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Trajectories of Knowledge Economy in SSA and MENA countries

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Abstract

In the first critical assessment of knowledge economy dynamic paths in Africa and the Middle East, but for a few exceptions, we find overwhelming support for diminishing cross-country disparities in knowledge-based economy dimensions. The paper employs all the four components of the World Bank's Knowledge Economy Index (KEI): economic incentives, innovation, education, and information infrastructure. The main finding suggests that sub-Saharan African (SSA) and the Middle East and North African (MENA) countries with low levels of KE dynamics and catching-up their counterparts of higher KE levels. We provide the speeds of integration and time necessary to achieve full (100%) integration. Policy implications are also discussed.

1. Introduction

With the recent trend of globalization, it has become abundantly vivid that for any continent, region or country to be actively involved in the global economy, it must adopt competition as a benchmark for progress. Competition derives from knowledge economy (henceforth, KE). The relevance of KE has emerged as a key theme in the late 1990s in the Organization for Economic Cooperation and Development (OECD) and World Bank reports (World Bank, 2007; Peter, 2008; Weber, 2011; Tchamyou, 2017; Andrés et al., 2015; Amavilah et al., 2017; Asongu, 2014a, 2014b; Tchamyou, 2019a; Tchamyou et al., 2019). Knowledge created through innovation and technical progress as a long-run driver of economic growth has now been well established. The governments of the Newly Industrialized Economies (Korea, Taiwan, Hong Kong & Singapore), China and Malaysia are playing quite a substantial role in shifting toward knowledge-based economies, from the product economies of the post-industrialization period (Chandra & Yokoyama, 2011). The main idea is that the process of creation and diffusion of knowledge depends on convergence in certain criteria (for instance, education, innovation, economic incentives, and Information and Communication Technology (ICT)) which would lead to more common policies across members of the convergence club. The European Union's Lisbon strategy is an eloquent example.

Consistent with recent literature (Tchamyou, 2017; Nyarko, 2013), there has been a wave of studies on the need to accelerate the move towards KE in Africa. The growing literature has consisted of *inter alia*: general surveys on KE (Anyanwu, 2012; Lin, 2006; Rooney, 2005); education (Amavilah, 2009; Chavula, 2010; Ford, 2007; Wantchekon et al., 2014; Weber, 2011); innovation (Carisle et al., 2013; Oyelaran-Oyeyinka & Gehl Sampath, 2007); economic incentives and institutional regime (Andrés & Asongu, 2013a ; Andrés et al., 2015; Cogburn, 2003; Nguena & Tsafack, 2014; Saxegaard, 2006; Letiche, 2006); information and communication technologies (Asongu, 2013a; Butcher, 2011; Chavula, 2010; African Partnership Forum, 2008); indigenous knowledge systems (Lwoga et al., 2010; Raseroka, 2008); intellectual capital and economic development (Preece, 2013; Wagiciengo & Belal, 2012); intellectual property rights (Andrés et al., 2015; Andrés & Asongu, 2013ab; Asongu, 2013b; Lor & Britz, 2005; Myburgh, 2011; Zerbe, 2005); the economy of knowledge in space transformation (Maswera et al., 2008; Moodley, 2003); spatiality in the production of knowledge (Bidwell et al., 2011; Neimark, 2012) and research and development (African Development Bank, 2007; German & Stroud, 2007; Sumberg, 2005).

The narratives highlighted above emphasize the need of bridging gaps in KE between countries (Aubert, 2005; AfDB, 2007; Chavula, 2010; Bizri, 2009; Makinda, 2007; Britz et al., 2006; Lightfoot, 2011). As far as we have reviewed, there is apparently no study that has tackled the concern of how Sub-Saharan African (SSA) and the Middle East and North African (MENA) countries are bridging disparities in KE. This paper aims to fill this gap and provide policy measures needed to enhance KE catch-up among countries.

In the light of the above, while some scholarly attention has focused on developed countries and the emerging economies of Latin America and East Asia, less attention has been devoted to SSA and MENA countries. A study on the current climate and future prospects in education, innovation and technology concludes that as far as the main cultural underpinnings of KEs are concerned (innovation, education, and technology), Arab countries may be on arid grounds but not in a total dessert. It further recommends more scholarly research on KE in the sub-region (Bizri, 2009). The pressing need for KE policy reform in SSA and MENA countries depends much on trajectories in the convergence processes of various KE dynamics. The intuition behind this assertion is that blanket policies are more likely to succeed across countries depending on the degree of convergence and time required for full (100%) convergence in KE dynamics. Within the framework of this study, convergence will imply the feasibility of common business and macroeconomic policies while, full (100%) convergence will indicate the enforcement of common business and macroeconomic policies without distinction of nationality and locality.

Given the growing role of KE in the development process, policy makers are more likely today to ask the following questions. Are KE dynamics converging within SSA and MENA countries? If so, then what are the rates and timing of the convergence processes? Answers to these questions could provide relevant policy orientation to the timing, enforcement, and standardization of KE-oriented policies. An additional motivation for this work also draws on the 'East Asian Miracle'. Additional support for the imperative of investigating convergence in KE dynamics is the possibility that, the level of industrial development could be traced to the common ability of East Asian countries to replicate existing technology. Some evidence suggests that the 'East Asian Miracle' could have originated from these nations' capacity to absorb, replicate and duplicate foreign innovations which might have contributed to their relatively high growth rates (Tchamyou, 2017). Assessing if SSA and MENA countries with low levels of KE dynamics are catching-up their counterparts of higher KE levels could be crucial in the formulation of appropriate policy recommendations. In contrast to mainstream research approach which is based for the most

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part on one or two dimensions of KE, this paper employs all the four components of the World Bank's Knowledge Economy Index (KEI): economic incentives, innovation, education, and information infrastructure.

The motivation of this study typically follows the evidence of cross-country income convergence which has been investigated in the context of neoclassical growth models. The theoretical underpinnings of income convergence are abundant in the empirical growth literature (Solow, 1956; Swan, 1956; Bruno et al., 2012) and have recently been applied to other fields of economic development. Whereas there are a theory and vast empirical studies on per capita income convergence, there is yet not a theory on convergence in other development fields. However, there is growing importance in the empirical application of convergence to other fields, notably: applications to financial systems (Bruno et al., 2012; Narayan et al., 2011; Asongu, 2013a) and KE (Karagiannis, 2007; Asongu, 2017a, 2017b)[1]. In the light of these recent developments, we are aware of the risks of 'doing measurement without theory'. Consistent with Constantini and Lupi (2005), we argue that reporting facts even in the absence of a formal theoretical model is a useful scientific activity.

The intuition underlying convergence in KE is that, it is the basis for competitive and dynamic economies. To understand why convergence in a knowledge-based economy (KBE) model is so crucial for developing countries, it is important to underline the European Union's strategic agenda. According to Karagiannis (2007), the effect that KBE-policies may have on economic growth was the ultimate objective of the EU's Lisbon Strategy (henceforth, LS). Prior to the LS, the importance of convergence in knowledge as an economic driver had been well documented (DTI, 1998; Stiglitz, 1999). In the current study, convergence will imply the feasibility of common business and macroeconomic policies while, full (100%) convergence will indicate, the enforcements common business and macroeconomic policies without distinction of nationality and locality. Since it is unlikely to find convergence within a very heterogeneous set of countries, the sample is sub-divided into two homogenous panels based on regional segmentation.

