are transferable to other countries, confirming earlier research recommending the Korean model to other developing countries (Suh & Chen, 2007).

This study represents a response to these calls for further research. 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)¹³.

Starkly contrasting with skeptical narratives on lessons for developing countries (Lucas, 1988, 1993; Lee, 2009), a common denominator to studies in the preceding paragraph is that Africa can draw lessons from successful developing countries. Every developing success story has a dimension, and, consistent with Fosu (2013a), there is substantial diversity in development strategies, including:

- “disinterested-government” political economy of China;
- “high-sector” and democratically-based Indian development approaches;

¹² Within the framework of this study, the East Asian miracle should be understood as the remarkable development of East Asia compared to Africa.

¹³ The papers have focused on South Korea, Malaysia, Thailand and Vietnam in East Asia & the Pacific (Lee, 2013; Jomo & Wee, 2013; Warr, 2013; Thoburn, 2013; Khan, 2013); the emerging Asian giants of China & India (Singh, 2013; Yao, 2013; Santos-Paulino, 2013; Asongu & Aminkeng, 2013); sub-Saharan Africa with examples of Botswana, Mauritius, Ghana and South Africa (Robinson, 2013; Subramanian, 2013; Lundahl & Petersson, 2013; Fosu, 2013b; Naudé, 2013); Latin America & 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; Balia-moune-Lutz, 2013; Nyarko, 2013b; Drine, 2013).

II. SOUTH KOREA AS A KNOWLEDGE ECONOMY AND LEARNING FROM SUCCESS STORIES

- reforms in China & Ghana based on the “Washington-Consensus”;
- diversification strategies in Bahrain, the United Arab Emirates (UAE) and Oman;
- optimal natural-resource management strategies in the UAE, Oman, Botswana & Bahrain;
- social-sector development programs underpinning progress in Tunisia and Costa Rica;
- democratic political system of diversity management in India and;
- the dynamic orthodox-heterodox strategy in Vietnam & Malaysia.

Inspired by the above narratives, this paper focuses on the KE success story of South Korea with particular emphasis on Africa. We can summarize the narratives highlighted in the introduction into one sentence: the need to emphasize KE in Africa as a development strategy.

Before engaging in empirical analysis, it is worthwhile to discuss the roles of foreign aid and technology transfer in South Korea’s KE development, as well as issues related to broader global political economy, notably (i) some obstacles presented by advanced industrial nations, such as patent/licensing, and (ii) the unfavorable global economic context for trade and African exports.

According to Korean government estimates, the country received about USD 12.7 billion between 1945 and the mid-1990s (OECD, 2008, p.9) in aid. This helped mitigate poverty, spur economic development and enhance KE strategies. This inference is consistent with Asongu’s position (2015) that South Korea’s KE-development was substantially aid-driven. Further, South Korean use of technology and science has depended mostly on foreign technologies (Pillay, 2010, p. 73). Apart from the availability of a massive labor force, Korea did not enjoy strong factors needed for industrialization. Given that South Korean firms lagged substantially in terms of world technological competence, it looked for foreign technology immediately after launching into industrialization in 1962. Technological progress in South Korea has combined indigenous R&D efforts and imported technologies. We note that (i) R&D efforts have substantially stemmed from initiatives by research institutes instead of universities, and (ii) strategies of economic development shape the country’s system of innovation¹⁴.

There has been considerable disagreement regarding legal protection of advanced technology between developing and advanced industrialized countries since the 1960s. Debate has principally centered on the patent system, which less industrialized countries have been attempting to change to boost technology transfer to their economies. The Paris Convention reduced protection for patent holders in many developing countries, while a new code of conduct on technology

¹⁴ While developed countries are more likely to engage in new technologies, less developed countries are more likely to rely on technological adaptations based on imitation and reverse engineering.

transfers has emerged (Van Wijk & 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 not attaining the Millennium Development Goal (MDG) of halving poverty by 2015. The continent’s contribution to world trade has dropped to below 1.5% from over 3.8% in the 1950s. Some have characterized this period as three “lost decades” and the “20th century’s economic tragedy”. During the same period, in Asia, and particularly in South Korea, the notion of a “development state” did not change significantly with globalization of neoliberal dogma, and living standards have improved and poverty substantially mitigated¹⁵. The April 2015 World Bank Development Indicators reveal that poverty has been decreasing in all regions of the world with the exception of Sub-Saharan Africa (SSA) (Asongu & Kodila-Tedika, 2015). About 45% of SSA countries are off-track from attaining the MDG poverty target.

¹⁵ A developmental state is a government-led macroeconomic planning; which is in stark contrast to the neoliberal ideology which is based on ‘private sector’-driven economic development.

3.1 Data highlights and fundamental characteristics

We examine 53 African countries with data from Principal Component Analysis (PCA)¹⁶ and World Development Indicators for 1996 to 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 obtained from the PCA are consistent with recent literature (Andrés et al., 2014; Andrés & Asongu, 2013). These KE variables include innovation, ICT, education and, economic incentives & institutional regime. We discuss fundamental characteristics in peripheral African countries, including legal origins (English common law versus French civil law), income-levels (low versus middle-income), openness to sea (landlocked versus not landlocked), political stability (conflict-affected versus stability), regional proximity (Sub-Saharan Africa versus North Africa), and natural resources (petroleum versus non-petroleum exporting) countries. Below, we discuss our classification into fundamental characteristics, corresponding with recent KE literature (Asongu & Andrés, 2013b).

Legal Origins: We include legal origin as a category because of evidence related to differences in countries based on colonial legacy, openness, education & 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 English common law countries in Africa have a better educational system and better economic incentives to promote economic prosperity compared to French civil-law African countries. In terms of institutional quality (or regime), recent studies confirm the relative superiority of English common law (Asongu, 2012ab) documented in pioneering law-finance literature (La Porta et al., 1998, 1999). The underlying reasoning for the superiority of British common law is that informal rules, formal norms and enforcement measures influencing an institutional regime are necessary for KE¹⁷. A consensus has emerged that French civil law emphasizes the power of the State, whereas English common law prioritizes private property rights needed for KE. Classification of countries in this dimension is in line with La Porta *et al.* (2008, p. 289).

Income Levels: Two main reasons motivate the use of income-levels: economic prosperity should come with higher opportunities for KE, and research has documented that the wealth

¹⁶ PCA is a technique that reduces variables with common information into a few variables with unrelated information.

¹⁷ English common law traditions place more emphasis on private property rights compared to the State power emphasised by French civil law. Hence, the former is more likely to create conducive conditions for KE, through entrepreneurship, competition, and innovation, among others.

status of African nations is instrumental in institutional quality necessary for KE (Asongu, 2012c). We use the World Bank's Financial Development and Structure Database (FSDS) to classify countries into low and middle-income countries (LICs and MICs).

