Innovation, Institutions and Economic Growth in Sub-Sahara Africa – an IV Estimation of a Panel Threshold Model

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Abstract

In this paper, we investigate the relationship between innovation and economic growth in sub-Sahara Africa taking into account the role of institutional development. This is against the backdrop that institution is the oil that greases the wheels of development. Using the number of scientific journals published as proxy for innovation and GDP per capita for economic growth, we assess a panel of 25 economies in sub-Sahara Africa with dataset (1996-2016) from reliable agencies such as World Bank, Polity IV, Heritage foundation, Elsevier Scopus (Scimago) and Economic Freedom of the World Project (EFW). Our evidence suggest among other things that innovation has a positive and significant effect on the growth trajectory of sub-Sahara Africa although the impact seems negligible. Institutional quality is seen to dampen innovation and the relation is persistent regardless of when the focus is on aggregate or decomposed institutional factors. While most countries in the region have offered financial support in strengthening institutions, we find barriers to the design and implementation of STI policies to be responsible for the sluggish contribution of innovation to the growth pattern in the region. Therefore a lot more has to be done in the area of coordination and finding the right mix of financing option in supporting the activities of public organizations and parastatals when it comes to the design and implementation of STI policies.

Key words: Innovation; sub-Sahara Africa (SSA); Science, Technology and Innovation (STI); Institutional Quality; Economic Growth.

JEL: O1; O2; O3

1. Introduction

Growth in sub-Sahara Africa (SSA) has been sluggish and for the past four decades, the region has had to endure a semblance of recession given the fragile nature of its economies. Consequently, there has as a result been increasing attempt to dissect on the challenges faced by the region through deliberation on the cause of the region's plight. Conspicuous among factors considered include political instability, governance, geographical location and corruption among others (Alesina & Weder, 2002; Bingab *et al.,* 2018; Boudreaux, 2017; Forson, 2016a; Forson et *al.,* 2016; Forson et al., 2017; Pellegrini, 2011). Notwithstanding, issues of diversification that may bring about structural change have not been addressed adequately in political and academic discourses. The financial sector which is thought to be the architect of these changes seem to lack innovation and this has thus stifled progress that has affected segments of the economy. This observation is shared by Durusu-Ciftci et al. (2017), who assert that the financial sector of an economy to a large extent, ought to serve as a conduit for changes such as the introduction of new financial instruments, institutions, services, among others to induce economic growth.

Innovation is essential and has no limit, yet its impact on certain key sectors of an economy can trigger what we call the multiplier effect (Peng *et al.,* 2020). The concept of innovation in general has therefore been understood to include both the concept of invention (the ongoing research and development function) and diffusion of new products, services or ideas (Casu et al. 2008:pp.39). Yet in the financial sector, financial innovation is the act of creating and making known new financial instruments as well as new financial technologies, institutions and markets (Casu et al. 2008:pp.39). Nonetheless the fundamental meaning of innovation in Africa seems to have been misunderstood in its entirety and that has been the reason the region continues to lag. Whiles the normative idea of innovation seem to have been linked to hi-tech, in truism, innovation is more than just technology. According to Lepage (2017), innovation is not hi-tech; innovation is 5% technology and 95% imagination. He emphasized that at a practical level, it is about examining pressure points and thinking about creative ways of dealing with that (Forson, 2019, 2020).

Thus, Africa's failure to embrace this creative thinking has affected the structure of its economy. Researchers such as Oyelaran-Oyeyinka (2012), Moghalu (2014) and Lepage (2017) have collectively described sub-Sahara Africa as a 'latecomer' to demonstrate how sluggish the

region has been in embracing new ideas leading to technological advancement. Thus for the region to make any meaningful strides would mean there should be a structural change. According to Oyelaran-Oyeyinka (2014), economic structural change is measured by quantifiable structural shift (i.e. GDP or employment share of the sector explained by the level of development). This situation includes observable economic transformation, followed by significant changes to the relative contribution of different sectors, in terms of production and factor use. That has not been achieved holistically.

It has been argued in other circles that sub-Sahara's challenges could be as a result of disjointed implementation of industrial policy spear-headed by a lack of innovation on a continuum. As pointed out in a report published by UNCTAD (2006), an economic transformation is only plausible if the much needed enabling policy is put in place that will ensure the process of capital accumulation, structural change and technological progress. Yet this can never be achieved on a silver-platter except when there is that collective agreement on the part of governments within the region to strengthen capabilities of its people to enable them achieve structural change.

East Asia and perhaps Latin America were once saddled with the same problem of 'weak policy' that is bedeviling Africa today, but through a focused hands-on endeavors, they have been able to overcome these problems using what has come to be known as 'dynamic capability development' (Oyelaran-Oyeyinka, 2014; Sen, 2000). Large volumes of literature have indeed cited the East Asian phenomenon as an experience that placed premium on state institutions and capacity. These sources have all emphasized the need to learn lessons from successful cases that led to capital formation and the advancement of technological capability accumulation (see Forson, 2016; Mcmillan & Rodrik, 2011; Oyelaran-Oyeyinka, 2014). On the flipside, it has been argued that governments' intervention is always susceptible to the menace of abuses such as corruption and inefficiency and may have accounted for its failure which is detrimental to development as market failure (Amsden, 1989). However, while innovation has been given a central role in the determination of growth elsewhere, little has been written about the drivers of innovation in sub-Sahara Africa.

The contribution of the paper is in two-fold: (1) to examine the role of institutional development on innovation and, (2) to assess the impact of innovation on economic growth. It must be emphasized that the more industrialized countries of East Asia and Latin America have

found a lasting solution to market imperfections, using extensive but context-based industrial policies to support the process of development through structural transformation (Oyelaran-Oyeyinka, 2012). This has not been the case in Africa. Although there are studies that provide narratives of the shift in growth dynamics within the African sub region (see Adeyinka et al., 2013; Mcmillan & Rodrik, 2011), there are still dearth studies that explore concurrently the synergies between institutional development and innovation on one side and innovation and economic growth on another taking into account a systematic review of innovation policies in the region. This has important implication for deepening understanding on how the entrepreneurial spirit and innovation has affected the growth dynamics after independence.

In this study, we operationally define innovation as the act of generating new ideas that are practical and can be translated into new instruments and technologies that can be applied at pressure points in an economy. It is our belief that our definition by extension draws on the three tenets of innovation: *institution*, *product* and *processes*. Having said that, the key question that rear its head regarding innovation drive in sub-Sahara Africa is: is there a regional framework for innovation to thrive? What are the segments and elements of this framework? How has institutions acting as fulcrum for innovation been financed? How has innovativeness of institutions impacted on regional economic growth? These questions and others were addressed in the study.

