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Asongu, Simplice and Biekpe, Nicholas

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Simplice A. Asongu
African Governance and Development Institute,
P.O. Box 8413, Yaoundé, Cameroon.
E-mail: asongusimplice@yahoo.com

Nicholas Biekpe
Development Finance Centre
Graduate School of Business,
University of Cape Town, Cape Town, South Africa.
E-mail: nicholas.biekpe@gsb.uct.ac.za

Research Department

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Abstract

This study investigates government quality determinants of ICT adoption using Generalised Method of Moments on a panel of 49 Sub-Saharan African (SSA) countries for the period 2000-2012. ICT is measured with mobile phone penetration, internet penetration and telephone penetration rates while all governance dimensions from the World Bank Governance Indicators are considered, namely: political governance (consisting of political stability and "voice & accountability"); economic governance (entailing government effectiveness and regulation quality) and institutional governance (encompassing the rule of law and corruption-control). The following findings are established. First, political stability and the rule of law have positive short run and negative long term effects on mobile phone penetration. Second, the rule of law has a positive (negative) short run (long term) effect on internet penetration. Third, government effectiveness and corruption-control have positive short run and long term effects on telephone penetration. Institutional governance appears to be most significant in determining ICT adoption in SSA.

JEL Classification: G20; O38; O40; O55; P37
Keywords: ICT; Governance; Africa

1. Introduction

Three main motivations underline the positioning of this study, namely: the growing role of information and communication technology (ICT) in development outcomes as well as the comparatively better potential for its penetration in Africa and (ii) the role of governance in innovation and ICT and (iii) gaps in the literature. The highlighted motivations are substantiated in chronological order.

First, compared to other regions of the world (e.g. Europe, Asia and North America), there is comparatively more room for ICT penetration in Africa (see Penard et al., 2012; Asongu, 2015a). According to the narrative, compared to Africa, high-end markets (or markets in developed countries) have reached saturation points in internet and mobile phone penetrations whereas; corresponding penetration rates in Africa are low. ICT has been documented to be associated with a plethora of development outcomes, *inter alia*: advancement of financial inclusion (Kirui et al., 2013; Singh, 2012); empowerment of the female gender (Maurer, 2008; Ojo et al., 2012); amelioration of health services for those in the low income strata (Kliner et al., 2013); reduction of the gap between urban and rural areas (Chan & Jia, 2011; Qiang et al., 2011); elimination of wastes in agriculture via reduction in demand- and supply-side constraints as well as well demand and supply mismatches (Muto & Yamano, 2009; Aker & Fafchamps, 2010); household management efficiency (Al Surikhi, 2012; Asongu, 2015b) and consolidation of business avenues (Ondiege, 2010, p. 11; Mishra & Bisht, 2013, p. 505).

The relevance of ICT in inclusive development is timely because a World Bank report on the achievement of the Millennium Development Goal (MDG) extreme poverty target revealed that extreme poverty has been decreasing in all regions of the world with the exception of Africa, where about 45% of countries in Sub-Saharan Africa (SSA) were substantially off-track from achieving the MDG extreme poverty target (World Bank, 2015; Asongu & Kodila-Tedika, 2017). This puzzling statistics is against the backdrop of a continent that has been enjoying more than two decades of growth resurgence which began the mid 1990s (Fosu, 2015a, p. 44). Furthermore, the role of governance in mobile phones for inclusive development has been recently established in SSA (Asongu & Nwachukwu, 2016a).

Second, the quality of institutions has been documented to be very crucial in driving non-exclusive growth in Africa and explaining the recent poverty tragedy of the continent (see Fosu, 2015b, 2015c; Kuada, 2015). Furthermore, good governance has been established to be associated with more non-exclusive growth, notably, in: consolidating the foundations of

societal change (Efobi, 2015) and improving standards of living via better management of economic resources (Fosu, 2013; Anyanwu & Erhijakpor, 2014; Fonchingong, 2014).

Unfortunately, despite the well established connections between ICT and inclusive development on the one hand and on the other hand, good institutions and non-exclusive development, most of the literature on the connection between ICT and governance in Africa has been focused on the influence of ICT on the quality of government[1].

To put the above point into greater perspective, the predominant African literature on causality flowing from ICT to governance include, *inter alia*: (i) Snow (2009) who has established a negative nexus between a country's mobile phone penetration rate and her perceived corruption level; (ii) Mathias (2012) who has documented the growing role of ICT on accountability in the continent; (iv) Gagliardone (2016) has engaged the role of mobile-radio interactions on the quality of government in Africa to conclude that government corrective and preventive measures are ameliorated by underlying interactions in Kenya; (v) Porter et al. (2015) have focused on Ghana, Malawi and South Africa to establish that the growing relevance of mobile usage in Africa by the youth population can be tailored to achieve greater consistency between policy and practice and (vi) Asongu and Nwachukwu (2016b) have investigated how the mobile phone in the diffusion of knowledge affects institutional quality in SSA.