“Landlockedness”: A country's ability to access seaports should provide KE advantages because landlocked countries incur higher trade costs. This is also in accordance with documented institutional costs of being landlocked (Arvis et al., 2007)¹⁸. Conversely, “landlockedness” could predispose certain countries to devote more efforts towards developing KE (e.g. Rwanda).

Political Instability: We must note that it is not easy to assign “conflict-affected” countries. Obviously, severe conflict and political strife inhibit a favorable KE environment, but we must distinguish the degree of conflict significance and the length of instability because countries are rarely entirely conflict-free. Hence, we categorize two-groups of countries as “conflict-affected”: First, a “civil war” group that includes 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. Second, we include Zimbabwe and Nigeria as “conflict-affected” due to the seriousness of internal strife, despite the absence of full-fledged civil war.

North and Sub-Saharan Africa: The distinction between North and Sub-Saharan African (SSA) countries has two premises: proximity to Europe is likely to influence KE, and, in accordance with Boyce & Ndikumana (2008), the distinction is consistent with the World Bank's regional classification, implying differing policy priorities.

Oil Exporting: Two issues arise in selecting petroleum-exporting countries. On the one hand, a country could qualify only for part of our study period either because of recent oil discovery or because of substantial decline in production. On the other hand, some countries (e.g Botswana) have macroeconomic characteristics similar to those of oil-exporting countries because they have heavy extraction-based economies. For our study purposes, we select only countries where oil has dominated exports over the last decade: Angola, Algeria, Chad, Cameroon, Congo Republic, Gabon, Equatorial Guinea, Nigeria, Libya and Sudan.

As a final note to our classification system, we note that some nations qualify for more than

¹⁸ According to the author, landlocked countries are associated with low institutional quality.

one category. In contrast to Weeks' approach (2012), we have not imposed constraints. In other words, a country may fall into multiple categories. Appendix 4 summarizes our categorization of African countries discussed above. We define variables in Appendix 1, and present the summary statistics in Appendix 2 and the correlation matrix in Appendix 3.

3.2 Methodology

We use *beta* and catch-up estimation empirical strategies. These are reductions in cross-country differences in a given variable. Whereas *sigma* catch-up is cross-sectional (many countries in one year) reduction of the underlying difference across years, we base *beta* catch-up on panel data (many countries in many years). Please see Appendix 5 for a complete discussion of the methodology.

4.1 Principal Component Analysis

Consistent with recent literature (Tchamyou, 2014; Asongu, 2014e), components of the World Bank's Knowledge Economy Index (KEI) correlate with each other. Due to the high degree of substitution among the components, some information is redundant. We tackle the issue by using principal component analysis (PCA) to reduce the variable dimensions into a single indicator for each component¹⁹. This PCA technique is a widely employed empirical strategy. It consists of reducing a set of highly correlated variables into a smaller set of uncorrelated indicators, or principal components (PCs), significantly varying from the initial set of indicators. This is consistent with Kaiser (1974) and Jolliffe (2002), who recommend using 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). Using PCAs for both frontier and peripheral countries illustrates that KE dimensions are comparable, based on the eigenvalues (reflecting the vectors). In Panel A for instance, ICTex, which is the first PC for ICT, represents about 73% of information in constituent elements (internet, mobile & telephone), and has an eigenvalue of above one (2.190). This is comparable with a corresponding 80% in Panel B.

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

¹⁹ 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, we can provide the underlying correlation analysis upon request.

4.2 Knowledge Economy Gaps

4.2.1 Absolute Beta Convergence

4.2.2.1 Catch-up specification

The two equations below are standard for estimating convergence (Fung, 2009).

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

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

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 $\varepsilon_{i,t}$ an error term. In line with the exogenous growth theory²⁰, 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 $W_{i,t}$, and with a corresponding height relative to the level of $W_{i,t}$ (Asongu, 2014a). The proxies contained in $W_{i,t-\tau}$ and the individual-effect η_i measures toward which KE is converging in the long run. 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 some potential correlation between the lagged endogenous variables and the individual-specific effect involves eliminating the latter by first differencing.

Hence, Eq. (2) becomes:

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

A means of further dealing with the correlation between the lagged endogenous variable and the error term consists of conducting regression on the equations in levels jointly with the equations in first difference to exploit all the orthogonality or parallel conditions. The process

²⁰ The basis for this theory lies in the consensus that economic growth is affected by factors outside the economy.

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)²¹, we prefer the system GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998) to the difference GMM specification (Arellano & Bond, 1991). We also prefer a two-step procedure to a one-step specification because it accounts for heteroscedasticity or variation of error terms.

Since yearly intervals are not appropriate for investigating catch-up because short-run disturbances may loom substantially large, we use three-year non-overlapping intervals (NOI). Hence, τ is set to 3. Therefore, 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 simplicity²². With the absolute value of the lagged coefficient less than one but greater than zero ($0 < |a| < 1$), we confirm the existence of catch-up. 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. We use the Sargan over-identifying restrictions (OIR) test and second-order Arellano & Bond autocorrelation (AR(2)) to assess the validity of the instruments and absence of autocorrelation in the residuals respectively.

4.2.2.2 Presentation of absolute beta catch-up results

We assess three main issues 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 the shortcomings discussed in the methodology section on conditional beta catch-up, we only model absolute beta catch-up. Hence, we estimate absolute (or unconditional) convergence with only the lagged difference of the dependent variable as independent variable. In other words, we model absolute catch-up without $W_{i,t}$.

²¹ "We also demonstrate that more plausible results can be achieved using a system GMM estimator suggested by Arellano & Bover (1995) and Blundell & 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).

²² 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 interpretation is in line with recent convergence literature (Prochniak & Witkowski, 2012a, p. 20; Prochniak & Witkowski, 2012b, p. 23; Asongu, 2013a, 2014a).

To investigate the validity of the estimation, and indeed the catch-up hypothesis, we perform two tests 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, we overwhelmingly reject the null of both tests.

Before discussing the results, we devote some space to elucidating how we have obtained the numbers in Table 2. 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 ($300%/16.33%$).

From analysis of the summary of the results presented in Table 2 below, we can make a number of conclusions in comparing African peripheral countries and the South Korean frontier country. First, with the exception of ICT where no catch-up is apparent, in increasing order catch-up is visible in innovation, economic incentives, education, and institutional regime. Second, we observe the soundness of using fundamental characteristics since we observe 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 (Nonoil in Economic incentive dimension) and 30.00% (Innovation dimension) with respective time to full or 100% convergence of 34.64 years and 10 years.

