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Africa's digital divide: Geography, policy, and implications

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Africa's Digital Divide: Geography, Policy, and Implications

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Abstract

This exploratory empirical study examines the extent of differences in information and communication technology (ICT) utilization among the various countries of Africa. This paper also enhances understanding of factors that impact ICT utilization and the digital divide in African countries. In contrast to previous empirical studies, we include more advanced forms of ICT such as broadband and social media technologies. In our conceptual model of ICT utilization, known as Spatially Aware Technology Utilization Model (SATUM), five dependent variables are posited to be associated with eighteen demographic, socio-economic, education, technology tariff, societal openness, infrastructure, and ICT services competitiveness variables. ICT utilization dependent variables are spatially analyzed to determine patterns of agglomeration or randomness, and regression residuals are tested for the presence of spatial bias. We determine that laws that relate to the use of ICTs is a dominant predictor of all forms of ICT utilization, a novel finding. The effectiveness of a national parliament/congress as a lawmaking institution is significantly associated with modern (broadband) as well as legacy forms (fixed telephones) of ICT. This is consistent with prior literature which emphasizes the role of national governments in Africa in framing ICT sector policies for investment, privatization, deregulation, and providing access in underserved areas. For a smaller sample of nations that excludes high utilization ICT nations of Africa, ICT laws have a somewhat reduced effect for two forms of ICT. However gross national income per capita is determined to a dominant predictor for three ICTs and mobile tariffs is negatively associated with mobile cellular subscribers. The findings are intuitive and mostly well supported by previous literature. Policy implications for African nations are provided.

1. Introduction

In this paper, we study the digital divide between information "haves" and "have-nots" in Africa. Specifically, we induce a theoretical model of information and communication technology (ICT) adoption and utilization for Africa, examine the extent of differences in ICT utilization among the countries of Africa, and examine various factors that impact ICT adoption and usage in the African nations. The Organization for Economic Cooperation and Development

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has defined the term digital divide as “gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access ICTs and to their use of the Internet for a wide variety of activities” (OECD, 2013). According to the United Nations (2013), Africa is the second largest continent behind Asia in terms of population (estimated to be 1.16 billion in 2015). However, a large majority of nations in the African continent, especially ones in sub-Saharan Africa are classified as low income or lower middle income nations (The World Bank, 2012). Exceptions are the northern African nations of Algeria and Libya, as well as South Africa and its neighbors Botswana and Namibia, which are classified as upper middle income nations. African countries also fare poorly in terms of social, health, and economic indicators such as life expectancy, undernourishment, participation in education, unemployment, and poverty. Most African nations are also ranked at the bottom end of the United Nations human development index (HDI), which is a composite measure that averages achievement in three basic dimensions of human development—a long and healthy life, knowledge and a decent standard of living. This is especially true for a vast majority of nations in sub-Saharan Africa.

ICT adoption and utilization in many African countries has lagged behind those of their more industrialized counterparts in other continents such as North America, Europe, and Asia. At the turn of the century, Africans had the use of one fixed landline telephone per 100 people (one per 200 people excluding South Africa) against the worldwide average of 50 telephones per 100 (Cooper, 2002). This considerable lack of availability of what many might argue to be a legacy form of ICT must be viewed as part of an overall infrastructural malaise comprised of deteriorating roads, unreliable electricity, and arbitrary regulatory and judicial systems (Cooper, 2002). In 2005, Africa with an estimated 14 percent of the world’s total population accounted for less than 2 percent of the world’s internet usage. However this has improved noticeably, and in 2014, Africa with an estimated 15.3 percent of the world population accounted for 10.3 percent of the world’s internet users. Africa’s internet penetration rate is 27.5 percent (of total population) in 2014 (Internet World Stats, 2015), lagging behind the worldwide rate of 42.4 percent and far behind the rates of North America (86.9%), Europe (70.2%), and Latin America/Caribbean (52.4%). Only six African nations, namely Morocco, Seychelles, Tunisia, Egypt, Reunion, and Mauritius,report internet penetration rates that exceed the worldwide rate. Perhaps unsurprisingly, internet usage in Africa is estimated to have grown by 3,606.7% during 2000 – 2012, compared to moderate rates of growth in all other continents or regional agglomerations such as the Middle East. Another factor is the high cost barrier for internet access. Average dial-up internet access for 20 hours a month cost $68 in addition to internet subscription fees (Gebremichael and Jackson, 2006). Warf (2013) indicates that while cybercafés are commonly found in commercial districts in African cities, they are mostly frequented by young tourists, students, and business executives. Since most cafes derive their profits from non-Africans, their fees are too high to make them accessible to the low income citizenry residing in the outskirts of the urban areas.

Onyeiwu (2002) observed that the digital divide literature has often tended to focus on the differences between Africa and the industrialized world, possibly at the cost of paying inadequate attention to the widely varying levels of digitization and ICT availability and utilization among the African nations. While countries such as South Africa, Namibia, Morocco, Tunisia, Botswana, Cape Verde, and Seychelles have made significant progress in ICT adoption and access, many other nations have lagged far behind, several of which are in sub-Saharan Africa. Onyeiwu (2002) has further commented that the digital divide in Africa is made even more interesting since countries with similar socio-economic foundations have tended to diverge in access to ICT. For example, Angola and Cameroon, both classified as low human development nations ranked 148 and 150 respectively in terms of the UN's human development index (The United Nations, 2013) and with comparable 2012 estimated populations of about 20 million, possess considerably different internet penetration rates of 14.8% and 5% respectively (Internet World Stats, 2013).

Given this context, our work has several novel features. (1) We focus on ICT availability and utilization and the resulting digital divide for the entire African continent at the country unit of analysis. Several studies have focused on sub-regions of Africa, most notably sub-Saharan Africa (Buys et al, 2009; Rhine, 2006; Ojedokun and Lumande, 2005; Gyamfi, 2005), or on ICT development, policies, practices, and impacts of specific African nations or provinces within a nation as examples (Mbatha, Ocholla, Le Orux, 2011; Bankole, Bankole, and Brown, 2011; Warschauer, 2003; Alemna and Sam, 2006); but only a handful of studies such as Fuchs and Horak (2008) and Onyeiwu (2002) have examined aspects of Africa's digital divide at the country level. (2) Unlike typical digital divide studies that concentrate on one particular ICT such as internet (Fuchs and Horak, 2008; Touray et al, 2015), broadband, or cellular services (Buys et al, 2009) ide, we consider five different forms or enablers of ICT – broadband, fixed/landline telephones, mobile phones, internet, and virtual social networks. Onyeiwu (2002) is the only study which has considered multiple forms of ICTs for Africa; however unlike our study, it excluded modern ICTs such as broadband and social networking in lieu of use of personal computers and internet hosts. (3) In addition to standard multivariate analysis of the predictors of Africa's ICT adoption and utilization, we employ spatial analysis of the same enabled by a geographic information system (GIS).

In this study, we supplement regression analysis by spatial analysis of ICT utilization clusters and outliers of African nations. Furthermore, geostatistical diagnostic testing, specifically evaluation of ICT dependent variables and regression residuals for the presence of spatial autocorrelation enables us to determine if regression findings are spatially biased and helps explain such findings based upon spatial agglomerations of the ICT dependent variable. The use of spatial analysis for a spectrum of ICTs for Africa is unique; while it has been used in a handful of previous digital divide studies for the United States (Pick, Sarkar, and Johnson, 2015; Grubesic and Murray, 2005), India (Pick, Nishida, and Sarkar, 2014), and Japan (Nishida, Pick, and Sarkar, 2014), or studies for specific ICT digital divide contexts (cell phone coverage

for Africa in Buys et al, 2009), the usage itself is consistent with Grubesic and Murray's (2005) contention that geographic space is in fact fundamentally important to issues concerning the digital divide and is contrary to the perception that advanced ICTs are meant to render geographic space as irrelevant.