In the light of the above, the purpose of this study is to examine whether cross-country differences in KE are increasing or decreasing in SSA and MENA countries. A decreasing

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[1] Accordingly, intuition for this study is consistent with the literature on income convergence which has been recently extended to other domains of economic development. Inquiries founded on convergence have been considerably documented within the framework of neoclassical growth theories, originally developed in the seminal studies of Baumol (1986), Barro (1991), Mankiw et al. (1992) and Barro and Sala-i-Martin (1992, 1995). In accordance with recent literature on policy harmonization (Asongu & Nwachukwu, 2016; Andrés & Asongu, 2016) it is reasonable to postulate that the reduction of cross-country differences in KE dimensions imply the feasibility of common policies among sampled countries.

cross-country difference in KE development is important to policy makers because it serves as a basis or foundation for common cross-country policies that are implementable without distinction of nationality, in order to further strengthen the current drive towards knowledge-based economies.

The rest of this paper is organized as follows. Section 2 examines the intuition and theoretical underpinnings motivating the study as well as the relevant literature. The data and methodology are discussed in Section 3. The empirical analysis is covered in Section 4 while Section 5 concludes.

2. Theoretical and empirical literature

Theories of growth have been classified as either neoclassical or endogenous. With respect to the neoclassical model (Solow, 1956; Swan, 1956), the convergence process is premised on the existence of decreasing returns in capital accumulation. Therefore, increases in capital lead to less than proportional increases in the product. This condition elucidates the existence of a steady-state level for the main magnitudes, such as product per unit of employment, on which the economy will depend after any transitory shock. Hence, poor economies will grow at higher rates than rich ones, guaranteeing convergence across all of them.

Conversely, endogenous growth models incorporate mechanisms that determine the non-appearance of convergence. At the onset, not imposing decreasing returns to capital (Romer, 1990) and mechanisms in which technological growth is a non-decreasing function of some factors, leads to models of non-steady state or long-run equilibrium. It follows that increases in output can be sustained in the long-term through knowledge-related investments that are not subject to diminishing returns at the aggregate level. Such investment is the source of beneficial external effects which offset the limiting consequences of increasing per worker capital in a given form. Therefore, whereas investments by individual firms remain subject to diminishing returns, there is no decline in the overall marginal product of capital.

New growth theories have shown that new knowledge is a valuable factor of production, due to the unique non-rival characteristics of information (i.e. it can be transferred between users without losing usefulness). Investment in equipment (encompassing new technological developments) and education, invention, and related knowledge-enhancing activities are viewed to be the key to overcoming the impact of the diminishing returns that come into play as workers are equipped with more capital. Technological progress makes it

possible to extract greater value from scarce resources and sustain the economy's growth over the long-run (Romer, 1990).

Lastly, the new theories maintain that characteristics that make knowledge a highly valuable and productive commodity also render it difficult to establish an efficient knowledge market. In other words, a market that provides incentives for both the production of knowledge and its distribution to all those who can benefit from it (Lamberton, 1996).

The focus of KE economy literature has been in developed countries and the emerging economies of Latin America and East Asia, particularly on the importance of good governance on KE development (Dahlman, 2007; Chandra & Yokoyama, 2011) and the incidence of KE in economic development (Karagiannis, 2007). On the one hand, a clear relationship between formal institutional quality and knowledge-based economic infrastructure has been established (Andrés et al., 2015). On the other hand, positive linkages between KE and economic growth have been confirmed (Chavula, 2010). As far as we know, with the exception of Chavula (2010), the sparse KE literature focusing on SSA and MENA countries has been limited to a few dimensions of KE (Aubert, 2005; Britz et al., 2006; Makinda, 2007; African Development Bank, AfDB, 2007). In order to clearly position this paper in the light of existing literature, we shall discuss the scope in two strands: policy issues on KE and the KE-growth nexus.

Although the need for policy reforms on KE determinants in MENA countries has already been highlighted in the introduction (see, for example, the Arab Report, 2009; Bizri, 2009), Makinda (2007) provides one of the most detailed accounts of reforms required in SSA. According to Makinda, in order to bridge the KE gap between SSA and the Western World, African policy makers need to: (i) define the type of knowledge their countries require; (ii) establish conditions for nurturing strategic leaders who will, in turn, seek the right forms of knowledge to tackle Africa's problems; (iii) build political and legal frameworks that encourage the absorption and application of scientific innovation and (iv) revamp universities, establish regional research centers and take capacity building more effectively. Chavula (2010) has also established that African countries need to direct policy efforts towards restructuring economic incentives that encourage the acquisition, adaptation, and utilization of knowledge for productive use. Earlier, Britz et al. (2006) had assessed the question of whether Africa is moving towards a knowledge society and found that Africa still has a far way to go and the journey could be quickened with certain preconditions, *inter alia*: investment in human capital, stopping of brain drain, as well as effective development and maintenance of a physical infrastructure.

In the second strand, the AfDB (2007) has investigated the impact of public expenditure on the education dimension of KE and found the following. First, in the short-term, there is a positive relationship between 'public expenditure on education' and economic growth on the one hand, and on the other hand, between knowledge generation and human capital development. These relationships ultimately, have a potential to positively affect aggregate labor productivity. Second, in the long-term, public expenditure is negatively related to economic growth due to the often lack of capacity to retain human capital and avoid 'brain drain'. Chavula (2010) has also recently used panel data from 1990 to 2007 to examine the role of KE in economic growth. Findings support the positive bearing of mobile subscribers, telephone lines, tertiary enrolment and FDI inflows in per capita economic prosperity. In MENA countries, the United Arab Emirates thanks to Dubai (an internet and media city with world class standard created from scratch), demonstrates the best performance (Aubert & Reiffers, 2003). Of the MENA countries which have shown significant improvements, it is worthwhile articulating that Jordan and Tunisia have heavily invested in education and the development of their ICT and/or electronic sectors. In SSA, South Africa distinguishes itself quite vividly. Among low-income countries in the sub-region, some significant progress is apparent in Uganda, Senegal, Rwanda and Mauritania (Aubert, 2005).

Europe and North America have fully understood the dynamics of KE and are inexorably driving developments in the global and international arenas. Other regions like South America and Asia are responding in calculated steps that underscore the role of KE in their current pursuit of national, regional and international initiatives. Consequently, the developed world and the emerging economies of Latin America and East Asia are already taking KE very seriously. Also, in Africa and the Middle East, KE issues are beginning to take central stage in discussions on development.

3. Data and Methodology
3.1 Data

Consistent with recent empirical literature (Chavula, 2010; Weber, 2011; Andrés et al., 2015; Asongu & Tchamyou, 2016), our variables are from the World Bank's World Development Indicators (World Bank, 2011). The data is freely available on the World Bank's website. Therefore, the study employs the variables identified under the World Bank's four KEI components which include: the economic environment, innovation, education, and information infrastructure. We estimate a panel of 21 African and Middle East countries over

the years 1996-2010. The limitation to 21 countries is due to data availability constraints[2]. We concur with the literature (Narayan et al., 2011; Asongu, 2013a) in asserting that it is unlikely to find convergence within a very heterogeneous set of countries. Therefore, we divide the data into two subsamples: SSA and MENA countries.