[Table 2: Summary of Results]

[Table 3: Dynamic System GMM]

We can explain the overwhelming absence of convergence in ICT in two main ways. First, substantial differences exist in initial conditions or endowments of ICT infrastructure across African countries. Second, substantial cross-country institutional and structural differences inhibit catch-up in ICT. As a policy implication, countries should consolidate regional integration efforts for ICT synchronization to accelerate catch-up. This narrative is broadly consistent with an evolving stream of African development literature on the need for reduction in infrastructural gaps to enhance economic integration and policy harmonization, notably Akpan (2014), Njifen (2014), Kayizzi-Mugerwa et al. (2014), Baricako & Ndongo (2014), Charaf-Eddine & Strauss (2014), Ebaidalla & Yahia (2014), Ofa & Karingi (2014), Nshimbi & Fioramonti (2014), Tumwebaze & Ijjo (2015), and Shuaibu (2015).

We devote space to clarifying the policy relevance of catch-up compared to full catch-up.

Consistent with Asongu (2014a), absolute *beta* convergence (ABC) is the result of common policy initiatives such as monetary unions. In this study, the context includes KE features based on fundamental characteristics of African development. Hence, ABC within this framework implies that countries share the same fundamental characteristics for a given KE dimension, such that differences between nations are only apparent in initial levels of the underlying KE dimension. On a practical front, significant ABC indicates that common policies are feasible among countries within a fundamental characteristic for a given KE dimension. Furthermore, evidence of full catch-up implies that countries can implement the underlying feasible policies without distinction of nationality for the given KE within the homogenous panel or fundamental feature. Hence, the timeline for policy harmonization is contingent on the implied catch-up rate and time to full catch-up.

Unfortunately, owing to initial conditions, full ABC does not guarantee full catch-up. It is for this reason that ABC is not a sufficient condition of *sigma* catch-up. While researchers should employ the terms catch-up and convergence for beta and sigma estimations, such distinctions are not apparent in the convergence/catch-up literature. Hence, we have used the terms interchangeably, but we shall endeavor to clarify the edge of the *sigma* approach. *Sigma* convergence is a reduction in cross-country dispersions necessary for real convergence to take place. In light of the above, we complement the absolute beta catch-up estimations with tabular and graphical *sigma* convergence patterns to promote robustness and greater subtlety in the analysis.

4.2.2 *Sigma* convergence: tabular and graphical KE dispersions

Table 4 below presents KE convergence between peripheral African countries and South Korea 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.

[Table 4: Tabular Representation of KE Dispersions]

We derive Figures 1-5 below from Table 4. As will be discussed in Section 4.3 below, using both tabular and graphical representations helps to calibrate “policy syndromes” for more targeted/focused policy implications/strategies.

[Figure 1: *Sigma* Convergence in Education]

We can see from Figure 1 above that the gap between Korea and African countries was very substantial in 1996, with middle-income and low-income countries (MICs and LICs) witnessing the highest and lowest gaps respectively. Notably, 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, the averages have remained stable, though fluctuating considerably in North Africa and Oil exporting countries. Korean KE strategies adopted at the beginning of the millennium explain the increase in gap from the year 2000. Consistent with Suh & Chen (2007, p. 25), in 2000 Korea embarked on human resource development in its transition to intensive KE by greatly improving on education.

[Figure 2: *Sigma* Convergence in ICT]

Figure 2 depicts the dispersions in ICT. We see three broad phases:

- Phase one, between 1996 and 1999, entailed sharp declines in the dispersions.
- Phase two, from 1999 to 2005, characterized by gradual improvement and slow decline, with a peak in 2002.
- Phase three, characterized by increase in the dispersions with mixed tendencies, sharp (North Africa, Conflicts, Low-income, Landlocked), and gradual (Non-conflicts, Oil-exporting, Not-landlocked).

[Figure 3: *Sigma* Convergence in Innovation)]

Dynamics in dispersions of innovation depicted in Figure 3 above display an oscillating pattern: first, a steep decline from 1996 to 1997, then a sharp rise between 1997 and 1998, followed by another steep decline to the year 2000. After, we observe two tendencies, with some countries leveling-up for two years before witnessing a another sharp rise to 2011 (Oil exporting, Conflicts, Low-income, Landlocked), and a second category of countries experiencing sharp rises and decreases between 2000 and 2002, before displaying wave-like reductions in the dispersions.

[Figure 4: *Sigma* Convergence in Institutional Regime]

The patterns of dispersions in institutional regime shown in Figure 4 above are almost uniform across fundamental characteristics. The breaks in 1997, 1999 and 2001 are due to missing data. Generally, the dispersions display 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 South Korea and peripheral African countries.

[Figure 5: *Sigma* Convergence in Economics]

In Figure 5 above, the tendencies 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, in increasing order, by the following dispersion magnitudes: 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 Figures 1-5 is an increasing gap in KE after the year 2000, an indication that countries need compelling catch-up strategies. The growing gaps are consistent with Anyanwu's (2012) finding that African KEI has decreased between 2000 and 2009.

4.3. Policy syndromes and Catch-up strategies

4.3.1 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 likely to have substantially contributed to Africa's poor record of post-independence growth. 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 cases is essential to ensure complete elimination of dispersions. This is essentially because SF situations are prone to become PS scenarios given the history of wave-like trends in the KE dispersion patterns. Therefore, the catch-up strategies are essential, both to prevent and to cure dispersions, in SF and PS scenarios. Hence, we specifically discuss PS before discussing the catch-up strategies.

As already discussed in Section 4.2.2 above, we require both tabular and graphical representations to calibrate PS for more targeted policy implications and strategies. Hence, Table 5 below depicts comparative PS and SF scenarios using 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, we can observe consistent patterns for the first-three dimensions of KE:

“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.

[Table 5: “Policy Syndrome” and “Syndrome Free” Information Criteria]

4.3.2 Catch-up strategies

Lee (2009) has argued that other countries can adapt the Korean model and “catch-up”. In our analysis, we first discuss broad policy implications before proposing more focused policies and recommendations relevant to the discovered policy syndromes²³. Hence, consistent with Suh & Chen (2007), we can take two important lessons from the experiences of Korea. First, human capital is essential for the development of science and technology and economic prosperity. Second, market competition is the greatest motivator of private business to engage in technology development. Thus, it is important to consolidate the capabilities of scientific research and improve conditions for innovation.