Noticeably, the above literature leaves room for improvement in two main areas: investigation of the role of governance in ICT penetration on the one hand and on the other hand, time-dynamic effects of such linkages. The interest of investigating both short-term and long-run effects is to increase room for policy implication. Overall, the policy relevance of the inquiry builds on the need to understand how governance dynamics affect the rate of ICT penetration. To this end, we aim to assess how political governance (political stability and "voice & accountability"), economic governance (government effectiveness and regulation quality) and institutional governance (the rule of law and corruption-control) affect ICT adoption. Three ICT (mobile phone, internet and telephone penetration) variables are considered because Penard et al. (2012) have recently concluded that some types of ICT (e.g. internet penetration versus mobile phone penetration) are significantly more adopted than others in the continent. In the light of above narratives, this paper seeks to answer the following question: how does governance affect ICT adoption in the short run and long term?

[1] Much has been documented on the nexus between ICT and governance (Suarez, 2006; Kiessling, 2007; Billon et al., 2009; Boulianne, 2009; Diamond, 2010; Grossman et al., 2014; Andrés et al., 2017), especially on the relevance of ICT in boosting collective action (Breuer et al., 2012; Pierskalla & Hollenbach, 2013; Weidmann & Shapiro, 2015; Manacorda & Tesei, 2016).

The rest of the study is structured as follows. Section 2 clarifies the concepts of governance and engages the relevant literature. The data and methodology are covered in Section 3 while Section 4 presents the results. Section 5 covers concluding implications with future research directions.

2. Clarification of governance concepts and theoretical highlights

We engage this section in four main categories, namely: (i) clarification of concepts of governance, (ii) conflicting positions in the appreciation of governance, (iii) empirical relevance of adopted governance concepts and (iv) conception of ICT-governance. In the first category, according to Asongu (2016), a plethora of definitions have been provided to elicit the concept of governance in recent literature.

In the first category, for the purpose of brevity, four main definitions of governance are discussed. (1) In accordance with Dixit (2009), economic governance is the "*…structure and functioning of the legal and social institutions that support economic activity and economic transactions by protecting property rights, enforcing contracts, and taking collective action to provide physical and organizational infrastructure*"[2] (p.5). (2) Governance in the perspective of Tusalem (2015) is a phenomenon that entails: corruption, the rule of law, bureaucratic effectiveness and regulatory quality. (3) With respect to Fukuyama (2013), the term governance can be consolidated through the adoption of four principal avenues that are essential to the understanding of "state quality", namely: political indicators, output measures and capacity variables which are made-up of professionalism and resources. (4) To the best of our knowledge, the most widely employed governance indicators are those of Kaufmann et al. (2010), which Andrés et al. (2015) have classified into three principal frameworks: (i) "political governance" which is understood as the election and replacement of political leaders (proxied with "voice & accountability" and political stability/no-violence); (ii) economic governance (measured with government effectiveness and regulation quality) is the formulation and implementation of policies that deliver public commodities and (iii) institutional governance (proxied with corruption-control and the rule of law) which is the respect by the State and citizens of institutions that govern interactions between them.

The second category of the discourse relates to concerns that have arisen in scholarly circles on the quality of governance indicators from Kaufmann, Kraay and Mastruzzi. One of the most interesting debates has been with Andrew Schrank and Marcus Kurtz. The debates

[2] Emphasis on original.

can be summarised into four main narratives, namely: models, measures and mechanisms; a reply; a defense and a rejoinder. (1) In "models, measures and mechanisms", Kurtz and Schrank (2007a) have questioned the wide popularity enjoyed by the indictors from Kaufmann, Kraay and Mastruzzi. Their argument fundamentally questions the positive causality flowing from governance to economic development. In essence, they have disputed that the confidence enjoyed by the underlying indicators is exaggerated because the indicators are potentially problematic given that they are characteristic of a plethora of concerns such as: sample adverse selection, conceptual conflation and perceptual biases.

(2) In response to the criticisms, counter arguments have been presented by Kaufmann et al. (2007a). They provide three arguments to dispel the criticisms. (i) They first demonstrate that the claims levelled at them on governance "perception-based measurement biases" are falsifiable, speculative and fail to withstand empirical consensus. (ii) The authors also provide empirical support to substantiate their rebuttals by further arguing that the short term relationship between growth and governance claim by their scholarly opponents is flawed from a conceptual perspective. (iii) Lastly, they dismiss some empirical studies used by the contending authors to substantiate the opposing perspective on the nature of the relationship between governance and growth.

(3) In defense of their previous standpoint, Kurtz and Schrank (2007b) respond to Kaufmann et al. (2007a) by articulating that their previous stance with concerns of opaqueness in the conception and measurement fundamentally builds on the conflicting scholarly literature surrounding directions of causality between governance and growth.

(4) In a rejoinder, Kaufmann et al. (2007b) reiterate that the criticisms from the contending authors are baseless and lack substance partly because the concerns of "potential respondent bias" raised by their scholarly opponents are not exclusively restricted to government effectiveness, but are also apparent in other variables.