The remainder of this paper is organized into sections on the ICT adoption and utilization in Africa and its digital divide, conceptual model of ICT utilization, research questions, methodology, analysis of geographical patterns of ICT utilization in Africa, regression findings, discussion and implications of results, and concluding remarks.

2. Literature Review

Literature on ICT availability, adoption, and diffusion, and the digital divide is extensive. While adoption/diffusion theory provides nuanced explanations of how technologies are adopted and diffused, its applications in the digital divide literature have been rather limited. Digital divides have been studied for various geographies – at the world, country, state, provincial, and city levels. Comparative digital divide studies – both within and between well-defined geographies, or between developing and developed economies, or specific agglomerations such as the OECD is common. Digital divides have also been examined through diverse lenses such as social, economic, demographic, political, regulatory, to name a few, and in the context of specific indicators of ICTs such as internet, broadband, and mobile wireless technologies. The body of empirical literature that attempted to understand influences of various factors on ICT adoption and utilization is vast. Sometimes this literature adopts theoretical frameworks of social reproduction (Agarwal, Animesh, and Prasad, 2009) and institutional factors (King et al, 1994) as theoretical foundations; while several other studies are atheoretical and employ a variety of empirical techniques. Most empirical studies have often found that income, education, and infrastructure are key determinants of ICT penetration, i.e. the influence of these key factors is almost context invariant. In more specific contexts, for example for developing economies, or for specific ICTs such as personal computer adoption, factors such as high costs of ICTs, English language dominance, the lack of relevant digital content, lack of technological support for disadvantaged communities, share of manufacturing in the overall economy, government trade policies, and societal openness are found to be key determinants of ICT adoption.

In this section, we primarily discuss the limited ICT and digital divide literature focused on Africa. In a recent study, Andoh-Baidoo, Osatuyi, and Kunene (2013) investigated the degree to which economic, human development, political, and population conditions impact ICT capacity in African nations. ICT capacity is estimated by five dependent variables: ICT expenditure as a percent of GDP, ICT expenses per capita, investments in telecommunications with private sector participation, internet users, and mobile phone subscribers per capita. The study employs data for 58 Africa nations from the World Bank's Africa Development Indicators from 1990 to 2008. Therefore, the temporal locus of the study is around 1999, almost a decade before data for this current study's variables were collected. Using Ordinary Least Squares

(OLS) stepwise regressions, the authors have determined that ICT capacity increases with increased corruption in a nation; however corruption is not a deterrent for private sector investment in telecommunications which is motivated mainly by human development factors such as life expectancy, enrollments in tertiary education and expenditures per student, and health expenses as percent of GDP. The study also found that tertiary school enrollment is not significantly correlated with mobile phone subscribers; this is explained by the utilization of mobile phones at both ends of the literacy spectrum. Also, relative size of rural population was found to be a significant predictor of mobile phone usage implying that users in rural areas rely on mobile services for communication due to infrastructural deficiencies in landline telecom.

For sub-Saharan Africa, Oyelaran-Oyeynka and Lal (2005) have analyzed the influences on internet diffusion from human capital, telecom infrastructure investment, PC density, telephone density, presence of internet hosts, and economic wealth estimated by GDP per capita. Data for these variables were collected for 40 sub-Saharan African nations for the 1995-2000 period and a simultaneous equation system approach was employed to determine predictors of internet diffusion. The authors found that apart from higher GDPs, density of PCs and internet hosts significantly influence internet diffusion; this is reasonable since both internet hosts and PCs increase the number of access points to the internet. Investments in telecommunication infrastructure with a one year lag and telephone density were also significant predictors of internet diffusion. The authors reason that telecom infrastructural investments manifest themselves in the form of higher internet penetration after a lag of about a year, whereas teledensity provides last-mile connectivity between internet users and internet service providers (ISPs).

In a related study, Roycroft and Anantho (2003) investigated the influence of economic development, estimated by the United Nations human development index, international internet bandwidth, domestic internet hosts, ISP market structure, the cost of a local telephone call, and the use of English as an official language on internet subscription in Africa. Data on the number of dial-up internet subscribers for each of Africa's 54 nations during the time of the study and all independent variables were from the period 2000 – 2002. Using OLS regressions, the authors determined that presence of English as an official language, monopoly ISP market structure, overall economic development, and the amount of international bandwidth predict internet subscription. The authors reason that higher economic development has a positive impact on internet subscriptions, while monopolistic market structure for ISPs results in higher prices and negatively impact internet subscribers. The findings regarding the positive influence of internet hosts on penetration is consistent with Oyelaran-Oyeynka and Lal (2005). Also the finding regarding English being a significant predictor of internet penetration is well supported in the literature, especially in nations in the European Union where English is not the first or predominant language (Vicente and Lopez, 2011). In the context of North African countries Danowitz, Nassef, and Goodman (1995) commented that the complexity of Arabic, which is their primary language for written communication, and lack of standards in keyboard layouts

reduce levels of computing and IT. Finally, Roycroft and Anantho (2003) have conjectured that the cost of a local telephone call is not a significant correlate possibly due to partial data availability for this independent variable.

Onyeiwu (2002) has examined the extent of digitization within African nations by estimating the impact of urbanization, human capital, growth of GDP per capita, openness of economy, and FDI on an IT index comprised of five components: the number of internet hosts, internet users, PCs, telephone lines, and cellular phones per capita. Data for 51 African nations for the year 2000 were used in this study. Using OLS regressions, this study determined that openness of the economy is the sole significant predictor of the extent of digitization as measured by the IT index. The author reasoned that a higher degree of economic openness in Africa is characteristic of nations that are either popular tourist destinations (such as Seychelles, Mauritius, South Africa, Egypt, and Morocco) or located along the oceanic coastlines with unfettered access to the global economy and trade flows. An interesting aspect of this study is the subsequent incorporation of geographical location of African nations as a regional dummy. This is motivated by the author's observation that countries in Southern Africa – South Africa, Namibia, Botswana, and Mauritius are all digitally advanced nations that are either contiguous or at least loosely agglomerated, providing a stimulus for digital contagion. In contrast, the digitally backward nations clustered in west, central, ad east Africa. However upon re-estimating the regression model with a regional dummy, the author determined that location in Southern Africa is not significant in explaining differences in IT access in Africa.

Buys et al. (2009),in an interesting spatial econometric study of cell phone coverage in sub-Saharan Africa, overlayed GIS locations of existing cell phone towers on a rectangular grid defined by more than a million evenly spaced points and estimated the probability of GSM cell tower location in relation to the size of the market, estimated by population, per capita income, installation and maintenance costs, and national competition policy. Using a probit model that controls for spatial autocorrelation, the authors determined that the probability of cell tower location increases with population, per capita income, and degree of competition, likely decreases significantly with higher levels of installation and maintenance costs. This study is unique since unlike previous studies, it attempted to capture the impact of cellular services infrastructure costs and also used a Geographical Information System (GIS) based approach to account for location and geographic attributes of the study area.