We control for macroeconomic conditions (*economic prosperity*, *financial depth,* and *inflation*), government policy (*government expenditure*) and the institutional environment (*rule of law*). We limit the analysis to only five control variables because of constraints in the Over-identifying Restrictions (OIR) test for instrument validity. We expect government expenditure to generally stimulate KE if resources allocated for investment purposes are not tainted with corrupt practices or poorly managed. From a broad perspective, *economic prosperity* should be a natural driver of KE. The effects of *financial depth*, *inflation,* and *rule of law* depend on the dimension of KE. For instance, while *inflation* could be stimulated by the demand for credit to compensate for falling purchasing power, it could as well decrease bank deposits (part of financial depth) and the need for ICT services. While the *rule of law* is an incentive to innovation, it could also substantially inhibit knowledge spillovers and hence, negatively affect the education dimension of KE.

Details about descriptive statistics (with the presentation of countries), and the definition of variables are provided in the appendices. The summary statistics (Appendix 1) of the variables used in the dynamic panel regressions show that there is quite some variation in the data utilized so that one should be confident that reasonably estimated linkages should emerge. Appendix 2 discloses definitions and corresponding sources of the variables.

3.2 Methodology

Given that each dimension of KE could be correlated with its component variables individually, one might criticize the redundancy in the information provided for each dimension of the KEI. Hence, we use principal component analysis (PCA) for the treatment of the variables. The PCA is a common statistical method that is used to reduce a larger set of correlated variables into a smaller set of uncorrelated variables called principal components that account for most of the variation in the original data set. As shown in Table 1, the first principal component (PC) accounts for approximately 65% of the variation in all four KE dimensions. *Educatex* for example which denotes about 77% of the information in the education dimension of KE is the first PC of primary school enrolment (PSE), secondary

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[2] The list of countries is presented in Panel B of Appendix 1.

school enrolment (SSE) and tertiary school enrolment (TSE). In the choice of the PCs, the criteria applied to determine how many common factors to retain are taken from Kaiser (1974) and Jolliffe (2002). Hence, only PCs with a corresponding eigenvalue greater than one are retained. It is worth noting that the first PCs are almost equal across dimensions. These results show that one PC model is appropriate for KE dimensions in our sample.

Accordingly, *ICTex* is the first principal component of internet penetration, mobile phone penetration, and telephone penetration. *Tradex* is the first PC of trade and tariffs while *Creditex* is the first PC of private domestic credit and interest rate spread. It is important to note that in the innovation dimensions, the number of scientific journal publications is adopted because of data availability constraints in patent and trademark applications. The justification is consistent with recent KE literature (Tchamyou, 2017; Tchamyou, 2019b).

Table 1: Principal Component Analysis

Knowledge Economy dimensions		Component Matrix(Loadings)			First P.C	Eigenvalue	Indexes
Education	School enrolment	PSE	SSE	TSE			
		0.535	0.620	0.574	0.771	2.313	Educatex
Information & Infrastructure	ICTs	Internet	Mobile	Telephone			
		0.653	0.661	0.371	0.705	2.115	ICTex
Economic Incentive	Trade & Tariffs	Trade		Tariffs			
		-0.707		0.707	0.645	1.290	Tradex
	Credit & IR Spread	Private Credit		Interest rate spread			
		-0.707		0.707	0.679	1.358	Creditex
Innovation	Scientific Journals FDI Inflows	Reducing the dimensions of these is impractical owing to low correlation and conceptual dissimilarity.					

PSE: Primary School Enrolment. SSE: Secondary School Enrolment. TSE: Tertiary School Enrolment. PC: Principal Component. ICTs: Information and Communication Technologies. IR: Interest Rate. FDI: Foreign Direct Investment.

We devote some space to substantiating potential concerns that might result from using PC-derived regressors. Consistent with Asongu (2016), these concerns were first raised by Pagan (1984, p. 242). The author maintained that there are three principal issues related to augmented regressors or second-stage variables that derived from an initial estimation, notably concerns related to the efficiency, inferential validity, and consistency of estimations. In accordance with the narrative, while a *two-step* process leads to efficient and consistent estimates, not all corresponding inferences are valid. The inferential concern broadly aligns

with an abundant supply of literature that has focused on the issues: (Oxley & McAleer, 1993; McKenzie & McAleer, 1997; Ba & Ng, 2006; Westerlund & Urbain, 2013a).

Concerning the specific framework of PC-derived regressors, Westerlund and Urbain (2012, 2013b) have provided insights into tackling the issue. The authors have built on more contemporary literature (Stock & Watson, 2002; Bai, 2003; Pesaran, 2006; Bai, 2009; Greenaway-McGrevy et al., 2012) to establish that normal inferences are possible with PC regressors in so far as the estimated coefficients converge to their real values at the rate of rate $\sqrt{NT}$, where N (T) is the number of cross-sections (time series).

The Generalized Method of Moments (GMM) methodology is selected because, apart from income convergence, it has been used in the literature to investigate convergence in other areas of economic development. Accordingly, there is growing empirical application of the theoretical underpinnings of convergence to other development areas, namely in: financial markets (Narayan et al., 2011; Bruno et al., 2012), IPRs (Asongu, 2013b; Andrés & Asongu, 2013b) and negative signals prompting violence and political instability like, bad governance, chaotic inflation and unemployment (Asongu & Nwachukwu, 2016).

The choice of the Beta(β)-convergence approach is due to constraints in the data set. The use of cointegration and unit roots estimation strategies are not convenient because of limited degrees of freedom in homogenous panels or convergence clubs. Our estimation procedure typically follows the evidence of income convergence across economies, which has been investigated in the context of pioneering works of neoclassical growth models (Baumol, 1986; Barro & Sala-i-Martin, 1992, 1995; Mankiw et al., 1992). The theoretical underpinnings of income convergence are well documented in the empirical growth literature (Swan, 1956; Solow, 1956).

The two equations below are the standard approaches in the literature for investigating conditional convergence if $W_{i,t}$ is taken as strictly exogenous (Fung, 2009).

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

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

Where σ = 1+ β, $Y_{i,t}$ is the proxy for KE in country i in 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 $\varepsilon_{i,t}$ the classical error term. Consistent with the neoclassical growth model, a statistically significant negative coefficient on β in Eq. (1) suggests that countries relatively close to their steady

state of KE growth will experience a slowdown in the growth of KE, known as conditional convergence (Narayan et al., 2011). In the same vein, according to Fung (2009) and recent African convergence literature (Asongu, 2013a), if $0 < |\sigma| < 1$ in Eq. (2), then $Y_{i,t}$ is dynamically stable around the path with a trend in KE the same as that of W_t, and with a height relative to the level of W_t. The variables contained in $W_{i,t-\tau}$ and the individual effects η_i are a measure of the long-term level KE is converging towards. Therefore, the country-specific effect η_i emphasizes other determinants of a country's steady state not captured by $W_{i,t-\tau}$.