In the third category, indicators from Kaufmann et al. (2007a, 2007b, 2010) are adopted in this inquiry because as far as we have reviewed, they are the most predominantly employed in the literature. Consistent with the motivation of the study, in order to provide more room for policy implications, all six governance indicators are employed. The interest of employing all governance indicators is in accordance with an evolving stream of African governance literature: the role of governance in knowledge economy (Andrés et al., 2015); revolution empirics in the prediction of the recent Arab Spring (Asongu & Nwachukwu, 2016c); governance channels in the battle against conflicts/crimes (Asongu & Kodila-Tedika, 2016) and software piracy (Andrés & Asongu, 2013) and; the most effective governance

determinants of innovation (Oluwatobi et al., 2015). Studies in the literature that are closest to the presenting study are Asongu (2016); Andrés et al. (2015), Andrés and Asongu (2013) and Asongu and Kodila-Tedika (2016). These studies have used six governance indicators to assess how governance affects: conflicts and crimes (Asongu & Kodila-Tedika, 2016); economic growth (Asongu, 2016); knowledge economy (Andrés et al., 2015) and software piracy (Andrés & Asongu, 2013).

It is important to clarify the concept of ICT-governance in the fourth category. According to Hellstrom (2008), the relationship can be defined as the use of ICT to ameliorate the benefits of governance. We argue that such a relationship is not a one-way traffic because governance standards also determine ICT adoption. For instance electronic (e)-governance is very likely to affect ICT penetration. In essence, once governance initiatives favouring e-governance are in place, it is very likely that all parties in e-governance (citizens, government units and businesses) contribute in one way or another towards enhancing ICT penetration.

In the light of the above underpinnings, governance can be employed to improve transparency. In essence, openness and policies designed to improve the free circulation of information is determined to a large extent by governance. For instance some policies by a government to facilitate ICT adoption may include: (i) the free circulation of information between the government agencies and citizens and (ii) direct citizenry participation in government. In summary, governance can influence how ICT brings societies together with more connection, participation, information and innovation.

The positioning of the study steers clear of recent literature which has fundamentally focused on the relevance of ICT in influencing governance. While a strand maintains that information decentralisation through ICT mitigates opportunities for governance (Suarez, 2006; Boulianne, 2009; Diamond, 2010; Grossman et al., 2014), another strand posits that ICT may offer opportunities for poor governance because it facilitates violent collective action (Breuer et al., 2012; Pierskalla & Hollenbach, 2013; Weidmann & Shapiro, 2015; Manacorda & Tesei, 2016) and reduces the quality of governance (Morozov, 2011). From an African specific perspective, the four main studies on the effect of ICT on governance have been discussed in the introduction. This study steers clear of the engaged literature by assessing how government quality affects ICT adoption.

3. Data and methodology

3.1 Data

This paper assesses a panel of forty-nine countries in Sub-Saharan African with data from World Governance Indicators and African Development Indicators of the World Bank for the period 2000-2012. In accordance with the recent African knowledge economy literature (Tchamyou, 2016), three ICT-related dependent variables are used, namely: mobile phone penetration (per 100 people), internet penetration (per 100 people) and telephone penetration (per 100 people).

Consistent with the narrative in Section 2, six good governance indicators from Kaufmann et al. (2010) are employed. These are indicators of: (i) political governance (political stability/non violence and "voice & accountability"); (ii) economic governance (government effectiveness and regulation quality) and (iii) institutional governance (corruption-control and the rule of law).

Five control variables are used to account for variable omission bias, namely: the lagged ICT indicator, economic growth, trade openness, population growth and primary school enrolment. The lagged ICT indicator is used to control for persistence in ICT. The other four indicators are intuitively expected to boost ICT penetration. First, economic prosperity in terms of economic growth is logically expected to be positively linked to ICT penetration because some of the income distributed (accruing from economic growth) at the microeconomic level increases the ICT purchasing power of household and corporate users. Second, trade openness involves more exchanges in goods and services which is partially enhanced by ICT availability. Hence, ICT can both be a cause and a consequence of more exchange in commodities. Third, it is very likely that ICT adoption increases with a growing population because the potential for penetration increases concurrently. This is essentially because ICT penetration is defined and measured as a proportion of people. Fourth, primary school enrolment should be positively linked to ICT for two main reasons: (i) a minimum level of literacy is required to use the ICT proxies employed in this study and (ii) compared to other academic levels, higher development externalities are expected from primary schooling when economies are still at the early stages of industrialisation (see Petrakis & Stamatakis, 2002; Asiedu, 2014).

After a preliminary assessment, control for more than five indicators leads to post-estimation instrument proliferation which negatively affects the validity of estimation models. The full definitions of variables are provided in Appendix 1, while Appendix 2 discloses the summary statistics. The correlation matrix is presented in Appendix 3.