Apart from the previously discussed empirical studies, a handful of articles have discussed ICT issues such as adoption and applications in specific sectors, and the digital divide in specific nations such as Egypt (Warschaeur, 2003), Ghana (Alemna and Sam, 2006), Kenya (Wamuyu, 2015), Nigeria (Bankole, Bankole, and Brown, 2011), South Africa (Ochara and Mawela, 2015; Mbatha, Ocholla, and Le Roux, 2011), Tanzania (Furuholt and Kristiansen, 2007), or in broader context of ICT impact on human development such as health information access (Rhine, 2006) and development of human capital through cooperative electronic networks of academic libraries (Ojedokun and Lumande, 2005). In light of the explosive use of mobile

phones, especially by “cheetah generation” for innovation (Ponelis and Holmner, 2015), recent studies have focused on mobile usage for various purposes such as banking (Mwangi and Brown, 2015) and e-participation (Ochara and Mawela, 2015) within the context of ICT use for development (ICT4D).

Most of the existing literature also provides commentary on strategies to bridge the digital divide among and within African nations, as well as Africa with the industrialized world. Among others, existing research has advocated that African nations (i) change telecommunications and economic policies to promote private and public investment in ICTs (Oyelaran-Oyeynka and Lal, 2005) especially in telecom (Andoh-Baidoo et al, 2013) to build infrastructure, (ii) deregulate telecom markets to encourage competition (Onyeiwu, 2002; Roycroft and Anantho, 2003), (iii) simplify licensing regimes (Buys et al, 2009), (iv) consider providing state support for infrastructure development in areas where private operators are hesitant to invest (Onyeiwu, 2002), (v) encourage use of ICT at elementary and secondary levels of education (Andoh-Baidoo et al, 2013), (vi) stimulate use of PCs at the individual level as well as organizational level at educational institutions, small businesses, and governmental organizations (Oyelaran-Oyeynka and Lal, 2005) to build human capacity, (vii) support growth of internet hosts (Oyelaran-Oyeynka and Lal, 2005), preferably in the native-language (Roycroft and Anantho, 2003), and (viii) expand international internet bandwidth (Roycroft and Anantho, 2003) . Fuchs and Horak (2008) has cautioned that neoliberal policies of market liberalization and privatization are not a panacea for the digital inequities in African nations. The authors corroborate by providing an example of Ghana where such policy shifts have hardly contributed to increase access to ICTs due to predominant social and poverty related problems that involve fundamental quality of life issues such as access to food, clean drinking water, shelter, education, lack of reliable electricity, etc. Other strategies discussed include to involve intermediaries such as telecenters (Gyamfi, 2005; Sein and Furuholt, 2012), to advance understanding of how users seek information (Gebremichael and Jackson, 2006; Gyamfi, 2005), and to keep abreast of rapid advancements of ICT itself (Gebremichael and Jackson, 2006).

None of the previous empirical studies on the digital divide in Africa have included broadband and social media (Facebook, Twitter, and LinkedIn) as part of the ICT tapestry. This is not surprising since both broadband and social media are more recent forms of ICT and data on related variables were not available uniformly for a majority of African countries until recently. Our study is the first attempt to include current ICTs such as broadband and social media. Also apart from Buys et al (2009) which used a GIS explicitly to account for geographic attributes and Onyeiwu (2002) which introduced a dummy variable to account of location in relation to ICT penetration, none of the previous empirical studies have used a GIS to systematically account for location-based agglomeration of ICT utilization among nations and hence ignored the possibility that regression results may be biased due to the presence of spatial autocorrelation. We have systematically employ a GIS to study spatial patters of ICT utilization

among African nations and account for spatial bias introduced in regressions by possible agglomerations of ICTs.

Research Questions

The research questions of this study are as follows:

1. What is an appropriate conceptual model to understand the geography of, and influences on levels of technologies in African countries?
2. What is the spatial clustering of levels of technologies for African nations and how do the clusters differ?
3. How agglomerated are the technology variables in Africa, based on spatial autocorrelation?
4. What are the social, economic, societal openness, infrastructure, and business factors that influence levels of technologies for the entire sample of African nations, and for a lower-tech subsample?
5. Does the regression model account for spatial agglomeration so the regression error terms are spatially random?

3. Spatially Aware Technology Utilization Model (SATUM)

Based on prior literature and authors' inductive reasoning, a conceptual model is proposed and justified. There is not yet a widely-accepted conceptual model for explaining technology utilization at the national and state/provincial levels. One framework that categorizes nations by technological level is the networked readiness index (NRI) (Dutta and Jain, 2006; Dutta and Bilbao-Osorio, 2013). This index seeks to represent factors that increase readiness for introducing technology. The NRI depends on component indexes of environment (market, political/regulatory, infrastructure), readiness (individual, business, government), and usage (individual, business government), which in turn depend on sub-indexes given in parentheses (Dutta and Jain, 2006). This framework has been updated several times, so in its most recent form, readiness and usage remain as before, but the environment is enlarged to encompass the additional factor of economic and social impacts and enlarged environment factor to include capacity of a society to benefit from ICT. This framework differs from formulating a conceptual model. It determines an index, rather than conceptualizing factors that can be evaluated and tested statistically. Nevertheless, some of its indexes and sub-indexes are valuable in conceptualizing the present model. In particular, our model has emphasis on social and economic impacts on technology, as well as on societal openness, which encourages societal capacity to benefit from ICT. Other components of our model relate to individual readiness in form of literacy and training, and government/business readiness in electricity availability and business efficiency. Further, business readiness is indirectly stimulated by greater competition.

Another stream of theoretical study that informs the present study of Africa is World Systems Theory. This theory considers the nations of the world as a set of interdependent

societies that tend to strengthen world stability, and have been present starting in rudimentary form for 500 years. The world is viewed as a global economic system that includes a division of labor (Shannon, 1996; Wallerstein, 2004). The nations are viewed as dominant or dependent for periods of time, perhaps a century or more, but that the inter-state relationships are not permanent. The world system includes parts of it that own or control the production of goods and services, and other parts that depend on the production and provide raw materials and primary products. The economic processes of the world system depend on the relationships between the core nations, which are "capital intensive, high wage, high-technology production," semi-periphery, which are a mixture of core-like and periphery-like activities, and the periphery, which is "labor intensive, low-wage, low-technology production involving high labor exploitation and coercion (Shannon, 1996). The relationships and balances/imbalances in the world system can lead to social change at the national and global levels.

A plus of this theory is its flexibility and adaptability to change, but it is often challenging to operationalize (Shannon, 1996). In the present study, world systems theory forms a theoretical background to understand evolving relationships within the continent of Africa, which traditionally was regarded as entirely periphery. For this background, we enlarge "high or low technology production" to consist of "high or low technology production and services." We utilize this theory not to explain the relationship of African nations to the rest of the world, but gain insight into the relationships of today's variegated maturities of the nations, and the relationships between them. We perceive that the portions of Africa which remain today as "periphery" are located mostly in the central parts of the continent and that they are dominated by primary production sectors with low-wage workforce. Both characteristics serve to reduce technology use, primary production in central Africa being low-tech and low-wage workers facing severe cost barriers for ICT. Other countries, such as South Africa, Egypt, and Morocco, that constitute today's semi-periphery, have "core" aspectsof industrialization, urbanization, and prosperity, all of which stimulate ICT use.

Our conceptual model (see Figure 1) posits that the socio-economic factors of demography, economy, education, training, human development, societal openness, technology costs, electricity, and business efficiency and competition are related to factors of technology utilization and availability. Further, the model recognizes the importance of geography to understand these relationships and to incorporate spatial explanation into the model.

The research makes a new contribution for Africa by adding this geographical explanation into the model. Digital divide models that include geography are few (Warf, 2001; Nishida, Pick, and Sarkar, 2014; Pick, Sarkar, and Johnson, 2015; Warf, 2013), so providing a geographical model of digital divide for Africa can add to this area.