Requirements for conditional convergence elucidated above are valid if and only if, $W_{i,t}$ exhibits strict exogeneity. Unfortunately, this is not the case in the real world because, while *institutional quality*, *economic prosperity*, *inflation*, *financial development* and *government expenditure* (components of $W_{i,t}$) influence KE, the reverse effect is also true. Thus, we are faced here with the issue of endogeneity where control variables ($W_{i,t}$) are correlated with the error term ($\varepsilon_{i,t}$). Also, country- and time-specific effects could be correlated with other variables in the model, which is very likely when lagged dependent variables included in the equations. A way of dealing with the problem of the correlation between the individual-specific effect and the lagged endogenous variables consists of eliminating the individual effect by first differencing. Therefore Eq. (2) becomes:

$$\ln(Y_{i,t}) - \ln(Y_{i,t-\tau}) = \sigma(\ln Y_{i,t-\tau} - \ln Y_{i,t-2\tau}) + \delta(W_{i,t-\tau} - W_{i,t-2\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \tag{3}$$

However Eq. (3), still presents another issue. Estimation by Ordinary Least Squares (OLS) is still biased because there remains a correlation between the lagged endogenous independent variable and the disturbance term. To address this concern, we estimate the regression in differences jointly with the regression in levels using the Generalized Method of Moments (GMM) technique. Arellano and Bond (1991) have suggested an application of the GMM that exploits all the orthogonal conditions between the lagged dependent variables and the error term. The procedure uses lagged levels of the regressors as instruments in the difference equation, and lagged differences of the regressors as instruments in the levels equation, thus exploiting all the orthogonal conditions between the lagged dependent variables and the error term. Between the difference GMM estimator (Arellano & Bond, 1991) and system GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998), the

system GMM will be given priority, consistent with Bond et al. (2001, 3-4)[3]. This GMM estimation approach has been extensively applied in the convergence literature. In contrast to Narayan et al. (2011), we shall adopt Fung (2009) owing to software specificities[4]. In the model specification, we opt for the *second-step* GMM because it corrects the residuals for heteroscedasticity. The assumption of no autocorrelation in the residuals is crucial as lagged variables are to be used as instruments for the dependent variables. Moreover, the estimation depends on the assumption that the lagged values of the dependent variable and other independent variables are valid instruments in the regression. When the error terms of the level equation are not autocorrelated, the first-order autocorrelation of the differenced residuals should be significant whereas their second-order autocorrelation should not be significant. The validity of the instruments is examined with the Sargan over-identifying restrictions test (henceforth, OIR). Instruments are highly correlated with the potentially endogenous variable. We need to look at the first stage regression equation and see whether our instruments are able to capture high variation in our endogenous variables. We should mention Staiger and Stock (1997) and the issue of weak instruments by employing a Fisher test. The concern about endogeneity is taken on board with the GMM empirical strategy from two main perspectives: (i) simultaneity or reverse causality is addressed with the use of internal instruments while (ii) the unobserved heterogeneity is taken into account by controlling for time invariant omitted variables in the estimation exercise.

In line with Islam (1995, 14), yearly time spans are too short to be appropriate for studying convergence because short-run disturbances may loom substantially in such brief time spans. Therefore, considering the data span of 15 years, we use two-year non-overlapping intervals (1996; 1997-1998; 1999-2000; 2001-2002; 2003-2004; 2005-2006; 2007-2008; 2009-2010). This implies in our analysis, τ is set to 2. Hence, we compute the implied rate of convergence by calculating '$\sigma/2$'. We divide the estimated coefficient (σ) of the lagged differenced endogenous variable by 2 because we have used a two- year interval to absorb the short-term disturbances. When the absolute value of the estimated autoregressive

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[3] *"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).
[4] Whereas, Narayan et al. (2011) have used Eq. (1) in the controlling for fixed effects, this paper applies Eq. (3) instead; in line with (Fung, 2009). The same methodology has been used in recent African convergence literature (Asongu, 2013a). The system GMM has been applied in recent KE convergence literature (Karagiannis, 2007).

coefficient is greater than zero but less than one ($0 < |\sigma| < 1$), we conclude the existence of convergence. The broader interpretation suggests that past differences have a less proportionate impact on future differences, denoting the variation on the left-hand side of Eq. (3) is decreasing overtime as the economy is converging to a steady state (Asongu, 2013a).

Before we dive into the presentation of results, it is important at the outset to understand the economic intuition motivating absolute and conditional convergence in KE. Absolute convergence in KE occurs when countries share similar fundamental characteristics with regard to their KE dynamics such that only variations across countries in initial levels of KE development exist. Absolute convergence, therefore, results from factors such as the formulation of monetary unions and adoption of a unique currency, among others (Asongu, 2013a). The quest for absolute convergence is usually in line with an overall global strategy in a monetary union (for instance, the Lisbon Strategy that was launched in 2000 by the European government leaders, see Karagiannis (2007)). This strategy is implemented through a combination of policies aiming at boosting the information society, improving research and development, accelerating structural reforms for competitiveness and enhancing innovation while modernizing the European social model. Simultaneously with the above, a growth-friendly macroeconomic policy mix is applied from 2000 to 2010.

In the same vein, absolute convergence may occur in SSA and MENA countries because of adjustments common to these countries. For instance, since the 1980s, many countries have undertaken structural reform initiatives engineered by the International Monetary Fund (IMF) and the World Bank (WB). These reforms have included improving education, development of ICT, innovation and economic incentives. The degree of internet penetration, extensive use of mobile phones, increasing literacy rate, among others, experienced by SSA and MENA countries over the past decade are factors that could facilitate absolute convergence in KE.

On the other hand, conditional convergence is that which depends on structural and institutional characteristics. Consistent with the economic growth literature (Barro, 1991), conditional convergence depicts the kind of convergence whereby one's own long-term steady state (equilibrium) depends on structural characteristics and fundamentals of its economy or market (Narayan et al., 2011). Therefore, findings are conditional on the macro-economic variables we empirically test. Owing to constraints in data availability and degrees of freedom required for the OIR test, we could not condition the analysis beyond five macroeconomic variables. This is consistent with the convergence literature in which only

two variables have been used (e.g. see Bruno et al., 2012). For a monetary union, identical structural characteristics could be reflected in real, fiscal and monetary policy convergence. This could ultimately lead to KE convergence if simultaneously, growth-friendly macroeconomic policies-mix are applied by all member states in view of a long-term KE strategic interest.

4. Empirical analysis

4.1 Presentation of results

This section examines three principal concerns: (i) assessment of the presence of convergence; (ii) computation of the speed of convergence and (iii) determination of the time needed for full (100%) convergence. The summary of overall results is presented in Table 2 in which the three issues are addressed. Results for absolute (or unconditional) and conditional convergence are presented in Table 3 and Tables 4-5 respectively.

Absolute convergence is estimated with only the lagged difference of the endogenous indicator as independent variable whereas conditional convergence is with respect to Eqs. (2) and (3), controlling for macroeconomic conditions, government expenditure and institutional quality. Thus, unconditional convergence is estimated in the absence of $W_{i,t}$: vector of determinants of KE (*rule of law*, *GDP growth*, *financial depth*, *inflation* and *government expenditure*). In order to assess the quality of estimated models, we have employed two types of specification tests, notably: the Sargan test, to check for the validity of our instruments, and the AR (2) test of error autocorrelation. The latter test does not show any evidence of error specification in almost all estimated models at the 1% significance level. The Sargan tests also confirm the validity of models.