3.2 Methodology

3.2.1 Specification

This paper employs the Generalised Method of Moments (GMM) with forward orthogonal deviations (Roodman, 2009a, 2009b). Five main reasons motivate the choice of the estimation technique. Whereas the first-two are basic requirements for the approach, the last-three are advantages related to the empirical strategy. First, the N(49)>T(13) condition for the application of the technique is met because the number of cross sections is higher than the corresponding number of time series in each cross section. Second, the requirement of persistence in the dependent variable is also met because the correlation between the ICT variables and their corresponding first lag is higher than the rule of thumb threshold of 0.800. In essence, the underlying correlations for mobile phone penetration, internet penetration and telephone penetration are respectively, 0.987, 0.987 and 0.996. Third, cross-country differences are not eliminated in the estimation strategy. Fourth, the strategy accounts for potential endogeneity in all regressors by using: (i) instrumented regressors to control for simultaneity and (ii) time invariant omitted variables to control for the unobserved hetereogeneity. Fifth, small sample biases in the *difference* estimator are mitigated with the *system* estimator. It is for this last motive that there is a strong consensus in the literature (see Bond et al., 2001; Asongu, 2013b) that the *system* GMM estimator (from Arellano & Bover, 1995; Blundell & Bond, 2001) should be adopted in place of the *difference* estimator (Arellano & Bond, 1991).

Within the framework of this study, a Roodman (2009, 2009b) extension of Arellano and Bover (1995) is adopted because it has been documented to limit the proliferation of instruments and restrict over-identification (see Baltagi et al., 2008; Love & Zicchino, 2006; Asongu & Nwachukwu, 2016b). In the specification, a *two-step* approach is adopted in preference of the *one-step* procedure because the former (latter) is consistent with heteroscedasticity (homoscedasticity).

The following equations in level (1) and first difference (2) summarize the standard *system* GMM estimation procedure:

$$ICT_{i,t} = \sigma_0 + \sigma_1 ICT_{i,t-\tau} + \sigma_2 G_{i,t} + \sum_{h=1}^{4} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$ICT_{i,t} - ICT_{i,t-\tau} = \sigma_1 (ICT_{i,t-\tau} - ICT_{i,t-2\tau}) + \sigma_2 (G_{i,t} - G_{i,t-\tau}) + \\ + \sum_{h=1}^{4} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + \varepsilon_{i,t-\tau} \quad , \quad (2)$$

where, $ICT_{i,t}$ is information and communication technology (mobile phone, internet and telephone penetrations) for country i at period t; σ_0 is a constant; G, governance (political, economic and institutional) and W is the vector of control variables (*GDP growth, trade openness, population growth* and *primary school enrolment*); τ represents the coefficient of serial correlation, ξ_t is the time-specific constant, η_i is the country-specific effect and $\varepsilon_{i,t}$ the error term.

3.2.2 Identification, simultaneity and exclusion restrictions

It is important to engage identification and exclusion restrictions because they are vital for the tight specification of GMM models. In accordance with recent literature (see Asongu & De Moor, 2017; Dewan & Ramaprasad, 2014), all independent variables are considered as suspected endogenous or pre-determined variables and the *gmmstyle* is employed for them. Conversely only "years" (or time-invariant omitted variables) are treated as strictly exogenous and the procedure for treating the *ivstyle* (years) is "iv(years, eq(diff))" because it is not likely for the years to become endogenous in first-difference (see Roodman, 2009b).

The issue of simultaneity is tackled using the lagged regressors as instrumental variables for forward-differenced indicators. Accordingly, in order to purge fixed effects that could eventually affect the investigated linkages, Helmet transformations are used in accordance with Love and Zicchino (2006) and Arellano and Bover (1995). These transformations encompass forward mean variations of the indicator. In other words, the mean values of all potential observations are deducted from the indicators, as opposed to subtracting the previous observation for the present ones. Such transformations enable orthogonal or parallel conditions between lagged observations and forward differenced values. Regardless of the number of lags, the suggested transformations are computed for all observations, with the exception of the last for each cross section. The purpose of engaging all observations is to limit data loss. "*And because lagged observations do not enter the formula, they are valid as instruments*" (see Roodman, 2009b, p. 104; Asongu & De Moor, 2017).

Concerning the exclusion restriction, we argue that the strictly exogenous instruments affect the outcome variable exclusively via the endogenous explaining variables. Moreover, the statistical relevance of the exclusion restriction is assessed with the Difference in Hansen Test (DHT) for the exogeneity of instruments. In essence, the null hypothesis of the test should not be rejected for the strictly exogenous instruments to elucidate the ICT dependent variables exclusively through the suspected endogenous or predetermined variables.

Moreover, while in the standard GMM procedure, the validity of the instruments is confirmed when the null hypothesis of the Sargan Overidentifying restriction test is not rejected (see Asongu & Nwachukwu, 2016d), in the GMM with forward orthogonal deviations, the DHT is employed to investigate if the time-invariant omitted variables (adopted as strictly exogenous) affect the outcome variable exclusively via the proposed channels. Hence in the findings that are reported in the section below, the validity of instruments is confirmed if the alternative hypotheses of the DHT corresponding to IV (year, eq(diff)) is not accepted.