The detailed conceptual model has justifications from prior studies.

Demographic factors of age structure influenced Japan's internal digital divide (Nishida, Pick, and Sarkar, 2014), in particular both higher young age dependency ratio structure and farm population (a proxy for rural) reduced use of technologies. The relationship of urban area to technology use was also noted for Japan by Arai and Naganuma, 2010), as well as for China (Fong, 2009). *We posit that young dependency ratio will reduce technology use and that urban will increase technology use*

Education and Training factors have repeatedly been significant correlates of ICT use (e.g. Robison and Crenshaw, 2002; Yates et al., 2011; Nishida, Pick, and Sarkar, 2014). These many studies explain this effect by the greater need for educated workers and citizens to utilize ICT and by the effect of national education on technology industries and innovation. Although literacy and training have been infrequently studied, they is appropriate to Africa, which has very low levels of education, so such simpler measures are needed that reflect substantial proportions of population that is uneducated . *We posit that literacy and training at firms will increase technology use.*

Socio-economic factors involve a wide variety of dimensions that include categories of life expectancy, health, income, and education. Although income and education are known to increase technology use, the health-related dimensions have not been studied. However, we reason that people who are healthier have greater opportunity to take advantage of technologies. Life expectancy does not directly link to technology, but serves as another indicator of health. We posit that the UN human development index (HDI) is associated with technology use.

Economic factors have been important in many prior studies. Income is well known to increase technology use (Baliamoune-Lutz, 2003; Dasgupta et al., 2005), while industry and manufacturing have not been important, e.g. in a study of the Indian digital divide (Pick, Nishida, and Sarkar, 2014), the variables, factory output and factory productive capita, were not significant. In China, export commodities value was very important and reflected manufacturing provinces (Pick, Nishida, and Zhang, 2013). However, world systems theory identifies high technology production of core areas with greater use of ICT. Since we see this as important for the semi-periphery in Africa, we include industrial output and manufacturing output. Likewise, that theory includes that the periphery has agricultural and other primary production that is low-technology. *We posit that gross national income, industrial output, and manufacturing output are related to technology use, while agricultural exports is inversely related.*

Societal openness refers to societies that have greater freedoms, legal system, effective and transparent government. Studies have included societal openness independent factors have found moderate to high correlations with technology use (Robison and Crenshaw, 2002; Balaimoune-Lutz, 2003; Guillén and Suárez, 2005). Robison and Crenshaw argued that governments that have an open attitude towards, and regulations favoring social and political feedback from its citizenry would be more likely to foster ICT uses especially ones that diffuse readily to society. On the other hand, we reason that an autocratic or highly controlling society

would limit ICT use since the information could threaten the government. *We posit that laws related to ICT and the effectiveness of lawmaking bodies are positively related to use of technologies.*

Surprisingly, *technology cost* has not been frequently included in digital divide studies. A study of internet subscription in Africa (Roycroft and Anatho, 2003) posited that the cost of a local call reduced internet subscriptions, but found it not to be significant. Yates et al. (2011) found that financial investment to develop and grow technology use was related to broadband use in developing nations. Financial investment would likely reduce costs, so this points to the cost factor. We reason that at the low income level of many African nations, many with annual incomes under $1500, cost of technologies loom as constraints to use. Many African citizens have to weigh technology use against basic necessities of life, and many would reject use unless cost is very low. *We posit that fixed broadband and mobile cellular internet tariffs reduce use of technologies.*

Infrastructure is an important factor in technology use, whether in poor developing nations or advanced ones. In an early study reflecting modernization theory, ICT infrastructure was shown as necessary to advance in economic and technological stages (Robison et al., 2002). In Japan, spatial inequalities in ICT infrastructure inhibited technology deployment and use (Arai and Naganuma, 2010). A study of ICT diffusion for Asian confirmed that infrastructure investment was a significant correlate of ICT growth (Quibria et al., 2003). In Ghana, supply of electrical power and other infrastructure were proven as crucial for ICT development and adoption (Ewusi-Mensah, 2012). *We posit that sales value lost from electrical outages and time delay in obtaining electricity reduce use of technologies.*

Business efficiency and competition have rarely appeared in the digital divide literature for nations and states/provinces. This might be due to limited information available until recently on these dimensions. One study found that a factor, business and technology utilization, which included underlying proxy variables for competition (Pick and Azari, 2011), was consistently influential in a structural equation model of use of technologies. In Africa, we reason that business efficiency and greater competition lead to a more vibrant private sector which stimulates technology use. *We posit that the delay in obtaining a business license is associated with reduced technology use, while competition, measured by a national competition index, increases the use.*

4. Methodology

Data for various dependent and independent variables were obtained from a variety of sources such as World Bank's World Development Indicators database (The World Bank, 2012), World Telecommunications/ICT Indicators Database of the International Telecommunications Union (ITU, 2012, 2013), the World Economic Forum's Global Information Technology Report

(WEF, 2012), and the International Human Development Indicators database from the United Nations (The United Nations, 2013). To control for population size, variables were converted to per capita (in terms of per person or per 100 persons) wherever possible. A handful of variables are expressed as indices and the young dependency ratio independent variable is expressed as a ratio. Missing data were a challenge during data compilation. Due to widespread missing data for a number of variables – mainly independent ones, seven nations had to be eliminated from the study (out of a total of 58 nations). Nations excluded are Mayotte, Reunion, Saint Helena, Sierra Leone, Somalia, South Sudan, and Western Sahara, which account for 2.6% of Africa's 2012 estimated population. Time simultaneity was honored to the extent possible and descriptive statistics for all 5 dependent and 18 independent variables are computed (Table 1).

The dependent variables were first tested for spatial autocorrelation to determine if high values are clustered or distributed randomly in space. The Moran's I statistic is an inferential test whose null hypothesis is values of a variable are randomly distributed spatially. Moran's I is interpreted by its *p*-value and *z*-score with the threshold for *p*-value being .05 in this case. A zero or low absolute value of the statistic indicates that spatial autocorrelation is not present. Further, if the Z score is positive, the values of a variable are geographically agglomerated (high values located near other high values and low values near other low values). If it is negative, the spatial pattern resembles a "checkerboard" pattern, in which high values are surrounded by low ones and vice versa (ESRI, 2011; Longley et al, 2011). K-means cluster analysis is employed and maps are produced to identify spatial agglomerations of the combined set of dependent variables.

Next, ordinary least squares (OLS) regression is performed for five dependent variables, based on the eighteen independent variables. Two sets of regressions were conducted for each ICT dependent variable, one for the full set of N = 51 nations, and another for a reduced set of N = 44 nations. The reduced set excluded nations that were found to be at the high end of ICT utilization spectrum from K-means cluster analysis. High ICT utilization nations dropped in the reduced sample are Egypt, Libya, Mauritius, Morocco, Seychelles, South Africa, and Tunisia. Two sets of regressions were performed to examine if moderate-low ICT utilization nations have the same correlates of ICT utilization as the entire continent. Also, for each sample, we further conducted two sets of regressions, one with Gross National Income per capita included as an independent variable but extent of urban population excluded as an independent variable, and in the other, Gross National Income per capita excluded but extent of urban population included. This was necessitated since income and urbanization, which are often significant correlates of ICT utilization in the digital divide literature, tend to be significantly correlated. In our study, GNI and urban are moderately positively correlated with a correlation coefficient of 0.461 that is significant at 0.01 level. Hence to avoid multi-collinearity problems, GNI and urban were not allowed to enter into regressions simultaneously. Missing values for a handful of independent variables were imputed by the mean of the variable. We chose to impute missing values and not shrink the sample size for variables to preserve the richness of regression analysis. However imputation by means may be considered a limitation of this work.