Table 2: Summary of results on convergence

	Panel A: Education and Information and Communication Technology							
	Education (Educatex)				Information & Communication Tech (ICTex)			
	AC	CC	SAC	SCC	AC	CC	SAC	SCC
Middle East & North Africa (MENA)	Yes	Yes	39.80% (5.02 Yrs)	33.85% (5.90 Yrs)	Yes	Yes	43.40% (4.60 Yrs)	42.65% (4.68 Yrs)
Sub-Saharan Africa (SSA)	Yes	Yes	39.85% (5.01 Yrs)	37.15% (5.38 Yrs)	Yes	Yes	37.85% (5.28 Yrs)	26.20% (7.63 Yrs)
MENA & SSA (Full Data)	Yes	Yes	39.45% (5.06 Yrs)	37.55% (5.32 Yrs)	Yes	Yes	41.20% (4.85 Yrs)	41.50% (4.81 Yrs)

	Panel B: Economic Incentive							
	Trade (Tradex)				Credit (Creditex)			
	AC	CC	SAC	SCC	AC	CC	SAC	SCC
Middle East & North Africa (MENA)	Yes	No	36.65% (5.45 Yrs)	n.a	No	No	n.a	n.a
Sub-Saharan Africa (SSA)	Yes	No	44.40% (4.50 Yrs)	n.a	Yes	No	36.20% (5.52 Yrs)	n.a
MENA & SSA (Full Data)	Yes	Yes	38.72% (5.16 Yrs)	30.45% (6.56 Yrs)	Yes	Yes	46.57% (4.29 Yrs)	31.60 % (6.32 Yrs)

	Panel C: Innovation							
	Scientific & Technical Journals				Foreign Direct Investment Inflows			
	AC	CC	SAC	SCC	AC	CC	SAC	SCC
Middle East & North Africa (MENA)	No	Yes	n.a	49.20% (4.06 Yrs)	Yes	Yes	27.50% (7.27 Yrs)	10.80% (18.51 yrs)
Sub-Saharan Africa (SSA)	Yes	Yes	49.20% (4.06 Yrs)	49.85% (4.01 Yrs)	Yes	No	23.40% (8.54 Yrs)	n.a
MENA & SSA (Full Data)	No	Yes	n.a	43.86% (4.55 Yrs)	Yes	No	26.80% (7.46 Yrs)	n.a

Yrs: Years. Educatex is the first principal component of primary, secondary and tertiary school enrolments. ICTex: the first principal component of mobile, telephone and internet subscriptions. Creditex: first principal component of Private credit and Interest rate spreads. Tradex: first principal component of Trade and Tariffs. n.a: not applicable due to the absence of convergence.

A summary of the results from Tables 3-5 is presented in Table 2. This includes findings for Absolute Convergence (AC), Conditional Convergence (CC), the Speed of Absolute Convergence (SAC), the Speed of Conditional Convergence (SCC) and the rate required to achieve full (100%) convergence.

From a general perspective, the following conclusions could be drawn. (i) With a few exceptions, there is overwhelming convergence in most KE dynamics. (ii) For the most part, the convergence rate within SSA is very substantially different from that within the MENA. (iii) Both the lowest and highest rates of convergence are apparent for CC in innovation with corresponding rates of 10.80% per annum (MENA) and 49.85% per annum (SSA) respectively. (iv) The hypothesis of convergence is highly significant for *education* and *ICT* (where all hypotheses are valid), followed by *innovation* (where four hypotheses are invalid) and lastly by *economic incentive* (where five hypotheses are invalid).

Table 3 below shows results of AC. *Education* and *ICT* findings are presented in Panel A while Panel B and Panel C respectively reveal results for *economic incentive* and *innovation*. Though all initial lagged endogenous variables are significant, estimated coefficients with a value greater than one do not meet the convergence criterion. From Panel A, it could be observed that almost all the estimated coefficients are quasi-equal across specifications and KE dimensions. But for MENA in the *Creditex* regressions, results of Panel

B denote convergence rates that vary from 36.65% per annum to 46.57% per annum (p.a)[5]. MENA and 'Full data' findings in the *Journals* dimension of KE in Panel C do not meet the convergence criterion. Having summarized the rates of convergence and time required to achieve full convergence in Table 2, the time to full convergence for the most part of between 4 and 7 years is an indication that from a projection date of 2010, it was feasible to start applying common KE policies across countries from 2014 onwards.

Table 3: Absolute convergence

	Panel A: Education and Information and Communication Technology					
	Education (Educatex)			Information & Communication Tech (ICTex)		
	MENA	SSA	Full Data	MENA	SSA	Full Data
Initial	**0.796*****	**0.797*****	**0.789*****	**0.868*****	**0.757*****	**0.824*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
AR(2)	**-1.182**	**-1.135**	**-1.314**	**-0.814**	**-0.145**	**-1.026**
	(0.237)	**(0.256)**	**(0.188)**	**(0.415)**	**(0.884)**	**(0.304)**
Sargan	**6.971**	**4.043**	**11.734**	**13.911**	**6.267**	**20.995**
	(0.994)	**(0.995)**	**(0.946)**	**(0.974)**	**(1.000)**	**(0.742)**
Wald test	**7.856*****	**407.06*****	**164.827*****	**988.40*****	**216.25*****	**903.90*****
	(0.005)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Countries	7	5	12	14	7	21
N	25	18	43	95	47	142

	Panel B: Economic Incentive					
	Trade (Tradex)			Credit (Creditex)		
	MENA	SSA	Full Data	MENA	SSA	Full Data
Initial	**0.733*****	**0.888*****	**0.774*****	**1.131*****	**0.724*****	**0.931*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
AR(2)	**0.989**	**-1.476**	**0.775**	**-1.303**	**-0.452**	**-1.098**
	(0.322)	**(0.139)**	**(0.438)**	**(0.192)**	**(0.651)**	**(0.272)**
Sargan	**9.897**	**6.010**	**17.169**	**7.735**	**3.892**	**14.853**
	(0.955)	**(0.999)**	**(0.841)**	**(0.999)**	**(1.000)**	**(0.960)**
Wald test	**11.362*****	**66.163*****	**45.921*****	**465.17*****	**11.680*****	**539.37*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Countries	12	7	19	9	6	15
N	40	26	66	44	41	85

	Panel C: Innovation					
	Scientific & Technical Journals			Foreign Direct Investment Inflows		
	MENA	SSA	Full Data	MENA	SSA	Full Data
Initial	**1.034*****	**0.984*****	**1.024*****	**0.536*****	**0.468*****	**0.550*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
AR(2)	**0.316**	**0.195**	**0.261**	**-1.110**	1.712*	**-0.809**
	(0.751)	**(0.844)**	**(0.793)**	**(0.267)**	(0.086)	**(0.418)**
Sargan	**13.041**	**6.909**	**20.584**	**13.651**	**5.699**	**20.978**
	(0.836)	**(0.906)**	**(0.360)**	**(0.977)**	**(1.000)**	**(0.743)**
Wald test	**20407*****	**143.99*****	**12190*****	**8.808*****	**17.500*****	**8.754*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.003)**	**(0.000)**	**(0.003)**
Countries	14	7	21	14	7	21
N	79	35	114	95	49	144

***,**,*: significance levels of 1%, 5% and 10% respectively. AR (2): Second Order Autocorrelation test. Sargan: Overidentifying Restrictions test. N: Number of observations. Initial: lagged endogenous estimated coefficient. SSA: Sub-Saharan Africa. MENA: The Middle East and North Africa. Tech: Technology.