Education and Innovation strategies

Recent research has pointed to lack of investment in education and “brain drain” as obstacles to consolidating education as a pillar of KE in Africa (Kamara et al., 2007; Ford, 2007; Amavilah, 2009; Chavula, 2010; Weber, 2011; Anyanwu, 2012; Andres *et al.*, 2014; Tchamyu, 2014). Africa suffers from poor knowledge infrastructure, limited support for R&D, brain drain, limited direct nexuses between science & industry, and outdated curricula. The continent-wide downward trend in KE (Anyanwu, 2012) jeopardizes new economy development unless countries implement bold measures to reinvigorate science & technology, innovation, and higher education (Kamara, 2007). We have established Africa’s deficiency in innovation in Section 2 (Oyelaran-Oyeyinka & 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 to GDP. It is important to note that primary schooling is associated with higher social returns compared to higher education only when economies are at initial

²³ While this entails some leap of logic based on the quantitative analysis, it is, to the best of our knowledge, an appropriate way of presenting corresponding policy implications.

stages of development (Petrakis & Stamatakis, 2002; Asiedu, 2014). As shown by Lee (2009), such measures are effective and possible only in conjunction with substantial improvements in other institutions and policy areas, including the capacity and autonomy of government. Education consolidates a nation's ability to acquire new technology and knowledge. It also promotes tacit individual knowledge essential to consolidate blocks of technology learning. African governments must thus promote core human resource development (Suh & Chen, 2007; Tchamyu, 2014). While Korea continues to import a substantial portion of its technology from more advanced nations, it has developed a solid indigenous R&D platform, allocating about 3% of its GDP to R&D. Essentially, these strategies for technology and education illustrate the disciplinary and practical dimensions that should motivate African countries in KE efforts.

Second, for workers to cope with changing technological conditions, African governments need to provide technical and vocational trainings and encourage workplace training.

As a nation becomes more advanced and prosperous, technological competence improves. To implement these strategies, African governments and policymakers should nurture engineers and high-caliber scientists capable of handling advanced science & technology. In Korea, industrialization and education complemented one another to accelerate and sustain development. Education produced technological learning and industrialization, and the latter boosted the return rate on educational investment, which further promoted demand for education (Such & Chen, 2007; Tchamyu, 2014).

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

It is important to note that whereas this paper builds on Kim et al. (2012) to argue for less stringent property rights, the more relevant implications avoid the debate over the role of more or less stringent IPRs. In essence, alternative forms of IPRs, such as *petit* patents (or utility models), may promote minor or adaptive innovations. This implication is consistent with Kim's (1997, p. 220) perspective that it is exceedingly difficult for developing countries to industrialize through technological innovation requiring huge R&D investments.

Based on the "policy syndromes", we propose an increasing relevance of KE strategies for African countries as follows:

(1) The education dimension is relatively more important for Middle-income, Not-Landlocked, English Common law, Oil-exporting, Non-conflict, SSA, Africa, Non-Oil exporting, French Civil law, Conflict-affected, North Africa, Landlocked & Low-income countries.

(2) The innovation dimension of KE is relatively more relevant for North Africa, Not Landlocked, Nonconflict, Africa, Non-Oil exporting, SSA, French Civil law, English Common law, Middle-income, Oil exporting, Conflict-affected, Low-income, and Landlocked countries.

ICT catch-up strategies

We have covered the plethora of African benefits related to ICT catch-up in Section 2 (African Partnership Forum, 2008; Chavula, 2010; Butcher, 2011). As we also highlighted above, reverse engineering of imported ICT and less stringent IPRs on ICT would promote African ICT by decreasing technology acquisition costs.

Korea's ICT success has hinged on soundly integrated approaches combining industrial policy, an active computing policy, and well enforced competition and regulatory policies.

Korea invested massively in internet equipment, telephone lines, and multimedia, among other relevant infrastructure. These investments have substantially contributed to its economic prosperity. Consistent with Such & Chen (2007) and Tchamyou (2014), the government clearly articulated the policy along three main areas: 1) R&D, venture capital and human resources (an industrial policy); 2) privatization and market liberalization (enforced competitive & regulatory policy) and; 3) establishing "e-government", constructing an advanced infrastructure (an active information policy). Combining the three areas of complementary policies has been the main cause for IT success. This lesson could inspire African countries because the well-tailored information infrastructure may have formed 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-conflicts and Oil exporting countries.

Institutional regime and Economic incentive catch-up strategies

Good institutions are central to the emergence of African economies (Fosu, 2013d). African countries are substantially lacking in this fourth pillar of KE (Cogburn, 2003; Letiche, 2006). Obstacles to growth include poor institutions (Andrés et al., 2014), especially corruption in upholding IPRs (Andrés & Asongu, 2013a), and lack of surplus banking liquidity or absence of credit to finance investment (Saxegaard, 2006; Nguena & Tsafack, 2014).

Institutional regime

African development literature has highlighted poor institutions and capital flight as key constraints to investment and economic prosperity (Boyce & Ndikumana, 1998, 2001, 2003, 2008, 2011; Fofack & Ndikumana, 2009). African institutions need development strategies that liberate competitive forces essential for KE dynamics to manifest. A market-oriented strategy requires competition, government accountability, and foreign investment and liberalized trade regimes that discourage capital flight, promote transparency of financial markets, and level the playing field for all market participants.

African government institutions should foster export-led industrialization. Accordingly, by adopting extensive development strategies, they would expose African corporations to global competition. This would ultimately compel domestic industries to invest substantially in innovation and technological assimilation to remain competitive.

The Korean government solution to its 1997 crisis sheds light on the advantages of having a credible institutional regime (Tchamyou, 2014) to mitigate capital flight. African governments can learn from the long-term fiscal prudence of the Korean government in establishing post-1997 reforms. While government measures—such as recapitalization of financial institutions, removal of non-performing loans, provision of financial support to low-income families, and creation of social programs such as unemployment insurance—placed substantial fiscal pressure on State public funds, the Korean government was able to issue new bonds to finance reforms because of its history of financial credibility and fiscal prudence. African governments should take from this that their ability to emerge from a potential financial or economic crisis depends on institutional credibility.

The issue of corrupt political elites in Africa is controversial (Garoupa & Jellal, 2007; Jellal & Bouzahzah, 2013). Narratives of the Korean model have been consistent on the position that effective government is crucial for KE strategies to achieve long-term development objectives. The pivotal role of the Korean government has been remarkable through the development process. The government has been visionary, providing effective leadership to enable a KE-conducive environment, including training, mass education, domestic R&D, modern infrastructure, assimilation of foreign technologies, among other key policies. Consistent with Tran (2011), Korean leader Park's pragmatic approach to thwarting elite corruption seems to have been enlightened. Instead of cracking down on elites, including businessmen, as the USA had urged, Park expropriated their bank shares and obliged them to invest in industries that encouraged import-substitution. The lesson for African governments is that they need to be

pragmatic in fighting corruption—a massive industry that accounts for about 25% of African GDP (Asongu, 2014d).

Based on the policy syndromes presented in Table 5 above, the importance of the policy recommendations apply to African countries with the following 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.

Economic incentives

Extensive or export-led development models would expose African industries to more competition, and outward-looking strategies would induce R&D. Fiscal government incentives are essential for success. In the same vein, protection necessary at the initial stages of an industry's development should eventually curtail, because regulatory protection encourages complacency in innovation.