Variables were pre-tested for multi-collinearity, using the variance inflation factor (VIF) to assure that it is not present. Stepwise regression methods are employed; they are useful for exploratory studies, where prior research only weakly points to factors of potential significance (Rosenshein et al, 2011). The regression findings are tested for conformance to regression assumptions by the Joint Wald Statistic, Koenker (BP) Statistic, and Jarque-Bera Statistic. OLS regression residuals are further tested for spatial autocorrelation using Moran's I to check for the presence of spatial bias. Spatially-biased regression residuals are explained later in this manuscript in light of agglomerations of ICT dependent variables. Further details and insights into the research methodology adopted in this study can be found in Nishida, Pick, and Sarkar (2014), Pick, Nishida, and Sarkar (2014), and Pick, Sarkar, and Johnson (2015).

5. Findings

The conceptual model is tested with five dependent technology use variables of internet users (as percent of population), broadband subscriptions per 100 persons, mobile-cellular subscriptions per 100 persons, fixed telephone subscriptions per 100 persons, and social network use, which is a Likert variable on a scale of 1 (lowest level of use to 7 highest level). Table 1 shows the five dependent variables as well as 18 independent variables. Variables for total nations are converted to per capita; however, henceforth in the paper, per capita will not be repeated, and the reader can find the per capita listed in this table.

The descriptive statistics show that technology use in Africa is at a low level by worldwide standards. For instance, in 2012 the average percent of individuals using the Internet and fixed broadband for the African nations was 13.8 percent and 1.0 percent respectively, which is much lower than the world average of 41.3 percent and 9.8 percent (ITU, 2012). Within Africa, there is large variation among nations, as seen by high coefficients of variation for Internet Users (102.3), Fixed Broadband Subscriptions (232.0), Mobile-cellular Subscriptions (57.1), and Fixed Telephone Subscriptions (166.3), while Social Network Use (17.6) is moderate. The variation implies large differences geographically throughout Africa, as seen for example in Figure 2 for mobile-cellular subscriptions. This paper concerns analyzing and explaining this variation. The more moderate differences for social networking variables can be ascribed to its use predominantly by more educated people in metropolitan areas, which would imply a more consistent level of use.

The dependent technology variables, with the exception of fixed phones, are highly correlated, as seen in Table 2. Even though four of them are closely related, prior research has indicated considerable variation in their correlates (Guillén and Suárez, 2005; Pick and Azari, 2008; Yates, 2011; Pick, Nishida, and Zhang, 2013), justifying keeping them separate rather than merging them into an index. The lack of correlation of fixed phone subscriptions can be explained by their displacement by mobile phones in most parts of Africa (Rashid and Elder,

2009). Fixed phones are fading due to their infrastructure, reliability problems, limited functionality compared to mobile phones, and advantages of the mobility itself.

For the independent variables, Africa's lower worldwide development level is evident. For instance, the average literacy is 63 percent and gross national income per capita (GNIPC) is only $3,194. Manufacturing is low throughout the continent, comprising only 10.5 percent of gross domestic output, while the continent has high agricultural production including substantial export of agricultural raw materials (excluding food) of 7.6 percent of merchandise exports. Incoming foreign direct investment has an average of $681 per capita, with a high coefficient of variation of 116. On average African nations have low societal openness, as gauged by effectiveness of lawmaking bodies and extent of development of laws relating to ICT. The high costs of fixed broadband and mobile cellular usage serve as constraints to wider adoption and use of technologies, e.g. broadband monthly subscription is $225 on average, which equates of 84 percent of average income, so that its use would be restricted to more prosperous nations and wealthier users. Likewise average mobile-cellular of 41 cents per minute is a barrier in poorer African nations. At this level of cost, it is unsurprising that level of competition for internet, mobile phone, long distance fixed phone services is relatively high (1.42 on a 0.0 to 2.0 worldwide scale). Another facet of Africa is business inefficiency, as seen by an over 4 month average delay in obtaining electricity and about a month delay for getting a business license.

5.1 Spatial Clustering of ICTs

Cluster analysis reveals distinctive technology-use clusters within Africa, which are mostly contiguous. The K-means cluster analysis was performed for four of the five dependent variables, namely, Internet users, Broadband Subscriptions, Mobile-cellular subscriptions, and Fixed telephone subscriptions. Social network use was not included in the cluster analysis due to many missing values in the west coast, central-north and central parts of Africa, and to its high correlation with Internet users, broadband subscriptions and mobile phone subscription, implying its addition to the analysis would have limited influence the overall cluster findings.

The clusters are seen geographically in Figure 3, with their characteristics given in Table 3. Clusters 1 and 5 stand out as much higher than the other clusters, with internet users at 44.5 and 33.5 and Broadband at 4.5 and 6.4 respectively, internet-use values corresponding to world average and broadband corresponding to half of world average. There is a strong geographic agglomeration, as expected from Tobler's Law (Longley et al., 2011). Mobile phone subscriptions are forty percent above world average reflecting leapfrogging and lower relative cost relative to their more prosperous economies. The economically more advanced nations in clusters 1 and 5, which historically established more mature fixed telephone bases, reflect fixed phone subscriptions that are seven-fold higher than for clusters 2, 3, and 4. The very high level of mobile phone subscriptions in these nations points to the mobile phone as the primary widespread mode for information technology in these nations. These African "high-tech"

countries are all coastal, which reflects Africa's historical greater urbanization/industrialization on its coasts, a topic discussed later.

Clusters 3 and 4 tend to be located in the northwest, central west, and south parts of the country, with exceptions of Sudan and Kenya. About half are coastal and they are agglomerated geographically, with the exception of Sudan and Kenya. These nations have low internet use and almost no broadband use by world standards, while mobile phones are somewhat higher than world average, reinforcing that cellphones are Africa's most widespread and primary technology. At the low end for the continent is Cluster 3, comprising mostly central and eastern countries. Here technology use is among the world's lowest. The reasons include history of less urbanization/industrialization, poor economies with lower productivity, less infrastructure including technological, and lower literacy and education (Davidson, 1994; Gebremichael and Jackson, 2006; Warf, 2013). Overall, the cluster analysis points to a continent with sharp inequalities in use of technologies, agglomerations of contiguous nations at similar technology levels, mobile phone "leapfrogging" occurring at a high rate but especially in the middle to high level clusters, and coastal location as a characteristic of higher technology levels.

5.2. Spatial Autocorrelation of ICTs

The amount of agglomeration for each of the five technology dependent variables is first analyzed for spatial autocorrelation using the Moran's I statistic. Moran's I was calculated for the full study sample of 51 countries, as well as for 44 "lower tech" nations that excluded the seven nations in Clusters 1 and 5, namely Egypt, Libya, Mauritius, Morocco, Seychelles, South Africa, and Tunisia. Four of them are Arab-speaking Mediterranean nations, while South Africa is Africa's most advanced economy, and the island nations of Madagascar and Seychelles are among the continent's most prosperous. The 44-nation sample, which in this section allows initial comparison of spatial agglomeration, will be repeated in comparing regression findings for the whole continent and its lower tech countries.