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[5] These rates are summarized in Table 2.

Tables 4-5 below report empirical findings for CC. While Table 4 displays the results for *Educatex*, *ICTex*, *Tradex* and *Creditex*, Table 5 reveals results for *innovation*. Not all control variables are used in certain equations due to constraints in degrees of freedom. However, to assess the validity of the results in models without all control variables, the conditioning information sets are used interchangeably. Results from the various specifications are not different from those finally reported in the tables.

Most of the control variables are significant with the right signs. (i) In Panel A of Table 4, government expenditure may either mitigate KE or not, depending on two factors. On the one hand, with regards to how funds allocated for education and communication infrastructure are managed. On the other hand, the enforcements of property rights through the *rule of law* mechanism (especially in business software piracy) may substantially limit knowledge spillovers and the smooth development of the ICT sector. (ii) In Table 5, economic prosperity and low inflation could be strong incentives to FDI inflows.

It is important to note that the growth variable is not an independent variable of interest but a control variable. The independent variable of interest is the estimated lagged dependent variable. A reason why growth is not driving knowledge economy may be that the fruits of economic prosperity are not being evenly distributed across the population. This point can be substantiated by two facts. On the one hand, compared to other regions of the world, the overall knowledge index has been decreasing in African countries since the year 2000 (Tchamyou, 2017). On the other hand, an April 2015 World Bank report on the achievement of the Millennium Development Goals extreme poverty target revealed that extreme poverty has been decreasing in all regions of the World with the exception of SSA, despite this sub-region enjoying more than two decades of growth resurgence (Asongu & Nwachukwu, 2017).

Table 4: Conditional convergence for Education, ICT and Economic Incentive

	Panel A: Education and Information and Communication Technology					
	Education (Educatex)			Information & Communication Tech (ICTex)		
	MENA	SSA	Full Data	MENA	SSA	Full Data
Initial	**0.677***	**0.743***	**0.751***	**0.853***	**0.524**	**0.830***
	(0.000)	**(0.000)**	**(0.001)**	**(0.000)**	**(0.022)**	**(0.000)**
Intercept	**0.265***	-0.034	0.315	0.564	0.305	**0.484***
	(0.000)	(0.743)	(0.486)	(0.256)	(0.343)	**(0.001)**
Gov. Exp.	0.004	**0.026****	0.015	**-0.004***	0.002	-0.003
	(0.272)	**(0.019)**	(0.185)	**(0.058)**	(0.784)	(0.155)
GDP growth	---	---	0.015	0.006	-0.040	0.010
			(0.165)	(0.541)	(0.570)	(0.146)
M2	---	---	-0.456	0.031	---	0.079
			(0.261)	(0.955)		(0.687)
Rule of Law	---	---	0.123	**-0.248***	---	**-0.227***
			(0.389)	**(0.000)**		**(0.000)**
Inflation	---	---	-0.011	-0.003	---	**-0.011****
			(0.575)	(0.813)		**(0.028)**
AR(2)	**-1.291**	**-1.091**	**-1.155**	**-0.173**	**0.943**	**-0.717**
	(0.196)	**(0.275)**	**(0.247)**	**(0.862)**	**(0.345)**	**(0.473)**
Sargan	**3.922**	**1.663**	**3.563**	**6.654**	**2.599**	**13.973**
	(0.999)	**(1.000)**	**(1.000)**	**(1.000)**	**(1.000)**	**(0.973)**
Wald test	**111.85***	**193.57***	**1704.7***	**1210.93***	**12.205***	**2753.3***
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.006)**	**(0.000)**
Countries	7	5	10	12	6	18
N	25	18	39	67	38	105

	Panel B: Economic Incentive					
	Trade (Tradex)			Credit (Creditex)		
	MENA	SSA	Full Data	MENA	SSA	Full Data
Initial	1.423	1.081	**0.609***	**1.305***	**1.092***	**0.632***
	(0.657)	(0.104)	**(0.001)**	**(0.003)**	**(0.084)**	**(0.092)**
Intercept	-10.978	0.061	0.391	0.043	-0.835	0.452
	(0.582)	(0.704)	(0.129)	(0.782)	(0.319)	(0.397)
Gov. Exp.	0.010	0.005	-0.005	0.0005	-0.015	-0.004
	(0.810)	(0.628)	(0.170)	(0.834)	(0.334)	(0.410)
GDP growth	-0.107	-0.047	-0.026	0.006	0.123	-0.019
	(0.731)	(0.406)	(0.367)	(0.721)	(0.227)	(0.234)
M2	12.879	---	-0.399	---	---	-0.766
	(0.571)		(0.255)			(0.372)
Rule of Law	2.354	---	-0.222	---	---	-0.140
	(0.491)		(0.207)			(0.365)
Inflation	0.045	---	-0.018	---	---	0.019
	(0.872)		(0.169)			(0.209)
AR(2) t	**0.694**	**-1.200**	**0.870**	**-1.397**	**0.112**	**-1.230**
	(0.487)	**(0.230)**	**(0.384)**	**(0.162)**	**(0.910)**	**(0.218)**
Sargan	**0.000**	**1.878**	**5.763**	**4.355**	**1.143**	**8.448**
	(1.000)	**(1.000)**	**(0.998)**	**(1.000)**	**(1.000)**	**(0.999)**
Wald	**59.356***	**10.195****	**480.33***	**87.254***	**10.083****	**1380.7***
	(0.000)	**(0.017)**	**(0.000)**	**(0.000)**	**(0.017)**	**(0.000)**
Countries	7	5	12	9	5	14
N	27	18	45	43	33	76

***,**,*: significance levels of 1%, 5% and 10% respectively. AR (2) Auto: Second Order Autocorrelation test. Sargan: Overidentifying Restrictions test. N: Number of observatıons. Initial: lagged endogenous estimated coefficient. SSA: Sub-Saharan Africa. MENA: The Middle East and North Africa. Tech: Technology. Gov. Exp: Government Expenditure. M2: Money Supply.