4. Empirical results

Table 1, Table 2 and Table 3 respectively, present findings corresponding to regressions on mobile phone penetration, internet penetration and telephone penetration. Four principal information criteria are employed to examine the validity of the GMM model with forward orthogonal deviations (see Asongu & De Moor, 2017, p. 200). First, the null hypothesis corresponding to the second-order Arellano and Bond autocorrelation test (AR (2)) in difference should not be rejected. This is essentially because it is the position for an absence of autocorrelation in the residuals. In addition, we exclusively report the second-order Arellano and Bond autocorrelation test (AR(2)) because when compared with the corresponding first-order test, it is more relevant in ascertaining the absence of autocorrelation. Accordingly, some studies exclusively report the higher-order test with no disclosure of the first-order test (Narayan et al., 2011; Asongu & Nwachukwu, 2016c).

Second, the Sargan and Hansen over-identification restrictions (OIR) tests should not be rejected because their null hypotheses argue for the position that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict the proliferation of instruments or limit identification, in specifications, the number of cross-sections should be higher than the corresponding number of instruments. A means of addressing the underlying conflict is to adopt the Hansen test and avoid the proliferation of instruments as much as possible. Such instrument proliferation is avoided in this study by ensuring that the number of instruments in each specification is lower than the corresponding number of cross sections.

Third, the Difference in Hansen Test (DHT) for the exogeneity of instruments is also employed to investigate exclusive restrictions emphasised in the identification strategy and

hence the validity of results from the Hansen OIR test. Fourth, a Fisher test for the joint validity of estimated coefficients is also provided.

Where estimated coefficients corresponding to the governance indicators are significant, the long-term effects are computed. For example in the second column of Table 1, the short term effect of political stability is 2.600 whereas the corresponding long run impact is -37.142 (2.600/ [1-1.070]), where 1.070 corresponds to the estimated lagged value of mobile phone penetration.

The following findings can be established. In Table 1 on the relationship between governance and mobile phone penetration, political stability and the rule of law have positive short-term and negative long run effects on mobile phone penetration. The effects from corruption-control, government effectiveness, voice & accountability and regulation quality are not significant. In Table 2 on the linkages between governance and internet penetration, only the rule of law has a significant effect on internet penetration. Its short term effect is positive while its corresponding long term influence is negative. The impacts from corruption-control, government effectiveness, voice & accountability and regulation quality and political stability are not significant. Table 3 provides findings on the connection between governance and telephone penetration. We notice that the short term effects of government effectiveness and corruption-control on telephone penetration are positive while the corresponding long run impacts are also positive. The effects from political stability, voice & accountability, regulation quality and the rule of law are not significant. Most of the significant control variables have the expected signs.

Table 1: Mobile Phone Penetration and Governance

	Dependent Variable: Mobile Phone Penetration					
	Political Governance		**Economic Governance**		**Institutional Governance**	
	Political Stability /Non Violence	Voice & Accountability	Regulation Quality	Government Effectiveness	Rule of Law	Corruption Control
Constant	-2.493	-2.539	-4.041	-5.509	-1.446	**-6.470***
	(0.514)	(0.568)	(0.215)	(0.275)	(0.733)	**(0.072)**
Mobile Phone (-1)	**1.070*****	**1.083*****	**1.069*****	**1.096*****	**1.097*****	**1.082*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Political Stability	**2.600****	---	---	---	---	---
	(0.013)					
Voice & Accountability	---	1.056	---	---	---	---
		(0.407)				
Regulation Quality	---	---	1.705	---	---	---
			(0.159)			
Government Effectiveness	---	---	---	0.476	---	---
				(0.790)		
Rule of Law	---	---	---	---	**2.935***	---
					(0.070)	
Corruption Control	---	---	---	---	---	0.259
						(0.851)
Economic Growth	0.010	-0.014	-0.004	0.012	0.011	-0.004
	(0.731)	(0.701)	(0.908)	(0.748)	(0.776)	(0.900)
Trade Openness	-0.010	0.0007	0.0007	0.001	-0.010	0.003
	(0.458)	(0.961)	(0.960)	(0.898)	(0.449)	(0.791)
Population Growth	**1.665*****	**0.999***	0.926	**1.099****	**1.380****	**1.058****
	(0.005)	**(0.078)**	(0.113)	**(0.034)**	**(0.015)**	**(0.031)**
Primary School Enrolment	**0.045***	0.041	0.036	0.055	0.037	**0.069****
	(0.079)	(0.229)	(0.272)	(0.166)	(0.289)	**(0.037)**
Long Term Effects	-37.142	na	na	na	-30.257	na
AR(1)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.004)
AR(2)	**(0.927)**	**(0.891)**	**(0.896)**	**(0.816)**	**(0.804)**	**(0.910)**
Sargan OIR	(0.005)	(0.000)	(0.003)	(0.000)	(0.000)	(0.001)
Hansen OIR	**(0.289)**	**(0.298)**	**(0.210)**	**(0.306)**	**(0.169)**	**(0.405)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**(0.411)**	**(0.105)**	**(0.078)**	**(0.159)**	**(0.041)**	**(0.142)**
Dif(null, H=exogenous)	**(0.258)**	**(0.591)**	**(0.501)**	**(0.499)**	**(0.563)**	**(0.675)**
(b) IV (years, eq (diff))						
H excluding group	**(0.270)**	**(0.284)**	**(0.786)**	**(0.564)**	**(0.718)**	**(0.489)**
Dif(null, H=exogenous)	**(0.363)**	**(0.361)**	(0.061)	**(0.186)**	(0.053)	**(0.330)**
Fisher	**2816.90*****	**2476.85*****	**4390.54*****	**2718.05*****	**2102.23*****	**3111.34*****
Instruments	32	32	32	32	32	32
Countries	45	45	45	45	45	45
Observations	376	376	376	376	376	376