As seen in Table 4, for the full 51-nation sample, broadband subscriptions, mobile subscriptions, and fixed telephone subscriptions are highly agglomerated, whereas internet users and virtual social network use have random spatial patterns. These significant effects are explained by the first three variables tending to have sharp contrast between high value agglomerations of the North African, Mediterranean nations plus southern tip ones, compared to the lower-valued agglomerated central swathe of Africa. The latter two variables are more random throughout the continent (e.g. for mobile phones as seen in Figure 2). For the 44-nation lower-tech sample, spatial autocorrelation results are weaker, present only for mobile-cellular subscriptions. This understandable since the high-value agglomerations are lessened in N. Africa and the far south.

The spatial autocorrelation for African nations differs from a sample of U.S. states (Pick, Sarkar, and Johnson, 2015), which has strong agglomeration results for all technology uses except for two social networking ones (see Table 4). Somewhat consistent to the two African samples, for Chinese provinces, there was strong and consistent spatial autocorrelations of technology variables for the full sample, but they weakened considerably in a sample eliminating the two highest-tech provinces of Beijing and Shanghai (Pick, Nishida, and Zhang, 2013).

5.3 Findings from Regression Analysis

Results of the regression analysis provide support for the conceptual model and validate the benefit of screening for spatial autocorrelation of error terms. Since the gross national income per capita and urban variables are very significantly correlated, two sets of regression runs were done, one with GNIPC included, urban excluded and a second with GNIPC excluded, urban included. Doing the two sets of runs is justified by the literature importance of both sets of variables for digital divide in developing nations. For each regression run, the independent variables were tested for multi-collinearity with the variance inflation factor (VIF) and in no instance was VIF found to be significant.

As seen in Table 5, for the full sample with GNIPC included, factors in the societal openness and economic categories dominate. The most important correlate, consistent across the five dependent variables, is ICT laws. Countries with well-developed laws for ICT were likely to have higher ICT levels. We reason that a country with well-developed ICT laws is encouraging to vendors, content providers, infrastructure developers, trainers/educators, and other service entities. On the other hand, effectiveness of law-making bodies reduced broadband subscriptions and fixed telephone subscriptions. We reason that ineffectiveness of congresses and legislatures characterize periods of turmoil, instability, and change, which might reduce regulation at times and necessitate better information exchange, provide openings and opportunities for deployment of technologies. Economic factors were influential selectively across all five dependent variables. GNIPC was associated with broadband and fixed telephone subscriptions, while industrial and/or manufacturing output related to internet users, mobile subscriptions, and social networks. The inverse association of agricultural exports on use of virtual networks is explained by countries with heavily agricultural economies being less amenable to social networking, which appears to be more present in Africa's metropolitan and urban areas.

For the full sample with urban included, ICT laws again was the most important determinant across all five regressions, with effectiveness of law-making bodies reducing only broadband. Economic influences disappeared for broadband and fixed telephone subscriptions and urban was of secondary importance for mobile and social networks.

For the "lower tech" 44-nation sample (see Table 6), with GNIPC included, economic categories dominate while societal openness is reduced. GNIPC, industrial output,

manufacturing output are important for reasons previously given. Export of agricultural materials reduces use of virtual networks, with explanation similar to the full sample. Since ICT laws are much more developed in the seven "high tech" nations, eliminating them reduces ICT laws' effect except for mobile subscriptions and social networks. An explanation is that for lower-tech nations, the latter two technologies remain sensitive to legislative ineffectiveness for the reason given above of rapid change/turmoil and can remain favored for the general citizenry by ICT laws. For the full sample with Urban included, urban, ICT laws, and manufacturing/industrial output account together for the effects. The somewhat greater influence of urban in the "lower tech" nations versus full sample is explained by urban standing out for technological uses more in this sample, which has overall a lower urbanization level.

6. Discussion: Implications of Findings

The study findings demonstrate that Africa's relatively high-tech countries are located in the North Africa adjoining the Mediterranean and in the far south of the continent, while the lowest tech nations are agglomerated in the middle and middle south of Africa. The locations relate to the greater industrial and urban development of continent areas due to their proximity to ocean transport and earlier history of economic development. The more central sections of the continent did not have the transport advantages and were too remote to industrialize and develop large cities. It can be expected in the 21st century that more of central Africa will industrialize/urbanize, especially since population is growing rapidly, a trend implying greater use of technologies. These central nations can be compared to the far western provinces of China (Pick, Nishida, and Zhang, 2013) or northeastern states of India (Pick, Nishida, and Sarkar, 2014), regions that are more remote from transport, trading, commerce, and industries and which trail considerably in technological growth.

The spatial randomness for internet users and social network users relates to the greater evenness of their distribution throughout the continent. They agglomerate less since these forms of technology are relatively inexpensive and hence not tied to the economic disparities of the continent, as is seen for fixed broadband and fixed telephones. For mobile phones, location does matter, which might relate to the cell-tower and other infrastructure which is tied to the economic level of nations.

For the regression model, the categories of variables most strong supported are economy, societal openness, demographic factors particularly urban, and technology cost. Education and literacy, so influential in the literature, in Africa have no impacts as measured by literacy and training. This implies that at the low standard of living for most of Africa, education and training are supplanted by more basic factors of income, urbanization, and industrialization. It is surprising that societal openness is highly influential, but less so if its recent influence at the national level of change in the Arab Spring and its often profound effects in advanced nations are

considered. The absence of effects for infrastructure (electricity) and business efficiency/competitiveness can again be explained as less important in very basic and poor environments of most of Africa. Those factors also can be expected to grow in importance as Africa industrializes/urbanizes in this century.

The model's weakness in incorporating spatial errors for certain dependent variables stems from strong starting spatial autocorrelation of the variable for broadband and fixed telephones in the full sample, although the spatial errors diminish for the "lower technology" subsample. The measurement of spatial autocorrelation proves useful as a gauge of how much the regression independent factors account for spatial effects, and if they do not, then what external forces might account for the agglomeration of errors. It is dangerous to trust solely regression for digital divide studies, since it ignores geographical proximity effects which often lead to having overconfidence in the findings.

Returning to the research questions, they are answered as follows:

1. *What is an appropriate conceptual model to understand the geography of, and influences on levels of technologies in African countries?*
   From this single exploratory test, the conceptual model appears robust to account for highly significant regression findings.
2. *What is the spatial clustering of levels of technologies for African nations and how do the clusters differ?*
   Cluster analysis demonstrates that there are distinctive clusters that are mostly spatially agglomerated, in concert with Tobler's Law.
3. *How agglomerated are the technology variables in Africa, based on spatial autocorrelation?*
   About half of the dependent variables are spatially agglomerated. Reasons are given why internet users and virtual network users are spatially random.
4. *What are the social, economic, societal openness, infrastructure, and business factors that influence levels of technologies for the entire sample of African nations, and for a lower-tech subsample?*
   The major categories of influences are economic, societal openness, and urban, followed by some technology cost effects. Surprisingly, literacy/training is not important, nor are infrastructure (electricity) and business efficiency/competitiveness.
5. *Does the regression model account for spatial agglomeration so the regression error terms are spatially random?*
   The regression model mostly accounts for spatial agglomeration, and explanations are offered for the instances where is does not.

7. Conclusions

This paper examined utilization of various forms of ICT including broadband and social media technologies in the countries of Africa and how they have shaped the digital divide in the world's second most populous continent. Our model of ICT utilization posits five ICT dependent variables to be associated with eighteen socio-economic, education, income, ICT price, legal effectiveness, and infrastructure independent variables. Spatial analysis of ICT dependent variables reveal clusters of high utilization in North Africa (Egypt, Libya, Morocco, and Tunisia) and southern Africa (Mauritius, South Africa, Seychelles) while west, central, and large parts of sub-Saharan Africa are at the low end of ICT utilization spectrum.