The paper is organized as follows. Section 2 reviews the extant literature on innovation and economic growth in general. The section further narrows its focus to explore the synergy between the state, institution and innovation on one side, and innovation and economic growth on another. Barriers to the design and implementation of STI[1] policies in sub-Sahara Africa is also explored in this section. Section 3 is the data and methodology. Empirical analysis and discussion are concurrently covered in Section 4. Section 5 concludes and makes recommendation for policy makers in the region.

[1] STI and innovation are interchangeably used in this paper to mean the same thing. Note should be taken that by innovation, we are referring to ideas that leads to creativity and the application of these ideas at pressure points in an economy.

2. Institutions, Innovation and Economic Growth Perspectives

2.1 The State, Institution and Innovation

Evans and Reuschemeyer (1985) conceptualize the state as a set of organizations invested with the authority to make binding decisions for people and organizations located in a particular territory and to implement these decisions, if necessary by force. Drawing on the link between the state and institutions, Aryeetey and Kanbur (2008; pp.15) explain that the state is 'a set of institutions that possesses the means of legitimate coercion, exercised over a defined territory and its population, known as society'. By implication, the performance of institution defines the progress of the state and the economy as a whole. These definitions syncs very well with what institutional theory postulates.

In the conceptualization of the term institutions from literature, it is important to note that two main deductions could be made. The first strand of literature looks at institutions as an organization or entity whiles the latter aligns the term with that of a practice or law. According to North (1991; pp.97) institutions are the rules of the game. On a continuum, he argues that institutions are the humanly devised constraints that structure political, economic and social interaction and may consist of both informal constraints (e.g. sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights). The notion of institutions (local, national, and international) as is generally known are far more than agencies. Institutions are complex social systems which thrives on relationships and networks (see de la Mothe, 2004; pp.526). To him, innovation arises out of complex combination of research, technology, and managerial acumen within the context of social demand and individual creativity. Successful institutions are learning organizations, able to adapt to knowledge, to network (de la Mothe, 2004).

According to de la Mothe (2004), institutions are the conduit through which ideas are formed and flow, from government labs, firms (small and large), universities, and agencies, providing community services, and developing the notion of what he termed as "*constructed advantage*". On the role of institutions when it comes to innovation policy, he emphasized institutions are concerned with stimulating, guiding, and monitoring knowledge-based activities within a political jurisdiction—typically a nation or a region. From this postulation, it is suggestive

that it takes the work of institutions to stimulate and guide the advancement of knowledge in a particular setting.

A well-resourced institution could be a platform for innovation to thrive as they become the conduit where knowledge generated are given a practical significance and this has been researched extensively by Nelson (2008) and Rasiah et al. (2016). In supporting this assertion, Rasiah et al. (2016) in an attempt to examine the relationship between host-site institutional support, innovation capabilities and exports observed that innovation capabilities is correlated with institutional support, and that it also enjoyed a positive relationship with export. At the firm level, Barasa et al. (2017) were able to prove that firm-level resources vary depending on the institutional environment and that regional institutional quality positively moderates the effects of the firm-level resources.

Other scholars such as Dollar and Kraay (2003) and Greif (2006) have collectively stressed that institutions that are properly designed can stimulate productive behaviors whiles those that are weak may lead to unproductive behavior. Institutions can reduce transaction costs and uncertainty and ease coordination between economic agents (Alonso & Garcimartin, 2013). Institutional quality encompasses (1) the process by which a government is selected, monitored and replaced (2) a government's capacity to effectively formulate and implement sound policies and (3) the economic and social interactions between citizens and the state are governed (Kaufmann & Mastruzzi, 2013). As such, the institutional environment can influence the propensity of firms to innovate in a variety of ways (North, 1993). For instance, weak enforcement of regulations and the absence of intellectual property rights may hinder innovation. Compared to countries in Latin America, Southeast Asia and Middle East and North Africa, countries in sub-Saharan Africa perform poorly in upholding the rule of law, regulatory quality, control of corruption and government effectiveness (Alence, 2004).

The impact of institutions on growth is indirect because institutions do not produce goods and services that are tangible, yet the institutional approach posit that both the amount and productivity of resources depend on the institutional environment. Seputiene (2009) asserts that a well-defined institution reduce uncertainty, decrease macroeconomic volatility, stimulate specialization, lower transaction costs, and invariably foster investments and innovation. Knack and Keefer (1995) study is credited with being among the early contributors to this discourse with

a proposition that supports the assertion that institutions causes growth. In the said study, there is an attempt to quantify the relationship between institutions, investment, and growth using alternative indicators. The research findings strongly indicate that institutions that protect property rights are crucial to economic growth and to investment. This effect of institutions on growth persists even when controlled in a regression model for investment. This goes to affirm the preposition that the security of property rights affects not only the magnitude of investment, but also the efficiency with which inputs are allocated. This empirics is supported in a similar study by DeLong and Shleifer (1993) that asserts that good institutions in the form of predictable and stable rules of law, efficiency bureaucracy, and property rights security are linked with economic growth.

Acemoglu et al. (2001) in a related study corroborated the effect of institution on growth in the European context. In the said study, the researchers treat European colonialism as a natural experiment and hypothesized that European colonizers imposed different types of institutions on their former colonies depending on whether those colonies were suitable for European settlement. They however conclude that institutions have a large effect on economic growth.

The importance of institutions for economic growth in terms of per capita incomes, infant mortality and adult literacy have been corroborated in related studies by Kaufmann et al. (1999, 2002). Moreover, Seputiene (2009) undertook a study aimed at exploring and quantifying the relationship of countries' income level with institutional environment, geography and openness to trade across the European Union. He concludes that there was a strong and positive link between various measures of institutions and economic development. The study also supported the primacy of institutions over openness to trade and geography. Próchniak (2013) used variant of institutional inputs such as democracy, economic freedom and the ease of doing business with a confirmation of a large positive impact of the quality of the institutional environment on the level of economic development measured by the 2005-2009 GDP per capita at PPP.

However, the most comprehensive cross-sectional study in recent times has been conducted by Barro and Sala-i-Martin (2003) and Pellegrini (2011b). In both studies, about 100 and 106 countries respectively have been sampled (1965-1995 and 1996-2005 respectively). Their results suggested that democracy, measured by electoral right from the Freedom House shows a nonlinear relationship with the growth rate of GDP. Moreover, they also found nonlinearities in

other institutional inputs like civil liberties. On the other hand, other institutional inputs like the quality of bureaucracy revealed a positive linear relationship on economic development. Other institutional factors were also tested using dummy variables that represented colony (i.e. French, Spanish/Portuguese etc.), landlocked and legal-structure (British and French). Rivera-Batiz (2002) tested political rights index compiled by the Freedom House as well as the quality of governance indicator compiled by Hall and Jones in 59 countries within the years 1960-1990. This research confirmed that the quality of governance positively and significantly affects economic growth. Leblang (1997) and Feng (1997) both analyzed democracy index from Gurr and Bollen for 91 and 96 countries during 1960-1989 and 1960-1980 respectively. Institutional factors like democracy, the probabilities of government changes have been understudied. Both studies converged that initial level of democracy positively and significantly influences GDP dynamics. However, Feng's study had a twofold impact: the direct impact was negatively associated with growth, whereas the indirect impact was positive because of the influence of the probability of government changes.