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. na: not applicable because at least one estimate required for the computation of long run effects is not significant.

Table 2: Internet Penetration and Governance

	Dependent Variable: Internet Penetration					
	Political Governance		**Economic Governance**		**Institutional Governance**	
	Political Stability /Non Violence	Voice & Accountability	Regulation Quality	Government Effectiveness	Rule of Law	Corruption Control
Constant	**2.193*** **	**1.908** **	1.021	-0.090	**2.674** **	1.027
	(0.005)	**(0.014)**	(0.204)	(0.932)	**(0.013)**	(0.129)
Internet Penetration (-1)	1.120	**1.1.30*** **	**1.136*** **	**1.140*** **	**1.097*** **	**1.121*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Political Stability	0.213	---	---	---	---	---
	(0.442)					
Voice & Accountability	---	0.041	---	---	---	---
		(0.856)				
Regulation Quality	---	---	-0.560	---	---	---
			(0.167)			
Government Effectiveness	---	---	---	-0.338	---	---
				(0.195)		
Rule of Law	---	---	---	---	**1.166** **	---
					(0.010)	
Corruption Control	---	---	---	---	---	0.322
						(0.241)
Economic Growth	**-0.017** **	**-0.017** **	-0.004	-0.012	**-0.019*** **	**-0.015** **
	(0.027)	**(0.028)**	(0.538)	(0.103)	**(0.002)**	**(0.025)**
Trade Openness	-0.003	-0.0005	0.0002	0.0003	0.001	0.0007
	(0.342)	(0.851)	(0.921)	(0.899)	(0.725)	(0.759)
Population Growth	**-0.284** **	**-0.348*** **	**-0.489*** **	**-0.251** **	-0.190	**-0.240** **
	(0.013)	**(0.000)**	**(0.000)**	**(0.016)**	(0.102)	**(0.010)**
Primary School Enrolment	**-0.010***	-0.008	-0.002	0.003	-0.009	-0.002
	(0.065)	(0.151)	(0.684)	(0.624)	(0.167)	(0.618)
Long Term Effects	na	na	na	na	-12.020	na
AR(1)	(0.028)	(0.028)	(0.027)	(0.027)	(0.024)	(0.028)
AR(2)	**(0.910)**	**(0.881)**	**(0.857)**	**(0.909)**	**(0.812)**	**(0.917)**
Sargan OIR	(0.012)	(0.002)	(0.001)	(0.005)	(0.009)	(0.006)
Hansen OIR	(0.098)	**(0.127)**	**(0.245)**	**(0.265)**	**(0.105)**	**(0.285)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**(0.822)**	**(0.878)**	**(0.619)**	**(0.670)**	**(0.736)**	**(0.897)**
Dif(null, H=exogenous)	(0.029)	(0.036)	**(0.143)**	**(0.146)**	(0.038)	**(0.106)**
(b) IV (years, eq (diff))						
H excluding group	**(0.593)**	**(0.490)**	**(0.457)**	**(0.409)**	**(0.527)**	**(0.307)**
Dif(null, H=exogenous)	(0.034)	(0.065)	**(0.175)**	**(0.221)**	(0.045)	**(0.319)**
Fisher	**5166.21*** **	**10144.44*** **	**10549.72*** **	**8257.88*** **	**3339.02*** **	**11656.65*** **
Instruments	32	32	32	32	32	32
Countries	44	44	44	44	44	44
Observations	369	369	369	369	369	369

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. na: not applicable because at least one estimate required for the computation of long run effects is not significant.