The leading determinants of ICT utilization for the full sample are laws that relate to the use of ICTs and the effectiveness of national parliament/congress as a lawmaking institution. This is supported by previous literature which has emphasized that national government in Africa must play a significant role to shape economic and telecommunications policies for public and private sector investments in ICT to build infrastructure, deregulate telecom markets to encourage competition, simplify licensing regimes, and encourage adoption of ICTs among individuals and organizations in education, government and business to increase ICT penetration and bridge the digital divide (Andoh-Baidoo et al, 2013; Buys et al, 2009; Oyelaran-Oyeynka and Lal, 2005; Onyeiwu, 2002; Roycroft and Anantho, 2003). For a reduced set of 44 nations that excludes high ICT countries, the effect of ICT laws is moderated but gross national income is a significant predictor for broadband, fixed landline phones, and internet users. Also, mobile tariffs are found to be negatively associated with mobile phone subscription. Combined, this makes sense, and is consistent with contentions in existing literature that higher tariffs act as a barrier for ICT penetration for low ICT-intensity nations.

A unique aspect of this study is the use of a diagnostic measure of Moran's I to check if regression residuals are spatially biased. We identify that the regression residuals for broadband (Figure 4) and fixed phones for the overall sample and for internet users (Figure 5) for the reduced sample are not distributed randomly. We attribute this to the spatial clustering of these dependent variables for Africa. In the absence of spatial analysis, such a bias would go undetected. This study reinforces the importance of including underlying geography in the study of digital divides.

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Variable category	Variable Name	Definition	Year of data collection	Source	Mean (N*)	SD
DEPENDENT VARIABLES						
ICT use	Fixed broadband internet subscriptions per 100 people	Fixed (wired) broadband subscriptions per 100 persons	2012	ITU	13.83 (53)	14.15
ICT use	Fixed telephone subscriptions per 100 people	Fixed telephone subscriptions per 100 persons	2012	ITU	1.00 (52)	2.32
ICT use	Internet users per 100 people	Percent of individuals using the internet	2012	ITU	71.76 (54)	41.00
ICT use	Mobile subscriptions per 100 people	Mobile-cellular telephone subscriptions per 100 persons	2012	ITU	3.77 (54)	6.27
ICT use	Use of social networks per 100 people	How widely virtual social networks are used (e.g., Facebook, Twitter, LinkedIn) for professional and personal communication per 100 persons	2010-11	WEF	4.43 (54)	0.78
INDEPENDENT VARIABLES						
Demographic	Young dependency ratio	Ratio of population aged 0-14 to population aged 15-64	2010	WB	73.06 (45)	16.59
Demographic	Urban	Urban population as percent of total population	2010	WB	41.43 (46)	18.40
Education	Literacy	Adult literacy rate per 100 people	2005-10	WB	62.55 (42)	18.41
Training	Firms offering formal training	Percent of firms offering formal training	2005-10	WB	30.54 (42)	10.80
Socio-economic	**Human development index of UN**	Composite index for long and healthy life, knowledge and a decent standard of living.	2010	UN	0.80 (51)	0.401
Economic	Gross national income per capita	Gross national income per capita ($)	2010	WB	3,194.08 (49)	6,673.95
Economic	Industry output	Industry output as a percent of GDP	2010	WB	32.92 (38)	17.34
Economic	Manufacturing output	Manufacturing output as a percent of GDP	2010	WB	10.50 (45)	7.65
Economic	Agricultural exports	Agricultural exports as percent of total exports	2010	WB	7.65 (37)	12.23
Economic	Foreign Direct Investment	Foreign Direct Investment per person	2010	WB	681.46 (45)	792.89
Societal openness	Effectiveness of lawmaking bodies	How effective is the national parliament/congress as a law-making institution (scale 1 lowest to 7 highest)	2010-11	WEF	3.49 (32)	0.784
Societal openness	Laws related to ICT	Laws relating to ICT (scale 1 lowest to 7 highest)	2010-11	WEF	3.35 (34)	0.72
Technology cost	Fixed broadband internet tariffs	Subscription charge for fixed (wired) broadband internet service (in PPP $/month)	2010	WEF	225.44 (33)	385.10
Technology cost	Mobile cellular tariffs	Average per-minute cost of different types of mobile cellular calls in PPP ($/min)	2010	WEF	0.41 (34)	0.18

Infrastructure	Sales value lost from electrical outages	Percent of sales value lost due to electrical outages	2005-10	WB	6.17 (42)	4.86
Infrastructure	Time required to get electricity in days	Time required (days)	2011	WB	133.40 (48)	109.72
Business efficiency/ competition	Time to obtain business license in days	Time required to obtain operating license (in days)	2005-10	WB	26.33 (40)	16.33
Business efficiency/ competition	Level of competition for internet, long distance fixed phone, & cell phone	Level of competition index for Internet services, international long distance services, & mobile telephone services on a 0 – 2(best) scale	2011	WEF	1.42 (34)	0.52
DATA SOURCES						
ITU = International Telecommunications Union, World Telecommunication/ICT Indicators 2012 ; UN = United Nations; WB = World Bank World Development Indicators, 2012; WEF = World Economic Forum						
* N: Sample size without imputation						

Table 1. Dependent and Independent Variables, 2010-2012, African Nations

	Internet users	Broadband subscriptions	Mobile phone	Fixed phone subscriptions
Internet users				
Broadband subscriptions	0.658***			
Mobile phone subscriptions	0.573***	0.477***		
Fixed phone subscriptions	-0.108	-0.016	-0.127	
Social network use	0.738***	0.488**	0.617***	-0.174

* signif. at 0.05 level

** signif at 0.01 level

*** signif. at 0.001 level

Table 2. Correlations of Dependent Variables

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Ratio of High to Low
Internet users	44.58	5.12	14.90	10.06	33.47	8.71
Broadband subscriptions	4.47	0.13	0.62	0.55	6.38	49.38
Mobile telephone subscriptior	120.57	38.36	83.85	168.72	153.41	4.40
Fixed telephone subscriptions	13.02	0.97	2.96	4.45	22.85	23.50
	Egypt	Angola	Algeria	Botswana	Libya	
	Mauritius	Burkina Faso	Benin	Gabon	Seychelles	
	Morocco	Burundi	Cameroon			
	South Africa	C. African Rep	Cape Verde			
	Tunisia	Chad	Côte d'Ivoire			
		Comoros	Equatorial Guinea			
		Democratic Rep. of	Gambia			
		Djibouti	Ghana			
		Eritrea	Guinea-Bissau			
		Ethiopia	Kenya			
		Guinea	Mali			
		Lesotho	Mauritania			
		Liberia	Namibia			
		Madagascar	Nigeria			
		Malawi	Republic of Congo			
		Mozambique	Sao Tome & Principe			
		Niger	Senegal			
		Rwanda	Sudan			
		Tanzania	Swaziland			
		Togo	Zambia			
		Uganda	Zimbabwe			

Table 3. Characteristics of Five K-Means Clusters Derived from 4 Dependent Variables, 51 African Nations, 2012