Moreover, important regular government changes favorably affect macroeconomic performance, whereas irregular changes had the opposite effect. Other institutional factors like economic freedom and the level of democracy have been understudied on an extensive variation by Prochniak and Witkowski (2012; 2013) on GDP growth using an innovative method of Bayesian model averaging. They conclude that economic freedom is one of the main drivers of growth in the EU. In explaining worldwide differences in economic development, Próchniak (2013) concludes that differences in physical capital, human capital and the institutional environment (measured by governance indicators) explained nearly 75% of the differences in economic development among 153 countries during the period 1994-2009. In Africa, Ganau (2017) investigated the relationship between institutions and economic growth with a sample of 50 countries in the region and concluded that democracy and regime instability negatively affects growth. Democracy, legislative effectiveness and regime instability were used as institutional factors whiles per capita growth GDP was a proxy for economic growth in the said study.

In contrast, there are other studies that have had opposing views on the relationship between institutions and economic growth. For instance, Glaeser et al. (2004) points out that growth rather improves institution and that such a hypothesis regarding institutions causing growth is non-existent. The OLS cross-country evidence for 1960-2000 used provided no support to the

purported claim of institutions causing growth. Plumper and Martin (2003) analyzed the relationship between democracy level and growth in 83 countries within the period 1975-1997. They found a nonlinear relationship between democracy and economic growth. They also concluded that the highest GDP dynamics were recorded by those countries that have had relatively moderate level of democracy. Based on the foregoing perspectives, this paper hypothesize the following:

H1: Institutional quality has a positive relationship with innovation

2.2 Innovation and Economic Growth

The significance of innovation on economic growth is highlighted in Schumpeter's (1942) theory of creative destruction, which elucidates on how capitalism pushes economic growth through innovation and entrepreneurship. Underpinned by the Schumpeter's theory, extant literature on this relation argues that institutions that are market-based may be in better positions to stimulate growth and such an assertion is supported in recent research (Aristizabal-Ramirez et al., 2015; Boudreaux, 2017).

The concept of innovation according to Sundbo (2003) is a combination of knowledge that result in new products, processes, input and output markets, or organization (not only technical innovation) but also organizational and managerial innovations, new markets, new sources of supply, innovations, and new combinations (Perlman and Heertje, 1991). To Padilla-Perez and Gaudin (2014), innovation is an interactive and gradual process, based on communication and knowledge exchange. Carayannis et al. (2006) argues that in a knowledge-based economy, innovation through the creation, diffusion and use of knowledge has become a catalyst in the build up to economic growth. Rycroft and Kash (1999) on the other hand points out that innovation policy is a complex process, not a single product, but as a result of a set of programs and policies, involving institutions.

Innovation however comes in different forms and facades. For instance, industrial innovation includes manufacturing, technical design, management and commercial activities used in the marketing of a new (or improved) product or the first commercial use of a new process or equipment (Freeman, 1982). Huang et al. (2007) are of the opinion, the factors required for industrial innovation are in manifold and may include technical knowledge, manpower, market

information, financial resources, R&D environments, a domestic market and an international market (Rothwell and Zegveld, 1982). Finding the right measure of innovation has given rise to intellectual argument. Huang et al. (2007) in a quick rebuttal had pointed out that macro measures such as R&D tax credit are not effective and pointless, and that policies must be designed to influence particular economic sectors. Product innovation differs from the generic concept, as it is basically the introduction of new good or service or the significant improvement of existing product with respect to its characteristics and intended use (Ayyagari et al. 2012; Barasa et al. 2017). But Salmenkaita and Salo (2002) disagreed and stressed that there are no straightforward answers to the question of what should constitute an innovation in the generic. Dilating on what should best describe innovation, Lepage (2017) argues that innovation in its essence is all about ideas; identifying pressure points and being creative to avert the existing pressures.

The awareness of the concept of innovation is not novel in itself, but over the last decade, its speed particularly in other sectors particularly the financial sector has created some challenges that impact financial development, including structural changes in the financial sector, the reshaping of financial services, and the emergence of new financial assets in the financial markets. Financial innovation brings to the fore and popularizes new financial instruments, institutions, and technologies to the financial system (Durusu-Ciftci et al. 2017). Yet Ductor and Grechyna (2015) demonstrates that the effect of financial innovation on economic growth may not necessarily be straight but is contingent on the growth of private credit relative to the real output growth. They therefore warned that very rapid financial development can decrease economic growth. To appreciate the link between innovation and growth, this paper hypothesize that:

H2: Innovation has a positive and significant relationship with economic growth.

2.3 Barriers to the Design and implementation of Innovation Policy in sub-Sahara Africa

The study further attempts to explore the barriers to the design and implementation of innovation policies in the region. This is against the backdrop that technological-capability indicators in the region still lags behind its compatriots (see Table 1). The study profiles and briefly discusses the bottlenecks that have led to the ensuing situation with emphasis on three (3) main policy areas (*e.g. institutional framework, financing and diffusion and interaction*) deployed by

selected countries in the region (see Table A-3). These are barriers faced by governments when designing and implementing science, technology and innovation (STI) in Africa.

To begin with, although there appear to be some form of political support in the design of innovation policies, the results from the technological-capability indicators have proved otherwise. Thus high-level political support for STI policies is superficial and therefore remains absent. Public organizations charged with the task of science and technology innovation policies (ministries, national council, secretariat, and parastatals) lack the resources and enough leverage to discretionary push their agenda. Moreover, recognition and the role of innovation to stimulate growth remains ambiguous, hence commitment levels being low comparatively. As posited before, countries such as Ethiopia, Kenya, Mali, Senegal and Ugandan despite increment in the commitment levels from 0.24%-0.61%, 0.36%-0.79%, 0.25%-0.66%, 0.37%-0.54% and 0.37%-0.48% of GDP, is still far from appreciable levels looking at what is being done elsewhere (e.g. US 3.1% of GDP, and Sweden 3.4% of GDP).