Table 5: Conditional convergence for Innovation

| | Innovation | | | | | |
| | Scientific & Technical Journals | | | Foreign Direct Investment Inflows | | |
	MENA	SSA	Full Data	MENA	SSA	Full Data
Initial	**0.877***	**0.997***	**0.984***	0.114	0.191	**0.216***
	(0.000)	**(0.007)**	**(0.000)**	(0.628)	(0.824)	**(0.078)**
Intercept	**0.396***	0.003	0.066	-1.613	0.839	-2.230
	(0.088)	(0.995)	(0.420)	(0.830)	(0.825)	(0.399)
Gov. Exp.	**-0.005***	0.001	-0.0003	-0.0004	0.061	0.031
	(0.053)	(0.348)	(0.817)	(0.995)	(0.304)	(0.457)
GDP growth	-0.003	0.010	0.0005	0.138	0.176	**0.309***
	(0.388)	(0.548)	(0.878)	(0.636)	(0.745)	**(0.067)**
M2	0.043	---	0.007	4.159	---	3.210
	(0.578)		(0.908)	(0.655)		(0.267)
Rule of Law	0.057	---	-0.012	1.916	---	-0.275
	(0.331)		(0.534)	(0.547)		(0.847)
Inflation	-0.0005	---	-0.001	**0.343****	---	**0.177*****
	(0.877)		(0.160)	**(0.041)**		**(0.004)**
AR(2) test	**0.150**	**-0.114**	**0.144**	**-1.107**	**0.643**	**-1.008**
	(0.880)	**(0.908)**	**(0.885)**	**(0.268)**	**(0.519)**	**(0.313)**
Sargan test	**2.158**	**0.182**	**9.397**	**8.994**	**3.856**	**15.086**
	(1.000)	**(1.000)**	**(0.966)**	**(0.999)**	**(1.000)**	**(0.955)**
Wald test	**2872.8***	**13.359***	**2599.8***	**21.868***	**29.867***	**37.183***
	(0.000)	**(0.003)**	**(0.000)**	**(0.001)**	**(0.000)**	**(0.000)**
Countries	12	6	18	12	6	18
N	55	30	85	67	40	107

***,**,*: significance levels of 1%, 5% and 10% respectively. AR (2): Second Order Autocorrelation test. Sargan: Overidentifying Restrictions test. N: Number of observations. Initial: lagged endogenous estimated coefficient. SSA: Sub-Saharan Africa. MENA: Middle and North Africa. Gov. Exp: Government Expenditure. M2: Money Supply.

4.2 Discussion of results, policy implications, and caveats

The progressive build-up of knowledge-based economies in SSA and MENA countries calls for more capacity building for research, technological development, innovation and economic incentives. Trajectories of and tendencies in *education* and *ICT* are encouraging.

Results of the *Education* and *ICT* dimensions of KE demonstrate that countries with lower levels of education and ICT are catching-up with their counterparts of higher levels in the corresponding KE dimensions. This interpretation holds for all types of convergences and is valid across samples. It follows that: (i) the objectives of the United Nations Educational, Scientific and Cultural Organization (UNESCO) are bearing fruits within Africa and the Middle East (see, for example, Iwamoto, 2005) and (ii) cross-countries differences in internet penetration, telephone subscriptions, and mobile phone usage are substantially decreasing.

The absence of conditional convergence in the trade and credit aspects of the economic incentive dimension of KE point to, the: (i) need for more intra-trade among sampled countries (in SSA and MENA) and (ii) absence of credit facilities for economic operators. The low intra-trade in Africa and the Middle East is far from surprising as has been substantially documented in the literature (Longo & Sekkat, 2004; Askari et al., 2003). The

absence of convergence in Creditex could be the result of the perennial issue of surplus liquidity in African formal financial institutions (Saxegaard, 2006; Tchamyou & Asongu, 2017).

From the innovation dimension, while the absence of AC in the publication of 'scientific and technical journals' demonstrates the absence of an overall strategy or framework aimed at improving contribution of knowledge in the scientific domain, lack of conditional convergence in FDI inflows shows how cross-country differences in structural and institutional characteristics matter in the attraction foreign capital. Thus, disparities in macroeconomic policies/conditions and government quality among countries could lead to this deficiency in conditional convergence.

On a general note, domestic credit and foreign investment inflows have very heterogeneous initial conditions and are influenced by different fundamental, institutional and structural characteristics of development. It implies that countries should work towards adopting common institutional and structural characteristics that favor financial allocation efficiency. Such institutional characteristics include government-quality dynamics of rule of law, regulation quality, corruption-control, government effectiveness, political stability (no violence), democracy, voice and accountability, and press-freedom.

Our findings are highly relevant for policy makers in terms of regional integration. The absence of CC in trade in SSA and MENA countries points to the need for more intra-regional trade. This brings us to the question of whether policies implemented by African and Middle East countries to promote intra-regional trade have had any noticeable effects on the observed convergence patterns. Though from an AC sense, integration may be occurring, it is not yet noticeable when structural and institutional characteristics are integrated into the equation. It is thus tempting to conclude that geographical proximity is neither a necessary nor a sufficient condition for trade convergence, which could further suggest that efforts at promoting trade liberalization may not be so apparent.

The absence of CC in economic incentives, especially in *Creditex*, implies that credit facilities are not converging contingent on structural and institutional characteristics. This is a call for more regional investment banks and investment funds which could be instrumental in addressing cross-country credit facility disparities. Also, given the substantially documented issues of surplus liquidity in African banks, innovation mechanisms should be developed that would facilitate the granting of credit to economic operators (Saxegaard, 2006; Asongu & Tchamyou, 2015). The mechanisms can encompass the institution to information sharing offices like public credit registries and private credit bureaus which have recently been argued

and established to enhance financial access by reducing information asymmetry between lenders and borrowers in the African banking industry (see Triki & Gajigo, 2014; Asongu et al., 2016; Tchamyou & Asongu, 2017).

The absence of AC in 'technical and scientific journals' implies that fundamental characteristics enabling countries with lower levels of publications to catch-up with their counterparts of higher levels are absent[6]. Thus, there should be *encouragement and validation activities targeting local and regional initiatives to promote the development of new innovating businesses and 'transfer and exchange' of best practices as well as the establishment of an environment more conducive to innovation*. The focus should be on:

-trans-regional cooperation to facilitate the development of research and innovation;

-strategies, as well as initiation of programs involving local actors and corresponding activities, should be developed in close coordination with inclusive regional policies;

-particular attention should be paid to the participation of sampled countries' regions, notably in relation to the transfer of schemes that have proved successful at local and national levels.

The development of research and innovation strategies, as well as inter-regional technology transfer, could greatly benefit sampled countries. This would include, *supporting the development of regional scientific infrastructure*. Hence, specific attention should be paid to the valorization or development of new scientific infrastructure in the regions, in collaboration and synergy with activities of the regional investment banks (or funds). The example of the EU has shown that modern scientific infrastructure is a key enabler of regional economic development. For researchers within the regions to be able to cooperate under 'state of the art' conditions with their counterparts in advanced regions as well as with the rest of the world, much needs to be considered. A good example is the broadband electronic interconnection backbone that could link SSA and MENA electronic research and education networks.

Within the context of research training networks and knowledge transfer, fellowships could be *developed to target more and better scientific and technical human resources*. Therefore, more opportunities should be offered to researchers originating from less favored countries. This will ease the convergence process. Special attention should also be paid to a number of factors affecting socioeconomic conditions of researchers, notably: gender equity, linguistic balance, and career structure. Ultimately, in view of further reinforcing the human potential for research in sampled regions, human resource and mobility actions should target,

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[6] It is important to note that the discussion related to scientific journals pertains to 'enabling conditions' that are important in boosting scientific publications.

inter alia: (i) the best and most promising researchers from undeveloped countries, promote the training of regional researchers abroad and stimulate the return of scientists established outside Africa and the Middle East; (ii) improving communication between experts and policy makers through the establishment of joint working and communication platforms between them at regional levels and (iii) clear statistical indicators that are able to describe the characteristics, structure, and performance of a knowledge-based economy should be developed at national and regional levels.