African governments should provide credit incentives for credit to improve liquidity, which experts have frequently cited as a problem (Saxegaard, 2006; Nguena & Tsafack, 2014). This would stimulate private sector development and respond to calls for investment in the continent (Anyanwu, 2007, 2009), and from recent African business literature (Rolfe & Woodward, 2004; Bartels et al., 2014; Bartels et al., 2009; Tuomi, 2011; Darley, 2012; Tchamyu, 2014). Moreover, as established by Suh & Chen (2007), Korean Government research institutes helped small & medium-size enterprises (SMEs)—a sector with more risk and greater capital requirements—to improve “know how” through collaborative R&D.

Based on the 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.

Catch-up horizons, cautions, and caveats

First, we must point out that while we have presented catch-up rates and timelines needed for full catch-up, we have derived insights into potential catch-up horizons in the absence of

multiple equilibria²⁴. While absolute *beta*-convergence procedure may have fewer drawbacks compared to the conditional *beta*-convergence approach (which we have not implemented for reasons discussed in the methodology section), multiple equilibria remains a caveat even in the absence of conditioning the information set. For these reasons, we have based the “policy syndrome” and “syndrome free” information criteria on *sigma* convergence dynamics because, while absolute beta catch-up is a necessary condition for *sigma* convergence, it is not sufficient.

Second, it is important to note that consistency between the original data with information obtained by PCA may not be apparent for two main reasons: the five KE indicators derive from fifteen underlying variables, and the KE indexes do not necessarily reflect their underlying constituents. For instance, *Educatex*, which is the educational index, could also comprise 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, a caveat — while the graphs in Figures 1-5 overlap and make dispersions less visible, these figures provide some visual sense of the trends in KE dispersions. The Policy syndromes presented in Table 5 summarise the plethora of graphs in Figures 1-5.

Fourth, while researchers have become distrustful of results based on system GMM²⁵ (Roodman, 2007, 2008, 2009; Bazzi et al., 2010; Clemens et al., 2012), we employ the GMM-oriented absolute *beta* convergence estimates in the paper to ascertain *sigma* catch-up estimations. Hence, we base the policy syndromes and resulting catch-up strategies on *sigma* estimations.

Fifth, some might consider comparing South Korea’s recent era of development (data from 1996-2010) with Africa to be misleading. South Korea’s comparable period of development to many of Africa’s developing countries was before 1996. However, most comparative KE data for the period before 1996 is not available. Moreover, the mobile phone revolution in Africa implies the possibility of “leapfrogging” certain phases of traditional development. Hence, we propose that contemporary KE lessons from South Korea are relevant to contemporary African nations. Sixth, we have not engaged the issue of whether KE dimensions are equally binding in the African context, nor have we discussed whether their importance differs depending on stages of development. A future line of inquiry emphasizing African and country-specific resource limitations can better address this issue of “binding constraint” or African-specific features.

²⁴ The absence of a general equilibrium and presence of partial equilibria.

²⁵ An example of a system GMM is the combination of Equations 2 and 3 of Section 4.2.2.1.

Interested readers can find more insights into the underlying issue in Kim (1997, p. 221-225), Lee & Kim (2009) and Kim & Kim (2014).

Seventh, it is also important to emphasize some weaknesses and failures of the South Korean experience, notably the tradeoff between quantity and quality. In essence, while boosting KE expenditure is important, the tailoring of the underlying expenditure is even more important. Accordingly, with democratization, Korea has traded quality of KE for quantity of KE by favoring egalitarianism over "selective but efficient" allocation of public resources. Hence, over-emphasis on social policies may engender sub-optimal KE externalities (Jeong, 2015, p. 116).

Eighth, consistent with Kim (1997, p. 221-225), there are five points to bear in mind when assessing South Korea's lessons for African countries, notably:

- (i) geopolitical significance to the United States at the early phase of development;
- (ii) a comprehensive developmental state from the onset, including state bureaucracy to accommodate effective and efficient implementation of policies;
- (iii) limited influence by dominant social groups and classes;
- (iv) comprehensive developmental state was accompanied by a very authoritarian and repressive regime, where millions of workers paid a high price (e.g. limited political rights and press freedom) for the success of the country's development model.

Africa's overall knowledge index decreased 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.

By positioning this paper on KE and the relatively little investigated Korean-African nexus, this study contributes to existing literature by addressing the following policy issues. First, the paper provides a KE diagnosis on the current growth situation and prospects of peripheral African countries by investigating KE gaps in relation to a frontier country (South Korea) and by providing compelling catch-up policies to bridge KE gaps. Second, the study also presents a unique opportunity to examine whether the impressive growth experienced over the last decade by African countries has moved hand-in-hand with catch-up trends in KE relative to South Korea. Third, in response to studies pointing to KE as a main axis for future development, comparison with South Korea is ideal to understand Africa's growth prospects. Accordingly, we offer practical policy lessons to African countries already embarking on the route to KE. Fourth, decomposition of peripheral countries by income levels, legal origins, access to sea, political stability, natural resources and regional proximity enable insights for more focused policy implications by categories of countries.

The intuition and theoretical motivations underpinning KE catch-up are typically in line with cross-country income convergence literature documented within the framework of neoclassical models of growth. Using updated data (1996-2010), this paper presents fresh South Korean lessons to Africa by assessing knowledge economy (KE) gaps, deriving policy syndromes, and providing catch-up strategies. We decompose the 53 peripheral African countries into fundamental characteristics of wealth, legal origins, regional proximity, oil-exporting, political stability and state of "landlockedness". Using the World Bank's four KE components—education, innovation, information & communication technology (ICT), and economic incentives & institutional regime—we employ absolute *beta* and *sigma* convergence techniques as empirical strategies. With the exception of ICT, for which catch-up is not very apparent, we observe African catch-up by categories (in increasing order) in innovation, economic incentives, education and institutional regime. The speed of catch-up varies between 8.66% and 30.00% per annum, thus requiring from 10 year to 34.64 years for 100% catch-up depending on category. Based on the trends and dynamics in the KE gaps, we discuss policy syndromes and compelling catch-up strategies. We dissect obstacles to KE in Africa before offering solutions based on the South Korean experience. The paper is original in providing practical policy initiatives, based on Korean experience, for African countries embarking on a transition to KE.

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

Panel A: PCA for Peripheral countries (Africa)										
Knowledge Economy dimensions		Component Matrix (Loadings)						First PC	Eigen Value	Indexes
Education	School Enrolment	PSE		SSE		TSE		0.658	1.975	Educatex
		0.438		0.657		0.614				
Information & 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 & 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)										
Knowledge Economy dimensions		Component Matrix (Loadings)						First PC	Eigen Value	Indexes
Education	School Enrolment	PSE		SSE		TSE		0.688	2.065	Educatex
		-0.359		-0.675		0.645				
Information & 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 & 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			

P.C: 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 nonresident). VA: Voice & Accountability. RL: Rule of Law. R.Q: Regulation Quality. GE: Government Effectiveness. PS: Political Stability. CC: Control of Corruption. Instireg (Institutional regime): First PC of VA, PS, RQ, GE, RL & CC. Creditex: First PC of Private domestic Credit and Interest rate spread.