In exploring other sources of funding for STI in the region, tax incentives seem to be the best option, yet countries in the region are already saddled with the problem of low tax revenue which makes it difficult to implement the policy on tax incentives. This poses as a strong barrier for increased STI public investment. According to figures from the World Bank (2009) tax revenues as a percentage of GDP in the region is low. For instance, in Ghana, tax revenue accounted for just 14.87% of GDP in 2012, in Nigeria 5.46% in 2008, in South Africa 26.50% in 2012, in Kenya 19.88% in 2012, in Tanzania 13.8% in 2012, in Cameroun 11.2% in 1999 and 12.46% for Angola in 2015 (World Bank, 2013). The implication therefore is that, funds for STI would not be forthcoming as countries are faced with more social issues that needs redress in the short term.

Political instability in the region remains a barrier to the implementation of STI policies. Countries such as Sudan, Liberia, Côte d'Ivoire, Gambia, and Mali have all experienced some form of political unrest. As a consequence, STI programs do not always survive the entrance of new government. This is a common practice in Africa. In relatively stable economies, new government often over-look policies initiated by its predecessors irrespective of the programs impact on general wellbeing.

The universities in the region are mainly focused on teaching or basic-science research which has a weaker link to private enterprises. Science and technology institutions that were

conceptualized from the outset to be the incubating grounds for entrepreneurs and inventors have taken to offering social science programs and business administration. For instance, universities such as the Kwame Nkrumah University of Science and technology (KNUST) in Ghana, the Federal University of Technology (FUT) in Nigeria, Central university of Technology (CUT) in South Africa have all diluted their programs by offering more programs in the arts and social sciences than its pure and applied science programs which is core to its mandate.

Coordination among public organizations and parastatals in the design and implementation of STI policies is weak. Departments and parastatals often elaborate their strategies but are not fully integrated and coordinated thereby leading to competition among these institutions. This is undoubtedly a barrier to improving the impact of STI policies and developing an efficient use of scant resources.

Financial systems in sub-Sahara Africa are not incentivized enough to support innovation in the region. New entrepreneurs and existing firms hardly get access to financial sector to finance innovation activities. Venture capital are also almost non-existent. The gestation periods for actualizing the full potential of new inventions often takes time, and this is a disincentive for existing financial institutions which are already grabbling with liquidity and solvency risks. In Ghana for instance, seven big banks collapsed and merged as a result of liquidity challenges in less than 18 months (Nunoo, 2018).

Table 1: Selected countries in sub-Sahara Africa

Country/Indicator	Nigeria	South Africa	Mali	Kenya	South Korea	Brazil	United States	Sweden
No. of graduates on ST areas (per 1000 inhabitants)	0.3	0.7	0.11	0.3	na	4.3	5.1	na
Researchers (per million inhabitants)- 2015	na	26,159	537.9	na		183,853	1,379,977	66,734
R&D Expenditure (percentage of GDP)	0.2	0.9	0.66	0.79	3.4	1.09	3.1	3.6
Patent applications by residents (per million inhabitants)	645	5 065	na	53	2745.9	37.7	801.8	2745.9
No. of Scientific publication (per million inhabitants)	11.4	46.4	64.2	6.6	464	187	1276.7	1053.1

Source: Authors construct based on World Development Indicators and UNESCO indicators. All available online.
Note: ST= Science and Technology, na = not available

In summary, countries in sub-Sahara Africa are trailing behind when it comes to science, technology and innovation due to the foregoing barriers identified which shares commonalities with what pertains elsewhere: design and implementation failure and political instability (see Woolthuis et al. 2005), weak education systems (Aubert, 2004; Segarra-Blasco et al., 2008), lack of resources (Aubert, 2004), lack of financing mix (Segarra-Blasco et al. 2008) and lack of

coordination among public organizations and failure to monitor (Hadjimanolis & Dickson, 2001; Willie et al. 2016).

3. Data and Methodology

3.1 Data

This study examines a panel of 25 economies in sub-Sahara Africa[2] with the most recent dataset (1996–2015) from the World Bank and other reputable agencies. The criteria for selecting these countries was purely based on data availability. The financial sector of an economy to a large extent serves as a conduit for changes such as the introduction of new financial instruments, institutions, services, and reporting could be brought (Durusu-Ciftci et al. 2017). Yet the waves of innovation on the economy is diversified and therefore no single variable can be considered as an appropriate indicator for measuring its significance in the economy (see Qamruzzaman & Janguo, 2017: pp.6). There are two dependent variables in this study: innovation measured by the number of scientific journals published and economic growth measured by GDP per capita. Our main research variable[3] is innovation.

The study controls for institutional and growth enhancing factors such as government effectiveness, corruption, size of government, bureaucratic quality, regulatory quality, rule of law, press freedom, population growth, economic prosperity, foreign aid inflows, natural resources, gross savings, Periodicals (citable documents) and Education as a measure of human capital endowments using primary, secondary and tertiary enrollments. Most of these variables have broadly been classified as policy variables in the growth literature.

These variables have been researched extensively in the institution and growth literature (see Earle & Scott, 2010; Prasad, 2003; Próchniak, 2013). Based on this, we are able to rationalize the choice of variables in this research. The resultant summary statistics, variable descriptions and presentation of countries (Table A-1), and correlation matrix (Table A-2) are detailed in the appendix respectively.

[2] By sub-Sahara Africa, reference is being made to black African countries excluding North Africa.

[3] The variables used in this study are lagged for a year to account for persistence. The lagged regressors on the right hand side of the equation is endogenous and may lead to what Nickell (1981) describes as 'dynamic panel bias' and the lagged dependent variable maybe correlated with the error term.

3.2 Model Specification

To understand the relationship between institutional development and innovation, the study builds on Boudreaux (2017) simple OLS model presented in equation (1);

$$I = \alpha + \beta EFW + \varepsilon \quad (1)$$

Where, I is innovation measured by the global innovation index (GII), and EFW is a measure of market institutions that facilitate innovation.

Consequently to answer the question on how institutional development affects innovation in sub-Sahara Africa on one side and the link between innovation and economic growth in sub-Sahara Africa on another, we expand Boudreaux (2017) model and have it presented as follows in equation (2) and (3) respectively;

$$I_{it} = \alpha_0 + \beta_1 Human\ capital + \sum_{k=1}^{k} \beta_{2k}\, INST_{it}^{k} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

$$Y_{it} = \alpha_0 + \beta_1 FI_{it} + \sum_{k=1}^{k} \beta_{2k}\, INST_{it}^{k} + \sum_{i=1}^{i} \beta_{3i} STOCKS_{it}^{i} + \sum_{s=1}^{s} \beta_{4i}\, SHA\_{}_{it}^{i} + \mu_i + \gamma_t + \varepsilon_{it} \quad (3)$$

Where I_{it} and Y_{it} represents innovation and economic growth respectively. Innovation and growth are measured by the number of scientific articles published and per capita GDP respectively. The subscripts i and t denotes country index and time dimension respectively. Visible from the model is an error term with three sub-components: μ_i represents unobserved country-specific determinants which is stationary; γ_t stands for the common time specific shocks, and ε_{it} is the unobserved determinants that vary over time in a country. The variables institutions, stocks and shadow are the categories of control variables pointed by theory in the literature (i.e. proxies for political, economic and legal institutions, capital stocks and for the accounting).