Three main caveats have been retained, notably the: negative spillovers due to trade convergence, absence of a theoretical basis and draw backs in the methodology. Firstly, during trade convergence periods, policy makers should be aware that economies are subject to spillover effects and a real shock emerging from a certain country/industry might spread quickly to other countries/industries. Secondly, using econometrics to accomplish more than just testing theory does not come without risks. The intuitive basis of the study implies that results should be interpreted with caution as the model is conditioned on the variables we choose and empirically test, which may not directly reflect implemented policies that drive KE convergence. Thirdly, as we have already outlined in the first paragraph of Section 3.2.2, the choice of the convergence approach which is based on constraints in data structure also has its drawbacks. Consistent with Apergis et al. (2010), skeptics of β-convergence argue that if countries converge to a common equilibrium with identical internal structures, then the dispersion of the variable under study should disappear in the long-term as all countries converge to the same long-run path. However, if countries converge to 'convergence clubs' or to their own unique equilibrium, the dispersion of this indicator will not near zero (Miller & Upadhyay, 2002). Moreover, in the latter case of country-specific equilibrium, the movements of the dispersion are contingent on the initial distribution of the variable under investigation with regard to final long-run outcomes. Overall, as maintained by Caporale et al. (2009), the approach may suffer from specific estimation deficiencies associated with the data structure. Indeed, data on KE dimensions is scarce and these issues can only be overcome with time.

5. Conclusion and future research directions

In the first critical assessment of knowledge economy dynamic paths in Africa and the Middle East, with a few exceptions, we find overwhelming support for diminishing cross-country disparities in knowledge based economy dimensions. The paper has employed all the four components of the World Bank's Knowledge Economy Index (KEI): economic incentives, innovation, education, and information infrastructure. The main finding suggests

that sub-Saharan African (SSA) and the Middle East and North African (MENA) countries with low levels of KE dynamics and catching-up their counterparts of higher KE levels. We have provided the speeds of integration and time necessary to achieve full (100%) integration. Policy implications have been discussed.

After summarizing the rates of convergence and time required to achieve full convergence, the time to full convergence for the most part of between 4 and 7 years is an indication that from a projection date of 2010, it was feasible to start applying common KE policies across countries from 2014 onwards. It is important to note that, the objective for the policy maker is to understand in what horizon common policies stated in the objective of the study and suggested policy implications can be implemented. Policy implications of the findings have been discussed in the previous section.

Future inquiries can improve the extant literature by engaging in comparative studies between less developed countries and KE frontiers such as OECD countries. Moreover, due to data availability constraints, some further empirical considerations that are more relevant to microeconomic and firm level data cannot be considered within the framework of this study, *inter alia*: (i) the localized feature of the process of learning and role of international spillovers in such processes by means of multinational corporation and more integration with the international scientific community and (ii) the relevance of internal spillovers, the role of public scientific infrastructure and incentives in such spillovers and the direction of the underlying knowledge flows. In engaging these areas of potential interest, Stiglitz and Greenwald (2014) provide insights into more robust theoretical background and econometric methodology. While this study has employed the beta convergence approach which is adapted to panel data, a sigma convergence approach involving graph plots and more adapted to cross sectional data can also be considered in future studies.

Appendices

Appendix 1: Summary statistics and presentation of countries

	Panel A: Summary Statistics					
		Mean	S.D	Min	Max	Obs.
Knowledge Economy	Educatex (Education)	-0.038	1.370	-4.344	1.858	126
	ICTex (Information & Infrastructure)	0.028	1.440	-3.750	3.183	310
	Tradex (First Economic Incentive)	-0.058	1.143	-2.901	2.635	161
	Creditex (Second Economic Incentive)	0.118	1.224	-2.296	3.488	193
	Scientific and Technical Journals	2.142	0.676	0.518	3.821	284
	Foreign Direct Investment Inflows	3.119	3.908	-4.025	33.566	319
Control variables	Rule of Law	-0.063	0.727	-1.606	1.258	264
	Inflation	5.585	6.274	-9.797	43.073	296
	Government Expenditure	12.318	11.321	-34.88	80.449	295
	Economic Prosperity	4.689	3.450	-4.300	26.750	313
	Financial Depth	0.523	0.291	0.121	1.279	240

Panel B: Presentation of Countries
MENA: Algeria, Bahrain, Egypt, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, United Arab Emirates, Yemen.
SSA: Botswana, Cameroon, Kenya, Mauritius, Nigeria, Senegal, Zambia.

S.D: Standard Deviation. Min: Minimum. Max: Maximum. Obs: Observations. MENA: Middle East and North Africa. SSA: Sub-Saharan Africa.

Appendix 2: Variable definitions

Variables		Variable definitions	Data sources
Panel A: Dimensions in Knowledge Economy (KE)			
Primary School Enrolment	PSE	Log of PSE	World Bank (WDI)
Secondary School Enrolment	SSE	Log of SSE	World Bank (WDI)
Tertiary School Enrolment	TSE	Log of TSE	World Bank (WDI)
Education in KE	Educatex	First PC of PSE, SSE & TSE	PCA
Internet Users	Internet	Log of Internet	World Bank (WDI)
Mobile Cellular Subscriptions	Mobile	Log of Mobile	World Bank (WDI)
Telephone lines	Tel	Log of Tel	World Bank (WDI)
Information & Infrastructure in KE	ICTex	First PC of Internet, Mobile & Tel	PCA
Trade Openness	Trade	Exports plus Imports of Commodities (% of GDP)	World Bank (WDI)
Tariff Barriers	Tariff	Tariff rate, most favored nation, weighted mean, all products (%)	World Bank (WDI)
1st Economic Incentive dimension in KE	Tradex	First PC of Trade & Tariff	PCA
Private domestic credit	Credit	Private domestic credit (% of GDP)	World Bank (WDI)
Interest rate spread	Spread	Lending rate minus deposit rate (%)	World Bank (WDI)
2nd Economic Incentive dimension in KE	Creditex	First PC of Credit and Spread	PCA
1st Innovation dimension in KE	Journals	Log of Number of Technical & Scientific Journals	World Bank (WDI)
2nd Innovation dimension in KE	FDI	Net Foreign Direct Investment (% of GDP)	World Bank (WDI)
Panel B: Control variables			
Rule of Law	R.L	Rule of Law (estimate)	World Bank (WDI)
Government Expenditure	Gov. Exp.	Government final consumption expenditure (% of GDP)	World Bank (WDI)
Inflation	Infl.	Consumer price index (annual %)	World Bank (WDI)
Economic Prosperity	GDPg	GDP growth rate (annual %)	World Bank (WDI)
Financial Depth	M2	Broad Money Supply (% of GDP)	World Bank (FDSD)

WDI: World Bank's World Development Indicators. FDSD: Financial Development and Structure Database. GDP: Gross Domestic Product. PC: Principal Component. PCA: Principal Component Analysis. Log: logarithm.

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