Table 3: Telephone Penetration and Governance

	Dependent Variable: Telephone Penetration					
	Political Governance		**Economic Governance**		**Institutional Governance**	
	Political Stability /Non Violence	Voice & Accountability	Regulation Quality	Government Effectiveness	Rule of Law	Corruption Control
Constant	**1.614****	**1.937*****	**2.244*****	**2.295*****	**2.021****	**1.888****
	(0.031)	**(0.003)**	**(0.003)**	**(0.007)**	**(0.011)**	**(0.022)**
Telephone Penetration (-1)	**0.964*****	**0.948*****	**0.954*****	**0.906*****	**0.936*****	**0.880*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Political Stability	0.067	---	---	---	---	---
	(0.657)					
Voice & Accountability	---	0.209	---	---	---	---
		(0.144)				
Regulation Quality	---	---	0.326	---	---	---
			(0.130)			
Government Effectiveness	---	---	---	**0.670****	---	---
				(0.015)		
Rule of Law	---	---	---	---	0.281	---
					(0.224)	
Corruption Control	---	---	---	---	---	**0.483****
						(0.043)
Economic Growth	**0.010****	**0.007***	**0.009***	0.007	**0.008***	**0.010****
	(0.038)	**(0.077)**	**(0.050)**	(0.158)	**(0.071)**	**(0.034)**
Trade Openness	0.00002	0.002	0.001	**0.004***	0.001	**0.004***
	(0.989)	(0.235)	(0.338)	**(0.057)**	(0.409)	**(0.060)**
Population Growth	**-0.400*****	**-0.401*****	**-0.368*****	**-0.378*****	**-0.351*****	**-0.448*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Primary School Enrolment	-0.004	-0.007	**-0.010****	**-0.011***	-0.008	-0.005
	(0.465)	(0.112)	**(0.031)**	**(0.077)**	(0.125)	(0.432)
Long Term Effects	na	na	na	7.127	na	4.025
AR(1)	**(0.287)**	**(0.288)**	**(0.287)**	**(0.286)**	**(0.290)**	**(0.290)**
AR(2)	**(0.337)**	**(0.336)**	**(0.333)**	**(0.331)**	**(0.338)**	**(0.337)**
Sargan OIR	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	**(0.719)**	**(0.482)**	**(0.485)**	**(0.789)**	**(0.451)**	**(0.801)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**(0.701)**	**(0.773)**	**(0.717)**	**(0.869)**	**(0.700)**	**(0.807)**
Dif(null, H=exogenous)	**(0.589)**	**(0.289)**	**(0.316)**	**(0.579)**	**(0.292)**	**(0.626)**
(b) IV (years, eq (diff))						
H excluding group	**(0.876)**	**(0.679)**	**(0.577)**	**(0.611)**	**(0.552)**	**(0.574)**
Dif(null, H=exogenous)	**(0.414)**	**(0.293)**	**(0.361)**	**(0.749)**	**(0.340)**	**(0.796)**
Fisher	**866.79*****	**962.13*****	**709.33*****	**301.46*****	**876.61*****	**958.67*****
Instruments	32	32	32	32	32	32
Countries	44	44	44	44	44	44
Observations	371	371	371	371	371	371

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests.

5. Concluding implications and further research directions

This study has investigated government quality determinants of ICT adoption using Generalised Method of Moments in a sample of 49 Sub Saharan African countries for the period 2000-2012. ICT is measured with mobile phone penetration, internet penetration and telephone penetration rates while all governance dimensions from the World Bank Governance Indicators are considered, namely: political governance (consisting of political stability and "voice & accountability"); economic governance (entailing government

effectiveness and regulation quality) and institutional governance (encompassing the rule of law and corruption-control). The following findings have been established. First, political stability and the rule of law have positive short run and negative long term effects on mobile phone penetration. Second, the rule of law has a positive (negative) short run (long term) effect on internet penetration.

Third, government effectiveness and corruption-control have positive short run and long term effects on telephone penetration. The positive effect of government effectiveness is broadly consistent with Oluwatobi et al. (2015) who have concluded that economic governance is the most significant driver of innovation in Africa. The relevance of corruption-control also in a broad sense, accords with recent African institutional literature which has concluded that corruption-control is the best governance tool in the fight against software piracy (Andrés & Asongu, 2013) and conflicts/crimes (Asongu & Kodila-Tedika, 2016).

The relevant policy concern that arises from the findings is how the rule of law can be leveraged to stimulate both mobile phone and internet penetrations in the long term. It is important to note that, like the rule of law, corruption-control (that positively affects telephone penetration both the short and long terms) is also an aspect of institutional quality. It follows that, of the engaged governance dynamics, institutional governance appears to be the most significant in determining ICT adoption in Sub-Saharan Africa (SSA). In other words, the respect by the State and citizens of institutions that govern interactions between them is critical to boosting ICT adoption in the sub-region. This would potentially contribute to significantly addressing SSA's extreme poverty tragedy.

The main contribution of the study to the extant literature is that it has steered clear of the ICT-governance literature which has fundamentally focused on the effect of ICT on governance. We have investigated the opposite relationship. Moreover, we have not been limited to country-specific cases on the one hand and a few governance and ICT variables on the other hand (Snow, 2009; Mathias, 2012; Porter et al., 2015; Gagliardone, 2016). Accordingly, we have used three ICT variables and all six government quality variables from World Governance Indicators of the World Bank.