(Source: Author's calculation)

Table 2: Summary of Results

Panel A: Education (Educatex)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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 (Yrs)	18.37	---	16.36	---	---	20.00	25.00	18.00	20.93	18.37	20.46	---	16.82
Panel B: Information & Communication Technology (ICTex)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
Catch-up(C)	No	No	No	No	No	No	No	No	No	No	No	No	No
Rate of C (%)	---	---	---	---	---	---	---	---	---	---	---	---	---
Time to FC (Yrs)	---	---	---	---	---	---	---	---	---	---	---	---	---
Panel C: Innovation (Innovex)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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 (Yrs)	---	---	---	---	10.00	---	10.00	---	10.22	---	---	---	---
Panel D: Institutional Regime (Instireg)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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 (Yrs)	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)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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 (Yrs)	---	---	---	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. Yrs: Years.

(Source: Author's calculation)

Table 3: Dynamic System GMM

Panel A: Education (Educatex)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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 & Communication Technology (ICTex)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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	10797***	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)
Panel D: Institutional Regime (Instireg)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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)													
	Income Levels		Legal Origins		Petroleum		Openness to sea		Stability		Regions		Africa
	Low	Middle	English	French	Oil	NoOil	Closed	Open	Conf	NoConf	SSA	NA	
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)

*, **, ***: significance levels of 10%, 5% and 1% respectively. Initial: Lagged dependent variable. AR(2): Second-order Autocorrelation test. Sargan: Sargan Overidentifying Restrictions (OIR) test. The significance of bold 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. 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. (Source: Author's calculation)

Table 4: Tabular representation of KE dispersions

Panel A: Education (Educatex)													
Years	Low.I	Mid.I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
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)													
Years	Low.I	Mid.I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
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
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)													
Years	Low.I	Mid.I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
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
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)													
Years	Low.I	Mid.I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
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)													
Years	Low.I	Mid.I	Eng.	Frch.	Oil	NOil	LL	NLL	Con	NCon	SSA	NA	Africa
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
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.

(Source: Author's calculation)

Table 5:

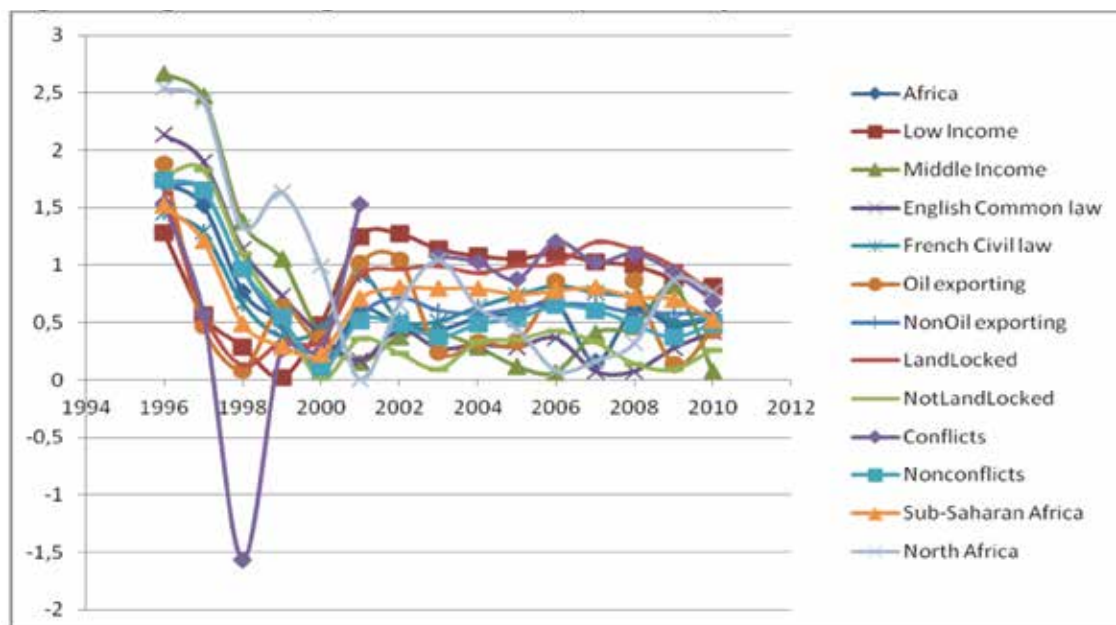
Policy Syndrome’ and ‘Syndrome Free’ Information Criteria

	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. P.C: 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 nonresident). VA: Voice & Accountability. RL: Rule of Law. R.Q: Regulation Quality. GE: Government Effectiveness. PS: Political Stability. CC: Control of Corruption. Instireg (Institutional regime): First PC of VA, PS, RQ, GE, RL & CC. Creditex: First PC of Private domestic Credit and Interest rate spread.

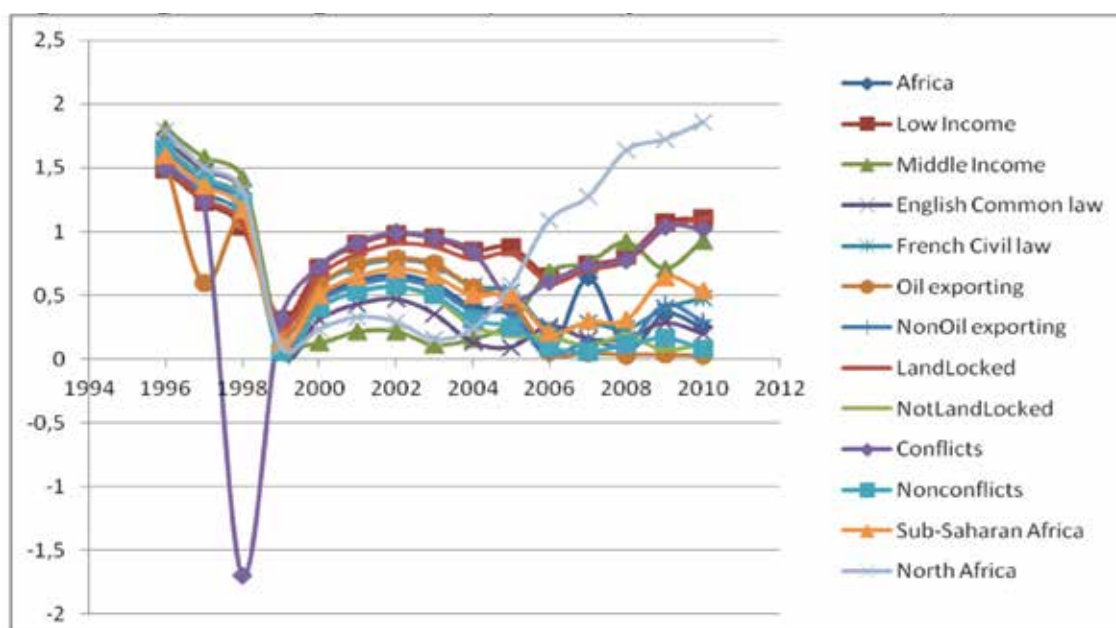
(Source: Author’s calculation)