On the estimation approach, with the understanding that the conventional fixed effects and OLS estimators according to Nickell (1981) becomes inconsistent when the time span is somehow small (Phillips & Sul, 2007), the study relies on three estimation techniques for consistency in

robustness: Pooled OLS (POLS), fixed effects[4] (FE) and variants of the Generalized Method of Moments (GMM) including instrumental variable (IV). The FE regression controls for omitted variables in panel data when the omitted variable vary across entities but do not change over time (see Stock & Watson, 2007: pg.356). Our decision to use either the variants of a typical GMM or IV is based on an avalanche of factors. For instance, Han and Phillips (2010) argues on the superiority of the GMM over the conventional IV on its efficiency in the face of heteroskedasticity. Stock and Watson (2007:pg.727) on the other hand explains that an efficient IV estimator is known as an efficient GMM when the errors are heteroskedastic. Stock and Watson (2007:pg.730) further posits that when the errors are homoscedastic, then the TSLS estimator is asymptotically efficient among the class of IV estimators. From these analogies and explanations, there are several classes of the GMM and ones decision to use either should be based on the nature of the data and the information it elicits through the diagnostic checks undertaken. It should further be noted that either of the variants of the GMM is designed to deal with the problem of endogeneity which is fundamentally a challenge when addressing issues that borders on institutions. Endogeneity may arise from two perspectives: (1) the endogenous variable being correlated with the error term and (2) cases of missing variables. Other approaches to bolster our diagnostic checks included an attempt to control the condition numbers and variance inflation factors to be lower than 100 and 10 respectively in each regression.

4. Estimation Results and Discussion

We begin our analysis with series of diagnostic checks. First, using our correlation matrix in Table A2, we are able to infer whether our variables are highly correlated. This procedure partly helps by giving firsthand information on multicollinearity. In the said table, none of our variable is seen to be collinear except innovation and periodicals. This validates our decision to use periodicals as an instrumental variable. Other check on Heteroscedasticity is conducted using a statistical test. Our statistical test using the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity on the residuals portrays an insignificant effect (Chi2=11.51, p=0.687). From

[4] To avoid the inconsistency of POLS estimation of the AR(1) processes, the FE estimator is chosen. Generally, the use of the FE is intentioned at eliminating the unobservable, time-invariant country fixed effects in order to eliminate the inconsistency caused by the dependence on the lagged regressors. This is achieved by a so-called 'within transformation'(see Acemoglu et al. 2008: pg.814).

the Bruech Pagan result, we reject the null hypothesis indicating heteroscedasticity. That is the error terms seem to have the same variance (homoscedastic). Therefore using the TSLS method to augment the POLS and FE appears to be enough.

We see innovation as a by-product of institutional development. It takes an effective and vibrant institutional set-up to implement and evolve national innovation plan. A well-resourced institution has what it takes to spur innovation. We therefore regress the variants of institutional factors controlling for human capital on innovation using equation (2). This is in attempt to answer the question as to what has been the role of both new and existing institutional frameworks in the generation and application of knowledge for a holistic development in the region. Our results from the POLS, FE and 2SLS regression are interesting and elicits a number of implications (see Table 2a and 2b).

As posited by Kaufmann et al. (2013) and de la Mothe (2004), institutional quality encompasses the process by which a government is selected, monitored and replaced, a government's capacity to effectively formulate and implement sound policies and the economic and social interactions between citizens and the state. The use of democracy, the governance indicators addresses these concerns as shown in the POLS regression. The study finds press freedom which is a component of democracy to be relevant in driving innovation in sub-Sahara Africa. Although the effect on a larger scale might seem to be indirect, the following could be some of the benefits of press freedom: (1) it ensures a level playing ground for businesses especially in the area of exposing corruption, and (2) it supports stable business operation. Press freedom promotes innovation. Innovation however, requires diversity of thought and action, as well as high level of trust. Therefore countries that outlaw and punish free expression destroy societal trust and encourage more even, rigid and narrow forms of thought.

However, government effectiveness that deals with the formulation of policies and regulatory quality had a contrasting impact on innovation policy in the region. Whiles regulatory quality which underscores the strength of policy briefs regarding innovation in the region is seen to be positive albeit insignificant, it is suggestive of the fact that a lot more needs to be done to ignite innovation considering the mixed results from the POLS, FE and TSLS. Property right protection after varying the host of control variables still remained significant to suggest property right protection could strengthen firms' incentives to innovate in the region. Our aggregate variable

education which is a measure of Human capital (primary, secondary and tertiary enrollments) suggest on a consistent manner that human capital in the region has what it takes to be a driver of innovation. Education offers the platform for knowledge to increase the probability to innovate, and this is possible through innovative teaching and learning methods. Economic prosperity which measures per capita income in the region is seen to be positively and significantly related to the level of institutional quality (Table 2b). Without a strong economic progress, financing the activities of existing institutions becomes a daunting task let alone to establish new ones to tackle emerging challenges. Yet the relation under the FE and TSLS approach although insignificant were both seen to be negative. This suggest at one point the rise in income levels provides support for building strong institutions and at another jurisdiction frustrates institutional development. This relation syncs with our previous discussion on the barriers to the design and implementation of STI policies in the region. It should be argued that there is no uniform economic gain in the region. Whiles some countries are economically active, others are struggling. Besides, governments in the region are saddled with the challenge of raising the much needed resources to push the innovation agenda owing to the lack of diversity in the raising of funds to spur innovation. Without a fund dedicated for innovation informed by a surge in economic output, the level of prosperity (often in the negatives) will continue to dampen both innovation and institutional development.

Under the TSLS approach in Table 2a (columns 1 - 3), the aggregate of institutional quality is regressed on innovation. Institutional quality is seen to dampen innovation. In the said models, endogenizing with one of the institutional variants - corruption on the left of the equation accompanied by our instrumental variables ethnic linguistic fractionalization and British colony on the right hand side. A test of endogeneity was further conducted under which the null hypothesis of the variables being exogenous was rejected. Both the Durbin chi-square = 2.736, p= 0.009 and Wu- Hausman F-stats = 2.475, p= 0.010 respectively were jointly significant to confirm the rejection of the null hypothesis. Therefore we were correct in treating corruption as an endogenous variable. We also tested the strength of our instruments and found a partial R^2 of 0.86 with an F-statistic of 38.80. Our F-statistic was larger than all the critical values shown on the table (e.g. 3.92 – 19.93). Moreover, both the sargan and Basman chi-squares were statistically insignificant (p=0.200 and 0.137) to point to the fact that the null hypothesis of the instruments used are valid and that our model is correctly specified under the test of over-identifying restrictions. Similar procedure is followed in Table 2b on models 1 through 3 respectively.