Future studies can improve the existing literature by investigating the long and short effects of ICT on inclusive human development in SSA. This recommendation is relevant to policy in the light of the post-2015 sustainable development agenda because growth in SSA has not been inclusive. In essence, despite the sub-region enjoying more than two decades of growth resurgence, it has been experiencing increasing extreme poverty.

Appendices

Appendix 1: Definitions and sources of variables

Variables	Signs	Definitions	Sources
Mobile Phone	Mobile	Mobile phone subscriptions (per 100 people)	WDI
Internet	Internet	Internet subscriptions (per 100 people)	WDI
Telephone	Telephone	Telephone subscriptions (per 100 people)	WDI
Political Stability	PolS	"Political stability/no violence (estimate): measured as the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional and violent means, including domestic violence and terrorism".	WGI
Voice & Accountability	VA	"Voice and accountability (estimate): measures the extent to which a country's citizens are able to participate in selecting their government and to enjoy freedom of expression, freedom of association and a free media"	WGI
Government Effectiveness	GE	"Government effectiveness (estimate): measures the quality of public services, the quality and degree of independence from political pressures of the civil service, the quality of policy formulation and implementation, and the credibility of governments' commitments to such policies".	WGI
Regulation Quality	RQ	"Regulation quality (estimate): measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development".	WGI
Corruption-Control	CC	"Control of corruption (estimate): captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests"	WGI
Rule of Law	RL	"Rule of law (estimate): captures perceptions of the extent to which agents have confidence in and abide by the rules of society and in particular the quality of contract enforcement, property rights, the police, the courts, as well as the likelihood of crime and violence"	WGI
GDP growth	GDPg	GDP growth rate	WDI
Trade Openness	Trade	Import plus Exports of Goods and Services (% of GDP)	WDI
Population growth	Population	Total Population Growth (annual %)	WDI
Education	PSE	Primary School Enrolment (% of Gross)	WDI

WGI: World Governance Indicators. WDI: World Development Indicators. GDP: Gross Domestic Product.

Appendix 2: Summary statistics

	Mean	SD	Min	Max	Obs
Mobile Phone Penetration	23.379	28.004	0.000	147.202	572
Internet Penetration	4.152	6.450	0.005	43.605	566
Telephone Penetration	3.039	5.810	0.005	32.455	565
Political Stability	-0.543	0.956	-3.323	1.192	578
Voice & Accountability	-0.646	0.737	-2.233	0.990	578
Government Effectiveness	-0.771	0.620	-2.450	0.934	577
Regulation Quality	-0.715	0.644	-2.665	0.983	578
Corruption-Control	-0.642	0.591	-1.924	1.249	579
Rule of Law	-0.741	0.662	-2.668	1.056	578
GDP growth	4.714	6.322	-47.552	63.379	608
Trade Openness	78.177	36.138	20.964	209.874	597
Population Growth	2.361	0.948	-1.081	6.576	588
Education	97.446	25.895	32.199	181.700	470

SD: Standard deviation. Min: Minimum. Max: Maximum. Obs: Observations. Adj: Adjusted.

Appendix 3: Correlation Matrix (Uniform sample size: 407)

Governance Variables						Control Variables				Dependent Variables			
PolS	VA	GE	RQ	CC	RL	GDPg	Trade	Popg	PSE	Mobile	Internet	Telephone	
1.000	0.636	0.605	0.538	0.614	0.767	-0.084	0.253	-0.271	0.255	0.298	0.312	0.470	PolS
	1.000	0.740	0.727	0.612	0.787	0.018	0.014	-0.250	0.248	0.274	0.325	0.459	VA
		1.000	0.845	0.979	0.874	0.030	0.021	-0.335	0.212	0.293	0.320	0.504	GE
			1.000	0.649	0.772	-0.025	-0.002	-0.247	0.217	0.264	0.176	0.286	RQ
				1.000	0.817	-0.090	-0.014	-0.309	0.118	0.273	0.342	0.565	CC
					1.000	-0.044	0.109	-0.286	0.219	0.274	0.332	0.530	RL
						1.000	0.029	0.157	0.083	-0.043	-0.002	-0.052	GDPg
							1.000	-0.380	0.167	0.259	0.158	0.228	Trade
								1.000	-0.172	-0.331	-0.414-	-0.581	Popg
									1.000	0.288	0.224	0.181	PSE
										1.000	0.690	0.479	Mobile
											1.000	0.695	Internet
												1.000	Telephone

PolS: Political Stability. VA: Voice & Accountability. GE: Government Effectiveness. RQ: Regulation Quality. CC: Corruption-Control. RL: Rule of Law. GDPg : GDP per capita growth rate. Popg: Population growth. PSE: Primary School Enrolment. Mobile: Mobile Phone Penetration. Internet: Internet Penetration. Telephone: Telephone Penetration.

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