Figure 1: Sigma Convergence in Education (X-axis for years and Y-axis for Education)



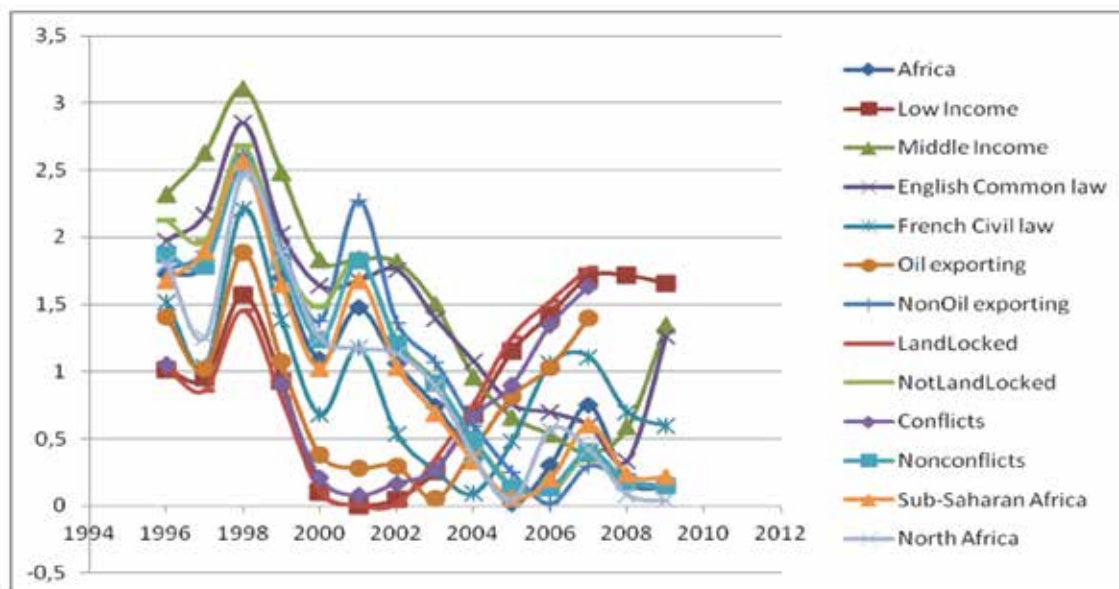
Source: Author's calculation

Figure 2: Sigma Convergence in ICT (X-axis for years and Y-axis for ICT)



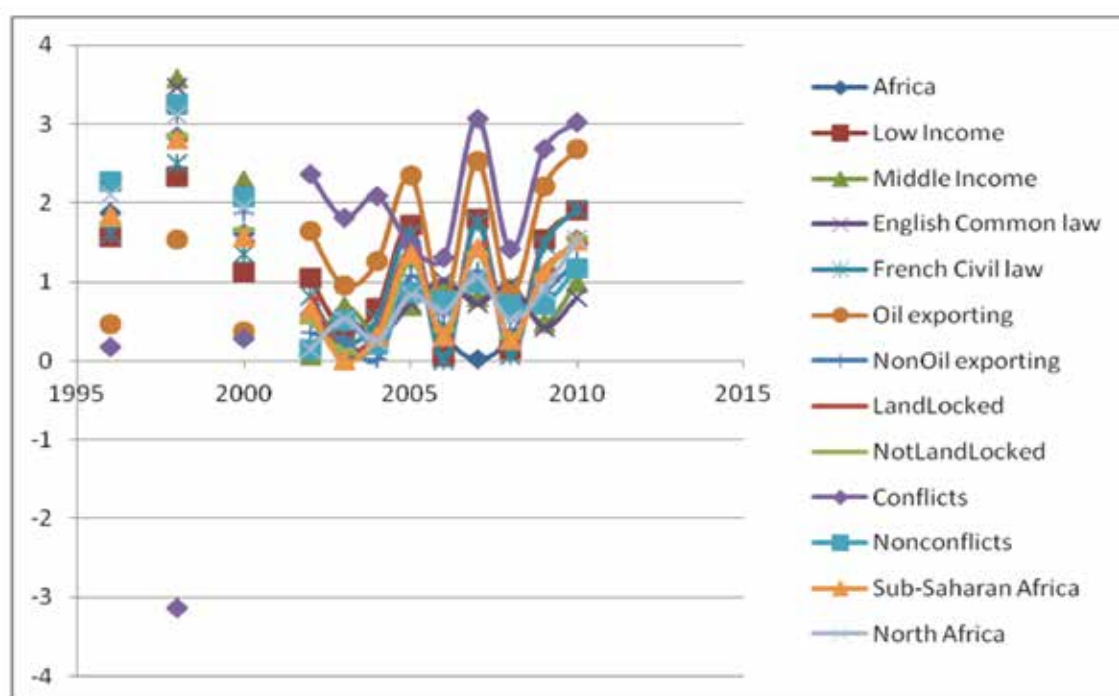
Source: Author's calculation

Figure 3: Sigma convergence in Innovation (X-axis for years and Y-axis for Innovation)