		Moran's I values for African Nations, N=51, 2010							
		Internet Users	Fixed-Broadband Internet Subscrip-tions		Mobile subscrip-tions	Fixed telephone subscrip-tions	Usse of virtual social networks		AVERAGE
		0.059	0.288***		0.277**	0.324***	0.001		0.223
		Moran's I values for African Nations, N=44, 2010							
		Internet Users	Fixed-Broadband Internet Subscrip-tions		Mobile subscrip-tions	Fixed telephone subscrip-tions	Usse of virtual social networks		AVERAGE
		0.034	-0.034		0.264**	0.133	-0.013		0.077
	Moran's I values for United States, N=50, 2010								
	Desktop/ Laptop in Household	Log of Internet Access at Home	Broadband Adoption in Household	Persons in Cellphone-Only Household	Mobile Wireless High-Speed Devices	Persons in Fixed-phone-only Household	Facebook Users	Twitter Users	AVERAGE
	0.547***	0.471***	0.457***	0.621***	0.230***	0.648***	-0.004	0.069	0.381
Moran's I values for China, N=31, 2009									
PCs per 100 Urban Families	PCs per 100 Rural Families	Internet Users per 100 pop.	Broadband Subscribers per 100 pop.	Mobile Telephone Subscribers per 100 pop.		Fixed Phone Subscribers per Capita	No. of Domain Names per 100 pop.	No. of Web Pages per Capita	AVERAGE
0.346***	0.206*	0.264**	0.272**	0.205*		0.252**	0.615***	0.086*	0.285
Moran's I values for China, N=29, Excluding Beijing and Shanghai, 2009									
0.343***	0.239**	0.137	0.258**	0.061		0.143	0.236**	0.177*	0.199
							(Source for China, author, 2013a)		

Table 4. Moran's I Values for African Nations, 2010-2012, U.S. States, 2010, and Chinese Provinces, 2009

		Dependent Variable									
		GNI included, Urban excluded					Urban included, GNI excluded				
Category	Independent Variable	Fixed broadband internet subscriptions per 100 persons	Fixed telephone subscriptions per 100 persons	Internet Users per 100 persons	Mobile subscriptions per 100 persons	Use of virtual social networks	Fixed broadband internet subscriptions per 100 persons	Fixed telephone subscriptions per 100 persons	Internet Users per 100 persons	Mobile subscriptions per 100 persons	Use of virtual social networks
Demographic	Dependency ratio										
Demographic	Urban						0.243			.258*	.267*
Education	Literacy										
Training	Firms offering formal training (percent)										
Socio-economic	Human development index of UN					0.233					
Economic	Gross national income per capita (Atlas method)	.350**	0.407**								
Economic	Industrial output as percent of GDP			0.227*	0.494***			0.234	0.227	0.438***	
Economic	Manufacturing output as percent of GDP			.384***		.337**			.384***		.278**
Economic	Agricultural exports					-0.342**					-.223*
Economic	FDI										
Societal openness	Effectiveness of lawmaking bodies (scale 1 lowest to 7 highest)	-0.406**	-0.301*				-.411**				
Societal openness	Laws related to ICT (scale 1 lowest to 7 highest)	.311*	.265*	.589***	0.461***	.641***	0.392**	.353*	.589***	.451***	.580***
Technology cost	Fixed broadband internet tariffs										
Technology cost	Mobile cellular tariffs ($/min) PPP	-0.241*					-0.215				
Electricity	Sales value lost from electrical outages										
Electricity	Time required to get electricity in days										
Bus. Efficiency	Time to obtain business license in days										
Bus. Competition	Competition Index			.233*					.233*		
Regression adjusted R square and significance level		0.314***	0.245***	0.428***	.305***	0.484***	.235**	.099*	.409***	.357***	.522***
sample size (N)		50	50	50	50	50	50	50	50	50	50
OLS REGRESSION TESTS											
Joint Wald Statistic		33.6*	22.1*	65.4*	41.8*	88.7*	12.7*	10.3*	65.4*	48.6*	72.8*
Koenker (BP) Statistic		3.840	3.714	2.498	1.732	5.463	5.182	1.002	2.498	1.655	1.902
Jarque-Bera Statistic		475.006*	333.964*	10.218*	2.094	1.751	327.960*	346.620*	10.218*	1.269	0.059
SPATIAL AUTOCORRELATION OF RESIDUALS											
Moran's Index		0.213**	0.236**	0.061	0.126	0.111	0.218**	0.298***	0.060	0.102	0.115
p-value		0.003	0.002	0.379	0.116	0.156	0.003	0.00008	0.379	0.188	0.146

* signif. at 0.05 ** signif. at 0.01 *** signif at 0.001

Table 5. Standardized Regression Results for Dependent Variables, 2012, 51 African Nations

		Dependent Variable									
		GNI included, Urban excluded					Urban included, GNI excluded				
Category	Independent Variable	Fixed broadband internet subscriptions per 100 persons	Fixed telephone subscriptions per 100 persons	Internet Users per 100 persons	Mobile subscriptions per 100 persons	Use of virtual social networks	Fixed broadband internet subscriptions per 100 persons	Fixed telephone subscriptions per 100 persons	Internet Users per 100 persons	Mobile subscriptions per 100 persons	Use of virtual social networks
Demographic	Dependency ratio										
Demographic	Urban						0.374*	0.458**		0.306*	0.392**
Education	Literacy										
Training	Firms offering formal training (percent)										
Socio-economic	Human development index of UN			-0.368**		0.294*					
Economic	Gross national income per capita (Atlas method)	0.750***	0.725***	0.529***							
Economic	Industrial output as percent of GDP				0.537***					0.436**	
Economic	Manufacturing output as percent of GDP					0.376**			0.324*		0.291*
Economic	Agricultural exports					-0.388**					
Economic	FDI				0.231						
Societal openness	Effectiveness of lawmaking bodies (scale 1 lowest to 7 highest)										
Societal openness	Laws related to ICT (scale 1 lowest to 7 highest)				0.393**	0.632***			0.459**	0.346*	0.589***
Technology cost	Fixed broadband internet tariffs										
Technology cost	Mobile cellular tariffs ($/min) PPP	-0.216			-0.297*						-0.263
Electricity	Sales value lost from electrical outages										
Electricity	Time required to get electricity in days		-0.177					-0.268			
Bus. Efficiency	Time to obtain business license in days	-0.174		-0.249							
Bus. Competition	Competition Index								0.272		
	Regression adjusted R square and significance level	0.583***	0.550***	0.351***	0.278**	0.385***	0.140*	0.218**	0.284**	0.280***	0.705***
	sample size (N)	44	44	44	44	44	44	44	44	44	44
	OLS REGRESSION TESTS										
	Joint Wald Statistic	268.5*	167.9*	146.2*	20.3*	74.6*	3.1	4.0	7.4	14.9*	48.7*
	Koenker (BP) Statistic	5.730	0.661	1.563	6.903	11.988*	7.570*	14.635*	7.336	5.278	3.347
	Jarque-Bera Statistic	190.497*	28.681*	28.803*	1.063	5.196	82.385*	31.694*	2.609	1.684	0.230
	SPATIAL AUTOCORRELATION OF RESIDUALS										
	Moran's Index	-0.043	0.086	-0.020	0.225*	-0.028	-0.014	0.086	0.078	0.152	-0.093
	p-value	0.82	0.24	0.975	0.0102	0.96	0.920	0.24	0.3	0.07	0.48

Table 6. Standardized Regression Results for Dependent Variables, 2012, 44 African Nations

Figure 1. Spatially Aware Technology Utilization Model for Technology Use in African Nations

Figure 2. Mobile Subscriptions per 100 persons, African Nations, 2012

Figure 3. K-Means Cluster Analysis, Use of 4 Technologies, 5 Clusters, N=51, Africa 2012

Figure 4. Standardized Residuals of Estimate of Fixed Broadband Subscriptions, 2012
(Percent urban included, Gross national income excluded)

Figure 5. Standardized Residuals of Estimate of Internet Users, 2012
(Percent urban included, Gross national income excluded)