Foreign aid inflows and wealth per capita are seen to inhibit institutional quality in Table 2b. We theorize that such relation could be possible due to the fact that donors of development aid do not necessarily pay attention to better or worse institutions in most cases. Foreign Aids come in handy and are meant to achieve certain purposes including to protect the interest of donors which in most cases are not made known to the general public. The variable wealth per capita is a composite indicator that cuts across the dimensions of sustainability (see Forson et al., 2017; Harris, 2000). The mixed results of the relation of wealth per capita lend credence to what economic prosperity seem to suggest as both reduce institutional quality. Africa's true savings taking into account the environmental cost associated with pollution, land degradation, desertification, and depletion of natural resources at a faster rate could mean the region virtually saves nothing when the appropriate deductions are made. This has what it takes to affect funding or investment in research and development leading to less of a sort of innovation.

Table 2a. Institutional Development and Innovation in Africa. *POLS, FE and IV estimates*

	POLS			FE			IV		
	(1)	(2)	(3)	(1)	(2)	(3)	(1) 2SLS	(2) 2SLS	(3) 2SLS
					Innovation				
Specification									
Corruption		21.689	33.187		-90.726***	-95.780***	-27.212*	-29.548**	43.798
		(43.691)	(36.856)		(39.163)	(32.155)	(15.635)	(13.037)	(45.895)
Press Freedom		6.343**	2.474		-0.785	-6.589			1.745
		(2.124)	(2.145)		(4.905)	(4.492)			(2.275)
Gov't Effectiveness		-139.931	-75.749		20.652	6.204			
		(87.495)	(87.511)		(81.550)	(82.005)			
Reg. Quality		239.643***	157.657**		-105.814	-64.148			
		(56.823)	(59.716)		(90.553)	(77.360)			
Prop. Right Prop.		1.887**	1.708**		0.881	0.598			
		(0 .839)	(0.712)		(0.744)	(0.602)			
Size of gov't								-8.537**	-6.069
								(3.120)	(4.363)
Education			7.781**			5.077***			0.333
			(1.630)			(1.383)			(1.167)
Economic Prosperity			-0.873*			-0.407*			275.314*
			(2.375)			(2.069)			(163.560)
Gross savings			0.337*			-5.613***			-3.085*
			(2.813)			(2.521)			(1.812)
Institutional Qual.	-231.53*		-210.940***	-282.871*		-114.000*	-414.370**	-363.244**	-300.462*
	(132.83)		(44.357)	(150.160)		(59.476)	(134.423)	(114.611)	(116.841)
Constant	740.46***	-275.632	-608.651***	774.232***	-316.224	-342.723*	147.295**	208.310***	-838.962*
	(131.34)	(177.289)	(141.735)	(105.03)	(283.447)	(265.890)	(56.231)	(54.000)	(368.772)
Year Dummy	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummy	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observation	84	98	120	84	98	120	84	98	120
R^2	0.012	0.71	0.90	0.016	0.40	0.72	0.874	0.914	0.962
F/Wald Chi2							113.72	172.76	408.45
							[0.00]	[0.00]	[0.00]

Note: Robust Standard Errors in Parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2b. Innovation and Institutional quality: *POLS, FE and IV estimates*

	POLS			FE			IV		
	(1)	(2)	(3)	(1)	(2)	(3)	(1) 2SLS	(2) 2SLS	(3) 2SLS
				Institutional Quality					
Specifications									
Corruption		-0.003	-0.077***		-0.005	0.014	0.096*	-0.399	-0.525**
		(0.026)	(0.034)		(0.015)	(0.023)	(0.181)	(0.183)	(0.239)
Press Freedom		0.013***	0.008		0.002	0.006***		-0.019**	0.002
		(0.002)	(0.001)		(0.002)	(0.002)		(0.007)	(0.009)
Foreign Aid Inflows		-0.178***	-0.213***		-0.008	-0.094***		-0.128	-0.137
		(0.040)	(0 .043)		(0.012)	(0.036)		(0.165)	(0.161)
Wealth per capita		-0.006***	0.004		-0.001***	-0.005***		0.004	0.016*
		(0.001)	(0 .003)		(0.000)	(0.002)		(0.006)	(0.009)
Natural Resource			0.020***			-0.003			0.052**
			(0 .003)			(0.003)			(0.024)
Education			0.002			0.0003			0.011
			(0 .001)			(0.0009)			(0.008)
Economic Prosperity			0.020***			-0.119			-2.482
			(0.003)			(0.292)			(1.681)
Gross Savings			-0.014***			0.0003			-0.026*
			(0.005)			(0.003)			(0.013)
Innovation	-0.0001*		-2.46	-0.0001*		-0.0001***	-0.0008	-0.0007	-0.002
	(0.00003)		(0.000)	(0 .00003)		(0.00002)	(0.000)	(0.000)	(0.001)
Constant	0.689***	1.668***	2.400***	0.689***	0.459***	1.094	-0.303	3.053*	8.478*
	(0.051)	(0.403)	(0.582)	(0.023)	(0.193)	(0.831)	(0.214)	(1.702)	(4.716)
Year Dummy	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummy	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observation	108	489	189	108	489	189	108	489	189
R^2	0.012	0.354	0.695	0.016	0.015	0.356	0.654	0.647	0.73
F/Wald Chi2							44.84 [0.00]	48.94 [0.00]	65.61 [0.00]

Note: Robust Standard Errors in Parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Assessing the link between innovation and economic growth in Table 3 indicates the former contributes significantly to wellbeing in Africa. Nonetheless, we can deduce that innovation maybe endogenously correlated with the error term. We look for a variable that is linked to innovation and indirectly connected to economic growth. We make a case that the variable periodicals may be directedly related to innovation but not economic growth. We conducted a test of endogeneity in which the null hypothesis of the variables being exogenous was rejected. Both the Durbin chi-square and Wu- Hausman F-statistics were jointly significant to confirm the rejection of the null hypothesis. Therefore we were correct in treating innovation as an endogenous variable. We also tested the strength of our instrumental variable and found a partial R^2 of 0.92 and 0.96 with an F-statistic of 76.134 and 318.309 respectively. Our F-statistics was larger than all the critical values. Both the sargan and Basman chi-squares were statistically insignificant to point to the fact that the null hypothesis of the instrument (periodical) is valid and that our model is correctly specified under the test of over-identifying restrictions (see Table 3).