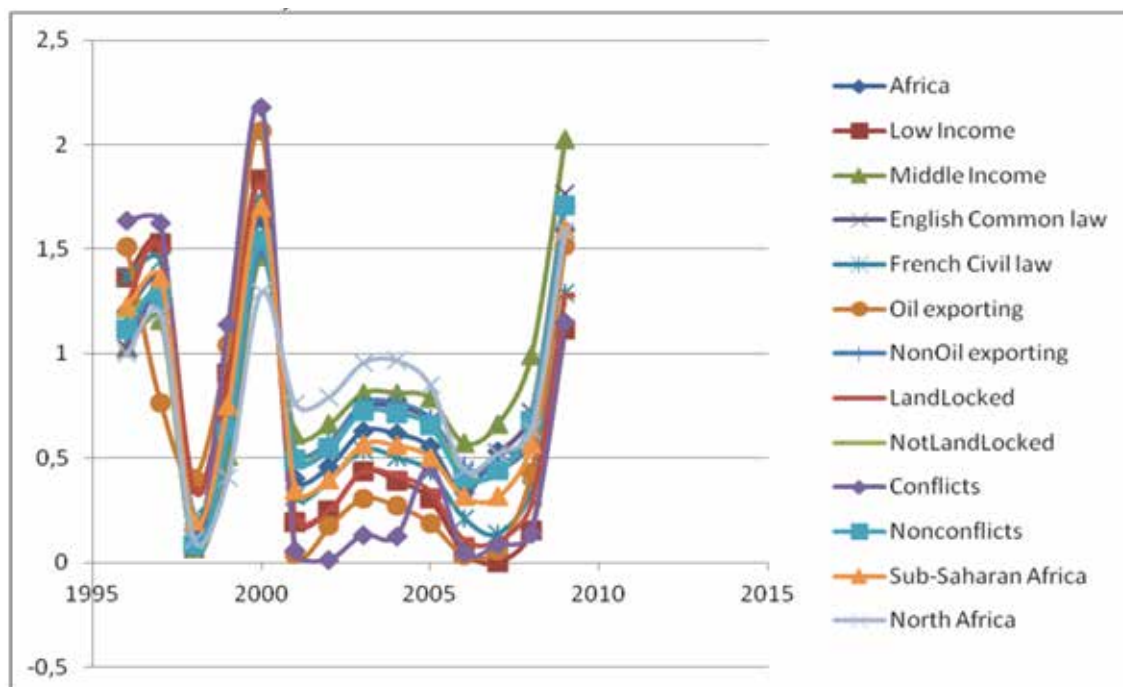
Source: Author's calculation

Figure 4: Sigma Convergence in Institutional Regime (X-axis for years and Y-axis for Institutional Regime)



Source: Author's calculation

Figure 5: Sigma Convergence in Economic Incentives (X-axis for years and Y-axis for Economic Incentives)



Source: Author's calculation

Appendix 1: Definition of Variables

Variables	Signs	Variable definitions	Sources
Panel A: Education			
Primary School Enrolment	PSE	School enrolment, primary (% of gross)	World Bank (WDI)
Secondary School Enrolment	SSE	School enrolment, secondary (% of gross)	World Bank (WDI)
Tertiary School Enrolment	TSE	School enrolment, tertiary (% of gross)	World Bank (WDI)
Education in KE	Educatex	First PC of PSE, SSE & TSE	PCA
Panel B: Information & Infrastructure			
Internet Users	Internet	Internet users (per 100 people)	World Bank (WDI)
Mobile Cellular Subscriptions	Mobile	Mobile subscriptions (per 100 people)	World Bank (WDI)
Telephone lines	Tel	Telephone lines (per 100 people)	World Bank (WDI)
Information & Communication Technology (ICT) in KE	ICTex	First PC of Internet, Mobile & Tel	PCA
Panel C: Economic Incentives & Institutional Regime			
Financial Activity (Credit)	Pcrbof	Private domestic credit from banks and other financial institutions	World Bank (FDSD)
Interest Rate Spreads	IRS	Lending rate minus deposit rate (%)	World Bank (WDI)
Economic Incentives in KE	Creditex	First PC of Pcrbof and IRS	PCA
Corruption-Control	CC	Control of Corruption (estimate): Captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests.	World Bank (WDI)
Rule of Law	RL	Rule of Law (estimate): Captures perceptions of the extent to which agents have confidence in and abide by the rules of society and in particular the quality of contract enforcement, property rights, the police, the courts, as well as the likelihood of crime and violence.	World Bank (WDI)
Regulation Quality	RQ	Regulation Quality (estimate): Measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	World Bank (WDI)

Political Stability/ No violence	PS	Political Stability/ No Violence (estimate): Measured as the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional and violent means, including domestic violence and terrorism.	World Bank (WDI)
Government Effectiveness	GE	Government Effectiveness (estimate): 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 & Accountability	VA	Voice and Accountability (estimate): Measures the extent to which a country's citizens are able to participate in selecting their government and to enjoy freedom of expression, freedom of association, and a free media.	World Bank (WDI)
Institutional Regime in KE	Instireg	First PC of CC, RL, RQ, PS, GE & VA	PCA
Panel D: Innovation			
Scientific & Technical Publications	STJA	Number of Scientific & Technical Journal Articles	World Bank (WDI)
Trademark Applications	Trademark	Total Trademark Applications	World Bank (WDI)
Patent Applications	Patent	Total Residents + Nonresident Patent Applications	World Bank (WDI)
Innovation in KE	Innovex	First PC of STJA, Trademarks and Patents	World Bank (WDI)

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

(Source: Author's calculation)

Appendix 2: Summary Statistics

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

Source: Author's calculation

Appendix 3: Correlation Analysis

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

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

Appendix 4: Categorization of Countries

Category	Panels	Countries	Num
	Middle Income	Algeria, Angola, Botswana, Cameroon, Cape Verde, Côte d'Ivoire, Egypt, Equatorial Guinea, Gabon, Lesotho, Libya, Mauritius, Morocco, Namibia, Nigeria, Sao Tome & 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 & 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 & 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 & Príncipe, 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-Bissau, Kenya, Lesotho, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Senegal, Rwanda, Sao Tomé & Príncipe, Seychelles, South Africa, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia.	41
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 & Príncipe, Seychelles, South Africa, Tanzania, Togo, Tunisia.	38
Num: Number of cross sections (countries)			

Source: Author's calculation

Appendix 5: Methodology

The first step in the empirical strategy consists of reducing the dimensions of the KE indicators with principal component analysis (PCA) discussed in Section 4.1. We then assess KE gaps 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. This process enables us to derive policy syndromes and catch-up strategy recommendations. While we highlight the methodology here, we discuss in detail concurrently with presentation of results to improve readability. For example, understanding of computation of catch-up rates improves when combining with corresponding estimated lagged values.

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 to study convergence. Notably, convergence across economies versus convergence within an economy; convergence in terms of income versus convergence in terms of economic growth; TFP (total factor productivity) convergence versus income convergence; stochastic convergence versus deterministic convergence; *sigma* convergence versus *beta* convergence; local or club-convergence versus global convergence; absolute (unconditional) versus 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 & formal approaches). Most of the approaches have been oriented towards cross-economy per capita income convergence. In addition, we employ the formal panel and cross-sectional approaches to investigate TFP and club convergence. We also employ the time series strategy to assess both across- and within-economy convergence. We use the cross-sectional strategy for *sigma* convergence, whereas we use the distribution measurement beyond the former and assess the entire shape of the distribution and intra-distribution dynamics.

The premise of income convergence bases on the assumption that returns decrease, which represents 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, a drawback of this approach is that 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 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, there is the possibility of multiple equilibria since every nation could converge to its own long-term equilibrium or steady state (Asongu, 2014a; Monfort, 2008, p. 4-5). In light of the above, we adopt the empirical strategy in this paper of absolute *beta* convergence and *sigma* convergence. We base the absolute *beta* approach on yearly averages and means of fundamental characteristics for two reasons: this approach enables comparison with *sigma* convergence, and it avoids misspecification in catch-up among peripheral countries. The latter point is very important because without using the means of fundamental characteristics, 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.

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