The contribution of innovation to the region's growth was just 0.014 percentage point and increased to 0.015 percentage point in models (2) under the 2SLS approach. It is also important to note that the significant rise in the coefficient of innovation in model (2) could be attributed to the attempt at improving the activities of institutions. We also find savings to be negatively related to economic growth in Table 3. Though the normative idea has been that savings in the generic stimulates economic growth, in the case of Africa saving rates are lower on average (15%) which accounts for the inverse relationship. The effect of agriculture through value addition is seen to be significantly negative in model (1). The application of knowledge and inventions thrives on financial resources and saving is a means to actualize this. We interact innovation and institutional quality to capture its effect on economic development. Our interaction elicits a mixed result. We find our interaction effect weakens economic development further. Thus from an initial positive 0.007 percentage point to a negative coefficient of 0.012 down to 0.021 from our TSLS approach. This implies with the right mix of ideas, institutional bottlenecks can be resolved to enhance growth in all facet of the economy. The negative relation is informed by the challenges institutions are encumbered with in the design and implementation of innovation in the region as discussed previously.

Table 3. Innovation and Economic Growth in sub-Sahara Africa: *IV estimates*

	Economic Growth			
	(1)	(2)	(1)	(2)
	1SLS	2SLS	1SLS	2SLS
	coefficient of corresponding instrumental variable			
Variable Instrumented				
Innovation		0.014**		0.015*
		(0.005)		(0.012)
Instruments				
Innovation	-0.007		-0.002	
	(0.006)		(0.013)	
Natural Resources		-0.038		
		(0.258)		
Foreign Aid		-2.691**		
		(1.316)		
Economic Prosperity		-7.577*		
		(4.169)		
Investment in Education		0.910		
		(0.316)		
Education			-0.259*	-0.120
			(0.142)	(0.108)
Agric. (value added)			-0.862***	0.663
			(0.246)	(0.406)
Population growth				7.707***
				(1.335)
Savings				-0.008
				(0.047)
Interaction (*institution*innov.*)	0.007**	-0.012***	0.002	-0.021***
	(0.003)	(0.002)	(0.006)	(0.006)
Corruption				10.568***
				(3.137)
Constant	2.412*	40.620*	6.722	-53.042***
	(1.263)	(22.332)	(19.080)	(14.843)
Year Dummy	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes
Observation	120	142	180	220
Adj. R^2	0.058	0.920	0.266	0.980
Wald Chi2		47.06***		58.91***
Durbin Chi2		5.884**		5.065**
Wu-Hausman F- stats		5.111**		4.280**
IV First-stage F-statistics		76.134***		318.309***

Note: Robust Standard Errors in Parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Expanding on the role of foreign aid, it is worth taking a throwback of the number of programs and projects organized by UNESCO to build technological drive for innovation in Africa. Series of workshops and training programs have been organized with funding coming from foreign governments through aid. That notwithstanding, portion of the results validates assertions by other schools of thought that aid has not been beneficial to the progress of the region. It has

been argued that aid contributes in creating macroeconomic challenges such as increasing the stock of money supply which leads to high inflation. Yet there are no systematic evidence of aid increasing inflation, or reducing the amount of credit to promote private businesses. Africa's governance challenges predicated on corruption is owed to a larger extent on foreign aid inflows. For instance in the study conducted by Ohler et al. (2012) on the operation of the Millennium Challenge Corporation (MCC) on aids to some developing economies did uncover a strong anticipation effect soon after the agency had announced the release of funds. Such a move increases uncertainty in recipient countries as well as weakens the incentive to fight the menace (Awoonor & Forson, 2020; Forson *et al.,* 2020; Forson *et al.,* 2015).

The impact of education on growth can be observed to be negatively significant. The ensuing situation could be explained from the following perspectives. First innovation emanates from human resource, most specifically the science and engineering fields but the number of students pursuing science and engineering continues to be least among the different fields of study in the region. Secondly, the colonial origin of skewed school enrolment which most countries in the region were exposed to seems to be at variance with their modern objective of industrialization. It should be readily pointed out that sub-Sahara Africa was colonized by the French, British, Portuguese, Danish and Germans.

5. Conclusion and Policy Recommendation

The purpose of this paper is to investigate the relationship between innovations and economic in sub-Sahara Africa. We control for institutional quality informed by the financing of government agencies. This is against the backdrop that institution is the oil that greases the wheels of development. Using the number of scientific journals published as proxy for innovation and GDP per capita for economic growth, we assessed a panel of 25 economies in sub-Sahara Africa.

Our evidence suggest among other things that innovation has a positive and significant effect on the growth trajectory of sub-Sahara Africa although the impact seems negligible. Institutional quality is seen to dampen innovation and the relation is persistent regardless of when the focus is on aggregate or decomposed institutional factors. While most countries in the region have invested in establishing institutional frameworks, we find barriers to the design and implementation of STI policies account for the sluggish contribution of innovation to the growth pattern in the region.

Governments in the region ought to take all necessary steps to develop national evaluation and STI data stand. The success of this approach will be contingent on the region first of all being able to evolve a specific conceptual and methodological tools for monitoring and assessing STI policies. Area of financing STI policies and coordination among state institutions have to be reconsidered. Tax incentives and havens for technology related businesses ought to be given priority to augment already existing instruments such as export-led instruments. Governments in the region must work in close partnership with financial institutions in boosting entrepreneurial spirit through innovative support to enterprises that are into inventions and discoveries.

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Appendix:

Table A-1: Summary Statistics and Presentation of Countries

Variables	Years	Description	Mean	Std. Dev.	Source
		PANEL A: *Summary Statistics*			
Innovation	1980-2015	The number of scientific articles published in journals in the region	486.27	1370	*World Bank*
Corruption Index	1996-2015	Perceived level of corruption. Countries ranked on a scale of 10 (very clean) to 0 (highly corrupt).	3.181	1.143	*Transparency International*
GDP per capita	1970-2015	Annual percentage growth rate of GDP per capita based on constant local currency.	1.114	6.776	*World Bank*
Wealth per capita	1980-2015	True level of investment and disinvestment in the productive base of an economy after adjustments (*degradation, deforestation and pollution*)	-2.245	2.384	*World Bank*
Agric. (Value added)	1980-2015	Agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs.	27.90	16.39	*World Bank*
Education	1970-2015	Aggregate total enrollments in primary, secondary and tertiary education, regardless of age.	42.25	27.93	*World Bank*
Population Growth	1970-2015	Exponential rate of growth of midyear population.	2.663	0.852	*World Bank*
Gross Savings	1970-2015	Gross savings are calculated as gross national income less total consumption, plus net transfers.	15.26	10.80	
Natural Resources	1970-2015	Sum of all rents (natural gas, coal (hard and soft), mineral, and forest).	11.967	13.755	*World Bank*
Foreign Aid	1970-2015	Logarithm of Aid inflow is the transfer of capital for the benefit of recipient country or its population.	8.147	0.742	*World Bank*
Economic Prosperity	1970-2015	A proxy of natural logarithm of per capita gross domestic product in a given country (constant, 2005 US$).	2.817	0.381	*World Bank*
Gov't Effectiveness	1996-2015	The quality of public services, civil service and the degree of independence from political pressures, ranges from -2.5 to 2.5, higher values = better governance outcomes.	-0.290	0.523	*WGI*
Economic Freedom	1998-2015	A measure of the fundamental right of every human to control labor and property. Countries ranked on a scale of 100 (very free) to 0 (less free).	57.826	5.118	*Heritage Foundation*
Press Freedom	1996-2015	The degree to which country permits the free flow of news and information. Scored from 0 (best) to 100 (worst).	45.237	14.780	*Freedom House*
Periodicals	1996-2015	Citable documents that includes articles, reviews, magazines, newspapers, conference proceedings etc.	779.981	2063.102	*Elsevier Scimagor*
British colony	1970-2015	Dummy variables for countries colonized by Britain or otherwise 1= Britain, 0 = otherwise	0.29	0.45	*Flags of the world*
Size of Gov't	1970-2015	The four components that indicates the extent to which countries rely on the political process to allocate resources and goods and services.	6.231	1.060	*Economic Freedom of the World (EFW)*
Ethnic Linguistic Fractionalisation	1980-2015	The probability that two random individuals in a population belong to different groups and percentage of population without similar language	0.758	0.125	*Alesina et al. (2002; Roeder (2001)*
Institutional quality	1996-2015	Aggregate governance indicators (*gov't effectiveness, Regulatory quality, rule of law, bureaucracy etc.*).	-0.220	0.480	*WGI*
		PANEL B: *Presentation of countries (25)*			
Zimbabwe, Ghana, Cameroun, Kenya, Congo, Rep., Nigeria, South Africa, Mali, Gambia, Guinea Bissau, Mozambique, Liberia, Senegal, Togo Uganda, Tanzania, Zambia, Malawi, Burkina Faso, Botswana, Côte d'Ivoire, Namibia, Ethiopia, Sudan, Angola.					

Source: *Authors' construct*

Table A-2: Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Innovation (1)	1																			
Agric. (2)	-0.271*	1																		
GDP growth (3)	0.019	0.056	1																	
Education (4)	0.091	-0.473*	0.021	1																
British Colony (5)	-0.202*	-0.193*	0.013	0.054	1															
Ethnic-Linguistic Fract. (6)	0.152	-0.043	-0.053	0.244*	-0.102	1														
Press Freedom (7)	-0.215*	0.084*	-0.135*	0.1313*	0.0384	-0.1981*	1													
Pop. growth (8)	-0.244	0.116*	0.264*	0.022	0.318*	0.007	-0.042	1												
Savings (9)	0.033	-0.295*	0.105*	0.229*	0.039	0.387*	0.159*	-0.035	1											
Natural Res. (10)	-0.024	0.081*	-0.051	0.139*	0.039	0.333*	-0.204*	-0.045	0.115*	1										
Foreign Aid (11)	0.147*	-0.002	-0.028	0.111*	0.026	-0.130*	0.075*	-0.004	-0.036	-0.004	1									
Econ. Prosperity (12)	0.353*	-0.761*	0.055	0.379*	0.689*	0.293*	0.235*	-0.110	0.345*	-0.058	-0.327*	1								
Corruption (13)	0.275*	-0.452*	0.098*	0.116*	0.496*	0.138*	0.351*	-0.140*	0.362*	-0.357*	0.022	0.528*	1							
Gov't Eff. (14)	0.365*	-0.476*	0.108*	0.042	0.432*	-0.159*	0.455*	-0.045	0.155*	-0.486	0.073*	0.474*	0.812*	1						
Reg. Qual. (15)	0.299*	-0.274*	0.124*	0.031	0.308*	-0.135*	0.533*	0.031	0.161*	-0.447*	0.036	0.356*	0.706*	0.8724*	1					
Prop. Right (16)	0.5947*	0.348*	-0.099	-0.090	-0.316*	-0.127	-0.040	0.051	0.155	-0.203*	-0.050	-0.048	-0.251*	-0.1245	0.0184	1				
Size of Gov't (17)	-0.263	-0.077	-0.072	0.054	-0.198*	0.1420	-0.264*	-0.261*	0.179*	0.074	-0.130	0.1403	-0.042	-0.125	-0.207*	-0.028	1			
Investment in Education(18)	0.2647*	-0.297*	0.046	0.221*	0.147*	-0.398*	-0.108*	-0.044	0.208*	-0.094	0.012	0.266*	0.171*	0.110	-0.040	-0.2255	0.0228	1		
Periodicals (19)	0.994*	-0.284*	-0.015	0.109*	-0.160*	0.095	0.250*	-0.233*	0.017	-0.057	0.104*	0.348*	0.283*	0.393*	0.307*	0.360*	0.077	-0.241*	1	
Wealth per capital (20)	0.0427*	-0.1712*	0.0419	-0.1435 *	0.2292*	0.456*	0.5061*	-0.3395	0.5585 *	-0.6537*	-0.0051	0.1903 *	0.4980 *	0.4171	0.4032	-0.1180*	-0.0396 *	0.3270	-0.0347	1

Note: Significant at *p < 0.05

Table A-3: **sub-Sahara Africa** - science*, technology and innovation policy*

Policy Instruments	Nigeria	South Africa	Ghana	Kenya	Tanzania
Institutional Framework					
1. National Plan of STI	*	*	*	*	*
2. Evaluating of STI policies					
3. Technology forecast exercise					
4. Administration Organization	*	*	*	*	*
(a) Regional (subnational) STI					
(b) Regional (subnational) STI Organization					
(c) Coordination mechanism among public organizations in charge of STI policies	*	*	*	*	*
5. Public education system: national strategy			*	*	*
(a) Strategy to promote mathematics and sciences in primary and secondary education	*	*	*	*	*
(b) Strategy to promote science and engineering in undergraduates and postgraduate education	*	*	*	*	*
6. Legislative Instruments				*	
Financing					
7. Fiscal incentives					
(a) Specifically designed for R&D expenditures					
8. Direct subsidies for R&D activities					
(a) Competitive funds					
9. Innovation financing					
(a)Public loan guarantees					
(b)Public funds to commercialize innovations					
10. Government Budget (% of GDP)	*	*	*	*	*
Interaction and Diffusion					
11. Program to interaction among the actors of the innovation system					
(a) Program to foster public-private joint research		*			
(b) Program to promote personnel exchange and secondments between universities and firms		*		*	
12. Public incubators	*	*			

Source: Authors elaboration

Note: Empty cells refers to non-availability of policy instruments